Chapter 2

On the Factors Responsible for Reserve Accumulation in India

2.1 Introduction

Over the last decade, there is a sharp rise in the global foreign exchange reserves and bulk of which is accumulated by the emerging countries. The reserves as percentage of world GDP has increased from 4.1 percent in 1990 to 14.7 percent in 2010. The share of world reserves held by emerging countries rose from 37 percent in 1990 to 66 percent in 2010 with larger share held by the Asian emerging countries. Not only there is an absolute jump, but also a sharp rise is witnessed in some of the basic metrics of reserves adequacy. For instance, reserves of Asian emerging countries as ratios of import, short-term external debt and broad money have shown an increasing trend over the past decade (Annual Report, IMF, 2011).

The authority builds up reserves for several reasons. Firstly, a country needs reserves to pay for its import and to service external debt if there is a temporary shortfall in export earnings or access for foreign exchange is temporarily closed. Secondly, reserves are built up as insurance against sudden stops or reversal of foreign capital. Thirdly, the authority may accumulate reserves to prevent real appreciation of domestic currency as it would help sustaining export growth. The first motive reflects the transaction demand while the second motive reflects the precautionary demand for reserves. The third motive describes the mercantilist view that reserve accumulation is triggered by concerns about export competitiveness.
The recent surge in reserve holding of emerging countries is largely attributed to increase in the volatility of cross-border capital flows, subject to sudden stops/reversal (Calvo, 1998; Edwards, 2004; and Aizenman and Marion, 2004). The available empirical evidence derived from panel data support the view that rising volatility of external transactions and increased frequency and intensity of banking and financial crises experienced by emerging countries in the 1990s have significantly increased the precautionary demand for reserves (see Flood and Marion, 2002; Aizenman and Lee, 2005 among others).

The empirical studies estimate reserve demand equation using panel data and assess the importance of precautionary motive by examining the magnitude and statistical significance of elasticity coefficient on volatility measures of external transactions. The volatility tends to be larger as country is more open. If external transactions are highly liberalized then the country is more vulnerable to unforeseen external shocks; hence, demand for reserves as precautionary balance tends to be larger. Hence, the crucial question is whether countries with large stockpile of reserves are more vulnerable to sudden stops or flight of foreign capital.

However, the large reserve holding of Asian emerging countries such as China, Taiwan, South Korea, India etc are still maintaining several restrictions on capital flows as it would limit the external vulnerability. In fact, the emerging Asian countries maintain administrative controls to restrict capital flight while providing incentives to encourage durable capital inflows. Such asymmetric capital controls has been an integral part of exchange rate management policy of emerging countries. Under this arrangement, capital

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3 Using panel data Flood and Marion (2002) have shown that the buffer stock model explains only 10 – 15 percent of the reserve holding while a larger part of reserve holding is explained by the country-specific fixed effect
inflow tends to be durable; hence, there will be persistent pressure on domestic currency to appreciate. Therefore, the available option for authorities which have concern for export growth is to buy foreign exchange to prevent real appreciation of domestic currency.

Moreover, prudent administration of capital flows tends to reduce volatility; hence, the coefficient on volatility may not be large and statistically significant. The study by Ramachandran (2004) and Ramachandran and Srinivasan (2007) have shown that volatility coefficient is upwardly biased due to measurement errors and established that the bias free estimates do not support the growing importance of precautionary demand in the India context. If it is not precautionary motive what lies behind the large stockpile of reserves?

The present study intends to examine the reason behind accumulation of reserves in India. We have chosen India as it is one among the large reserve holding emerging economies. While introducing the market based exchange rate system in March 1993, the volume of reserves stood at $ 9.832 billion. Subsequently, the level of reserves has steadily increased to $ 304.8 billion as on end of March 2011. The widely used reserve adequacy indicators allude that the current level of reserves is beyond what is optimally required to ensure balance of payments stability. At the end of March 2010, reserves stood at 22 percent of GDP. As on 31st March 2011, the volume of reserves was equivalent to 9.6 months of import; 99.6 percent of external debt; 21.3 percent of short-term external debt; 98 percent of reserve money; 15.9 percent of broad money; and 149 percent of currency with public. Indeed, the strong reserve position, *inter alia*, led the

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4 See Ramachandran and Srinivasan (2007) for further evidence on insignificant role of precautionary demand for reserves.
International Monetary Fund to designate India as a creditor country under its Financial Transaction Plan (Report on Currency and Finance, 2010-11).

The RBI has erected its reserve management policy upon the changing composition of balance of payments, liquidity risks associated with different types of capital flows, unanticipated pressure on balance of payments due to external shocks and movement of repatriable foreign currency deposits of non-resident Indians (Annual Report, RBI, 1999-00). The intermittent excessive capital inflows followed by episodes of ebbing put strain on exchanger rate stability; hence, the RBI had to formulate its foreign exchange market intervention policy with main objectives of maintaining orderly condition in the foreign exchange market without any target or band for exchange rate, enhancing the intervention capacity and avoiding undue overvaluation of rupee. Given the nature of exchange rate policy that prevailed during an era of continued net capital inflows, we believe that the RBI’s intervention to prevent persistent appreciating pressure of rupee has been the root cause for larger reserve accumulation. In other words, the authority’s fear against undue erosion of export competitiveness has triggered the reserve accretion.

In this chapter, we estimate an augmented version of the buffer stock model of Frenkel and Jovanovic (1981) and show that a model based measure of incremental reserve volatility has negligible impact on reserve demand. On the contrary, the significant response of the RBI to exchange rate variations seems to have been the cause for large stockpile of reserves.

2.2 The buffer stock model

The buffer stock model of Frenkel and Jovanovic (1981) defines reserve movements in continuous time period as an exogenous Wiener process:
\[ dR_t = -\mu d_t + \sigma dW(t) \]  

(2.1)

where \( R_t \) is reserve and \( W(t) \) is the standard Wiener process with mean zero and variance \( t \). The change in reserves in a small time interval \((dt)\) is normally distributed and at every time the distribution of reserve holding is defined as:

\[ R_t = R^* - \mu t + \sigma W(t) \]  

(2.2)

where \( R^* \) is the optimal initial level of reserves; \( \mu \) is deterministic part of the instantaneous change in reserves and \( \sigma \) is the standard deviation of the Wiener increment in the reserves. Frenkel and Jovanovic (1981) assume that the balance of payment on an average balances; hence, \( \mu \) is zero. Under this condition, a second order Taylor series approximation of optimal reserve holding yields\(^5\):

\[
R^* = \sqrt{\frac{2c\sigma^2}{(2r\sigma^2)^{0.5}}} 
\]  

(2.3)

where \( c \), \( \sigma \) and \( r \) are fixed cost of reserve adjustment, standard deviation of reserve increment, and opportunity costs of holding reserves respectively and equation (2.3) can be written as:

\[
\log R^* = \beta_0 + \beta_1 \log \sigma + \beta_2 \log r 
\]  

(2.4)

where \( \beta_0 > 0 \) implying that higher fixed cost incurred in reserve restocking increases the optimal reserve holdings; \( \beta_1 = 0.5 \) indicating that higher volatility of incremental reserves increases the frequency of reserves hitting the lower bound; hence, rises the optimal level of reserve demand; and \( \beta_2 = -0.25 \) indicating that increase in the opportunity cost of reserves holding reduces the optimal demand for reserves.

\(^5\) A detailed theoretical exposition can be found in Frenkel and Jovanovic (1981).
Assuming that the actual reserve is proportional to optimal level up to an error term, Frenkel and Jovanovic (1981) estimated the following equation:

\[
\log R_t = \beta_0 + 0.505 \log \sigma_t - 0.279 \log r_t + u_t \\
(0.110) \quad (0.149) \quad R^2 = 0.97, \quad SE = 0.234 \quad n = 110
\]

(2.5)

where \( u_t \) is error term, which is uncorrelated with \( \sigma \) and \( r \) and figures in parentheses are standard errors. Note that the elasticity estimates lie much closer to theoretical prediction.

2.3 Correcting the bias due to skewness

Frenkel and Jovanovic (1981) defined \( \sigma \) as fifteen years rolling standard deviation of change in trend adjusted reserves. Flood and Marion (2002) illustrates the upward bias in the estimated co-efficient on such measure of volatility due to reserve restocking\(^6\).

The buffer stock model states that reserve follows a random walk process with a drift:

\[
\Delta R_t = \eta + \varepsilon_t \\
(2.6)
\]

This is an untenable assumption in the presence of speculative attacks and occasional restocking of reserves. Assume that \( R_{t-2} \) was at its lower limit; hence, \( \varepsilon_t \) is large and positive. It is inventory restocking under the null and therefore, \( \varepsilon_t \) is non-normal. Let the reserve volatility be one period rolling variance:

\[
\sigma_t^2 = \varepsilon_{t-1}^2 \\
(2.7)
\]

If buffer stock model is correct in assuming that observed reserves \( (R_t) \) are around its optimal level \( (R^*) \) then least square coefficient on reserve volatility can be defined as:

\(^6\) To avoid bias, Flood and Marion (2002) has used volatility of fundamentals that determines changes in shadow exchange rate. See also Lizondo and Mathieson (1987) for different volatility measures.
\[ \beta_i = \frac{\text{cov}(R^*, \sigma_i^2)}{\text{var}(\sigma_i^2)} \]  

(2.8)

In reality, however, observed reserves stay far off from the optimal level at some time. For instance, \( R_{t-2} = R^* \). Due to random walk process, \( R_{t-1} = R^* + \eta + \varepsilon_{t-1} \) and \( R_t = R^* + 2\eta + \varepsilon_{t-1} + \varepsilon_t \). If so,

\[ \text{cov}(R_t, \sigma_i^2) = \text{cov}(R^*, \sigma_i^2) + E(\varepsilon^3) \]  

(2.9)

If \( \varepsilon \) is positively skewed due to reserve restocking, then \( \beta > 0 \) regardless of optimal inventory behaviour and vice versa. Ramachandran (2004, 2006) has empirically proved that skeweness in reserve restocking produces biased estimates and provided an alternative measure of volatility to avoid such bias. Ramachandran (2004) defined \( \varepsilon \) having a conditional variance of GARCH (1, 1) process following Engle (1982) and Bollerslev (1986).

\[ \Delta R_t = \omega + \sqrt{\sigma_i^2} \nu_t \]  

(2.10)

where \( \nu_t \) follow normal distribution and \( \sigma_i^2 \) is the conditional variance, defined as:

\[ \sigma_i^2 = \delta + a\varepsilon_{t-1}^2 + b\sigma_{t-1}^2 \]  

(2.11)

where \( \varepsilon_{t-1} = (\Delta R_{t-1} - \omega) \) and equation (2.11) describes GARCH (1,1) model. If we define

\[ \sigma_i^g = \sqrt{\sigma_i^2} \]

the conditional standard deviations from the above equation as:

then

\[ \text{cov}(R_t, \sigma_i^g) = \text{cov}(R^*, \sigma_i^g) \]  

(2.12)

Therefore,

\[ \beta_i = \frac{\text{cov}(R^*, \sigma_i^g)}{\text{var}(\sigma_i^g)} \]  

(2.13)
Thus, the coefficient in equation (2.13) is unbiased estimate on volatility of reserve increment.

2.4 The Empirical Results

We estimate the reserve demand equation (2.4) as a benchmark using weekly data for the period from 06 December 1996 to 25 March 2011. The reserve is measured as foreign currency assets of the RBI\(^7\). The implicit yield on 91 days treasury bills at cut-off price is used as a proxy for opportunity cost\(^8\). The data are collected from various issues of the *Reserve Bank of India Bulletin* and *The Handbook of Statistics on Indian Economy*.

**The bias in the estimates**

We examine the upward/downward bias in the estimated coefficient on reserve volatility, measured as rolling standard deviation of change in log of reserves. The measure of Pearson skewness statistic for weekly reserve increment during the sample period is found to be -0.444. Hence, the data on reserve increment seems to be largely dominated by frequent negative adjustment in response to depreciating pressure on rupee. Hence, multi-period rolling standard deviation tends to capture the large negative adjustment in reserves and therefore, the bias in coefficient on volatility tends to be negative and falling with increase in window size used for constructing rolling standard deviation.

\(^7\) The gold stock and SDRs are not included, as they constitute a very negligible proportion and gold is not used as an intervention asset.

\(^8\) Indeed, the difference between the domestic interest rate and short term interest rates on the United States, European and Japanese government securities could have been a better proxy for opportunity cost, because the bulk of the RBI’s foreign currency assets are held in these instruments. Nevertheless, we use only the domestic interest rate; since the short-term rates in these countries are small and the difference between the domestic and foreign rates are largely influenced by domestic interest rates.
In this context, Flood and Marion (2002) reports insignificant coefficient on reserve volatility measured as three years rolling standard deviation of reserve increment and increasingly positive and highly significant coefficient as the window size extended for constructing volatility measure. Ramachandran (2004) finds downwardly biased coefficient as weekly reserve increment data for the period 1 April 1999 to 27 June 2003 was negatively skewed.

![Fig 2.1 Estimates of volatility coefficient](image)

The coefficient estimates on volatility from the benchmark inventory model for different window size are plotted in Fig. 2.1. The estimates seem to be much lower than the predictions of buffer stock model and turned out to be negative as window size for constructing rolling standard deviation increased beyond 7 weeks. However, the elasticity estimates on opportunity cost (not produced here) are found to be negative and statistically significant.
Modeling the volatility of reserve increment

First, we examined the presence of ARCH effect in the variance of reserve increment using LM test. The test statistics consistently rejected (not produced) the null hypothesis of no ARCH effect at 1% significance level irrespective of lag specifications. This amply justifies using a conditional standard deviation as a measure of volatility.

After an extensive search for an appropriate ARCH specification, we arrive at the following model for the construction of time varying conditional volatility of reserve increment:

\[
\Delta \log R_t = 0.327 + 0.657 \Delta \log R_{t-1} - 0.236 \varepsilon_{t-1} + \sqrt{\sigma_{t-1}^2} \varepsilon_t
\]

\[
\sigma_t^2 = 0.528 + 0.481 \varepsilon_{t-1}^2
\]

ARCH- LM (4) F= 0.578 (0.67)

where \( \varepsilon_{t-1} = \sqrt{\sigma_{t-1}^2} \varepsilon_{t-1} \) and figures in parentheses are p values. The mean equation contains a constant and ARIMA (1, 1) process while the variance equation follows ARCH (1) process. All the estimated coefficients of both mean and variance equations are statistically significant at conventional level. The Ljung-Box Q statistics that follows the \( \chi^2 \) distribution suggest that the standardized residual of the mean equation (\( \nu_t \)) is free from autocorrelation upto fourth lag and the ARCH-LM test that follows the F distribution indicates that the null hypothesis of no ARCH effect in the square of standardized residuals cannot be rejected.

The plots of time varying conditional standard deviation (\( \sigma_t \)) is produced in Fig. 2.2. The volatility of reserve increment seems to be higher and clustered during crisis periods.
and in times of extensive net capital inflows into the stock market. For instance, high volatility is observed during the period from 1996-1998 and this is the period during which there was a slowdown in capital inflows reflecting the reversal of market sentiments and expectations. There are several reasons for the rise in volatility and the most important among them are: (i) imposition of economic sanctioning in the aftermath of nuclear tests during May 1998; (ii) the contagion due to Asian financial crises and Russian crisis of 1997-98. Further, the high volatility observed during mid 2007 to 2009 reflects the impact of sub-prime lending crises of US. Thus, the model based time varying volatility of reserve increment seems to have closely reflected the frequent intervention of the RBI to minimize the undue fluctuations in the exchange rate in times of turbulence in the market.

Fig.2.2 Plots of conditional volatility

![Conditional volatility graph]

**The estimates of reserve demand equation**

In this section, we estimate buffer stock model of Frenkel and Jovanovic (1981) and its augmented versions especially by the incorporation of exchange rate variations in order
to capture the impact of exchange rate intervention on reserve demand$^9$. The exchange rate variables is measured as $em_t = \log(e_t / e_{t-1}) \times 100$, where $e$ is Re/US$ exchange rate.

In addition, $em_t$ is split to understand the differential impact of appreciating rupee ($em^n_t$) and depreciating rupee ($em^d_t$) against US$. These variables are constructed as follows:

$$em^n_t = D1 \times em_t \quad \text{where} \quad D1 = 1 \quad \text{if} \quad em_t < 0; \quad \text{otherwise zero}$$

$$em^d_t = D2 \times em_t \quad \text{where} \quad D2 = 1 \quad \text{if} \quad em_t > 0; \quad \text{otherwise zero}$$

Also, the accretion in reserves took place at different pace during the sample period as it is evident from Fig. 2.3. It is very apparent that there are breaks in the trend in reserve accumulation during the sample period under consideration. Therefore, it is ideal to estimate the reserve demand model for different samples based on the rapidity of reserve accretion.

We have identified three phases. The first phase is identified as the period from 6th December 1996 to 11th November 2005 during which the volume of reserve increased from US$ 19.43 billion to 136.12 billion. While there was many fold rises in the volume of reserves in the first phase, it was rising at a slow pace. The second phase is identified as the period from 18th November 2005 to 18th April 2008. Although it is a short time span of around 30 months, there was a steep rise in volume of reserves to reach its peak.

$^9$ Ideally, we should use the deviation of exchange rate from target or from equilibrium real exchange rate. Instead, nominal exchange rate is chosen since the Reserve Bank of India does not follow any explicit targeting framework. In fact, 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.”
level of US$ 302.99 billion. Thus, more than 50% of the current reserve holdings were accumulated during the second phase. The third phase is running from 25\textsuperscript{th} April 2008 to 25\textsuperscript{th} March 2011 as there was a sharp decline in reserves from its peak of US$ 302.99 as on 4/18/2008 to US$ 237.52 as on 11/4/2008 and subsequently it was fluctuating around US$ 250 billion.

**Fig. 2.3: Reserve accumulation in million US$**

![Reserve accumulation graph](image)

**Time period in weeks**

**The ARDL approach**

According to equation (2.1), $R_t$ follows a Wiener process in continuous time (random walk process in discrete time); hence, log ($R_t$) is also likely to follow the same process. If so, estimation of equation (2.4) is meaningful only if log ($\sigma$) and/or log($r$) are/is I (1) process and cointegrated with $R_t$. The standard unit root tests confirm that log ($R_t$) and log ($r_t$) are I (1) process while log ($\sigma_t$) and ($em$) are I (0) process. Hence, it is inevitable to check for cointegration and to confirm the robustness of our findings. However, the
maximum likelihood approach of Johansen and Juselius (1990) to test for cointegration may not be appropriate, as it requires all the variables to follow same order of integration.

Nevertheless, we can use the bounds test procedure proposed by Pesaran, Shin and Smith (1996) and Pesaran, and Shin (1998) as it does not involve pre-testing the integration properties of the data. It yields asymptotically efficient long run estimates irrespective of whether the underlying regressors are I (0) or I (1) process.

This procedure involves two steps. First, we have to estimate an unrestricted error correction model of reserves:

\[
\Delta \log R_t = aX_t + \sum_{i=1}^{m} b_i \Delta \log R_{t-i} + \sum_{i=0}^{n} c_i \Delta \log \sigma_{t-i} + \sum_{i=0}^{p} d_i \Delta \log r_{t-i} + \gamma_1 \log R_{t-1} + \gamma_2 \log \sigma_{t-1} + \gamma_3 \log r_{t-1} + \varepsilon_t
\]

(2.16)

where \(X_t\) is a vector of deterministic variables; \(b_i, c_i, d_i\) are short run dynamic coefficients; \(\gamma\)s are long run multiplier; and \(\varepsilon_t\) is white noise error. And, rejecting the null hypothesis \(\gamma_1 = \gamma_2 = \gamma_3 = 0\) indicates that there exists long-run relationship among variables irrespective of variables’ integration properties. However, we have to use the critical bounds available in Pesaran, Shin and Smith (1996) for testing the null, as the asymptotic distribution of Wald or F statistics is nonstandard. If variables have long-run relationship, we can estimate the long run coefficients and the corresponding error correction model. This involves estimating an autoregressive distributed lag model:

\[
\log R_t = a_0 + a_t t + \sum_{i=1}^{q_1} \delta_i \log R_{t-i} + \sum_{i=0}^{q_2} \lambda_i \log \sigma_{t-i} + \sum_{i=0}^{q_3} \psi_i \log r_{t-i} + \nu_t
\]

(2.17)
The OLS estimates of equation (2.17) can be used to obtain the long-run relationship:

\[
\log R_t = \alpha_0 + \alpha_t + \phi_1 \log \sigma_t + \phi_2 \log r_t + \eta_t
\]  

(2.18)

We estimate the error correction representation of benchmark buffer stock model \( \{ R \mid \sigma, r \} \) and its augmented versions: \( \{ R \mid \sigma, r, em \} \) and \( \{ R \mid \sigma, re^a, em^d \} \). The split of \( em \) into \( em^a \) and \( em^d \) is more appropriate as there are evidences to prove that the official intervention in the foreign exchange market is asymmetric [Ramachandran, 2004 & 2006; Ramachandran and Srinivasan, 2007]. The lag orders i.e. the length of \( m, n \) and \( p \) are determined by Akaike information criterion. In all the specifications, a linear trend and a constant are included.

The F statistics for testing the null hypothesis of no long-run relationships for three subsamples are produced in Table 2.1. The F statistics for the benchmark model are less than the lower bound for phase 1 and phase 2 while it falls in the inconclusive region during the third phase; suggesting that there is no long run relationship among these three variables. When the benchmark model is augmented by incorporating percentage change in exchange rate, there exist long run equilibrium relationship among reserves, volatility of reserve increment, opportunity cost and percentage change in exchange rate during the first and third phase. The cointegration exists only during the first phase when reserve demand equation is re-specified with the incorporation of asymmetric response to exchange rate behaviour. What is more striking from Table 2.1 is that there is no long run relationship among the variables under consideration during the second phase; suggesting that the buffer stock model and its augmented versions failed to explain the large stock pile of reserves that occurred in a short span of time.

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10 The standard errors of cointegrating coefficients can be derived from delta-method.
Table 2.1: F statistics for testing cointegration

<table>
<thead>
<tr>
<th>Models</th>
<th>Phase 1 (06/12/96 - 11/11/05)</th>
<th>Phase 2 (18/11/05 - 18/04/08)</th>
<th>Phase 3 (25/04/08 - 25/03/11)</th>
<th>( L_F - U_F )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R</td>
<td>\sigma_r )</td>
<td>4.198</td>
<td>2.512</td>
<td>4.071</td>
</tr>
<tr>
<td>( R</td>
<td>\sigma_r \text{em} )</td>
<td>9.126</td>
<td>2.384</td>
<td>7.113</td>
</tr>
<tr>
<td>( R</td>
<td>\sigma_r \text{em}^a \text{em}^d )</td>
<td>10.678</td>
<td>1.823</td>
<td>3.816</td>
</tr>
</tbody>
</table>

The critical bounds for 5% significance level for three, four and five variable models that includes constant and a linear trend are presented in the last column (Pesaran, Shin and Smith, 2001). If \( F > F_U \), one can reject \( \gamma_1 = \gamma_2 = \gamma_3 = 0 \); hence, there is a long-term relationship between the dependent and independent variables. If \( F < F_L \), one cannot reject \( \gamma_1 = \gamma_2 = \gamma_3 = 0 \). In this case, a long-run relationship does not seem to exist. Finally, if \( F_L < F < F_U \) the inference is inconclusive.

The long run elasticity estimates for the first phase are produced in Table 2.2. The coefficients on volatility of reserve increment and opportunity cost are statistically significant and have theoretically expected sign. However, the coefficient on volatility is found to be much less than the theoretical predication; suggesting that reserve accumulation does not reflect any jump in precautionary demand. This evidence is consistent with the findings of Ramachandran (2004 and 2006) and Ramachandran and Srinivasan (2007). The exchange rate elasticity in the second model turns out to be negative and statistically significant indicating that the RBI has been leaning against wind. In case of asymmetric specification, the official response to defend the rupee value is relatively more aggressive than to prevent rupee appreciation. This is possible because there were incidences of financial crises during the first phase that led to undue pressure on rupee to depreciate; hence, there is intervention to defend the rupee value. Since there is no cointegration among the variables in the second phase we do not attempt for estimating the long run elasticities of the reserve demand equation. Although cointegration is not found in the case of benchmark buffer stock model and its asymmetric specification during the third phase, we report the estimates of long run elasticities in Table 2.2 as they largely turn out to be statistically significant in all the
specifications. In all the three specifications, the coefficient with respect to volatility of reserve increment appears to be negative and statistically significant. It is difficult to interpret negative impact of intervention volatility on reserve demand. The opportunity cost variable seems to have insignificantly influenced the reserve demand during the third phase. Nonetheless, the negative and significant coefficient on $em$ suggests that the RBI is leaning against wind. Although the evidence with respect to asymmetry is not much strong, the RBI seems to have been relatively aggressive in preventing rupee appreciation.
Table 2.2: Long run elasticity estimates (06/12/1996 to 11/11/2005)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model: 1 [3,0,0]</th>
<th>Model: 2 [2,0,0,4]</th>
<th>Model: 3 [2,0,0,0,1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_t$</td>
<td>0.248 (0.05)</td>
<td>0.312 (0.01)</td>
<td>0.404 (0.02)</td>
</tr>
<tr>
<td>$r_t$</td>
<td>-0.604 (0.00)</td>
<td>-0.641 (0.00)</td>
<td>-0.761 (0.00)</td>
</tr>
<tr>
<td>$em_t$</td>
<td>-</td>
<td>-0.668 (0.00)</td>
<td>-</td>
</tr>
<tr>
<td>$em_t^e$</td>
<td>-</td>
<td>-</td>
<td>-0.311 (0.04)</td>
</tr>
<tr>
<td>$em_t^d$</td>
<td>-</td>
<td>-</td>
<td>-0.851 (0.01)</td>
</tr>
<tr>
<td>$t$</td>
<td>0.004 (0.00)</td>
<td>0.003 (0.00)</td>
<td>0.003 (0.00)</td>
</tr>
<tr>
<td>Constant</td>
<td>10.986 (0.00)</td>
<td>11.148 (0.00)</td>
<td>11.427 (0.00)</td>
</tr>
<tr>
<td>$ecm_{t-1}$</td>
<td>-0.013 (0.00)</td>
<td>-0.013 (0.00)</td>
<td>-0.012 (0.00)</td>
</tr>
</tbody>
</table>

Note: Figures in [#] indicate the lag order of variables chosen by Akaike Information Criterion and figures in (#) are p-values.

We further probe the issue of steep rise in reserve holding during the second phase. This is the time period during which there was stock market boom and there were huge inflows of speculative capital especially into the stock market. Hence, modeling reserves ignoring the significant growth in the stock market transaction may not be appropriate.

We examine this issue by including log of BSE sensex ($s$) as one of the variables in the model.
Table 2.3: Long run elasticity estimates (25/04/2008 to 25/03/2011)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model: 1 [1,2,0]</th>
<th>Model: 2 [1,2,0,1]</th>
<th>Model: 3 [3,2,0,1,0]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_t$</td>
<td>-0.274 (0.02)</td>
<td>-0.309 (0.00)</td>
<td>-0.285 (0.01)</td>
</tr>
<tr>
<td>$r_t$</td>
<td>-0.033 (0.07)</td>
<td>0.030 (0.62)</td>
<td>0.045 (0.44)</td>
</tr>
<tr>
<td>$em_t^e$</td>
<td>-</td>
<td>-0.117 (0.01)</td>
<td>-</td>
</tr>
<tr>
<td>$em_t^{d0}$</td>
<td>-</td>
<td>-</td>
<td>-0.143 (0.02)</td>
</tr>
<tr>
<td>$em_t^{d1}$</td>
<td>-</td>
<td>-</td>
<td>-0.106 (0.02)</td>
</tr>
<tr>
<td>$t$</td>
<td>0.0007 (0.29)</td>
<td>0.0002 (0.00)</td>
<td>0.0001 (0.70)</td>
</tr>
<tr>
<td>Constant</td>
<td>12.711 (0.00)</td>
<td>12.679 (0.00)</td>
<td>12.624 (0.00)</td>
</tr>
<tr>
<td>$ecm_{t-1}$</td>
<td>-0.039 (0.02)</td>
<td>-0.038 (0.01)</td>
<td>-0.039 (0.00)</td>
</tr>
</tbody>
</table>

Note: Figures in [#] indicate the lag order of variables chosen by Akaike Information Criterion and figures in (#) are p-values.

The F statistics for testing the cointegration between reserves and other variables are presented in Table 2.4. In all the models under consideration, trend and constant are not used as they turned out to be statistically insignificant. Hence, the bound statistics produced in the third column of the Table 2.4 are corresponding to the error correction representation that excludes trend and constant. The F statistics are found to be above the upper critical bound when the buffer stock model includes log of BSE sensex as an additional variable; indicating that there is cointegration among the variables that figure in each model presented in the first column of the Table 2.4.
Table 2.4: F Statistics for testing cointegration (18/11/05 - 18/04/08)

<table>
<thead>
<tr>
<th>Models</th>
<th>F Statistics</th>
<th>$L_F - U_F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R</td>
<td>s$</td>
<td>6.400</td>
</tr>
<tr>
<td>$R</td>
<td>s\sigma$</td>
<td>5.772</td>
</tr>
<tr>
<td>$R</td>
<td>s\sigma r$</td>
<td>4.604</td>
</tr>
<tr>
<td>$R</td>
<td>s\sigma em$</td>
<td>4.669</td>
</tr>
<tr>
<td>$R</td>
<td>s\sigma em^e em^d$</td>
<td>3.398</td>
</tr>
</tbody>
</table>

The corresponding long run elasticity estimates are produced in Table 2.5. First, we consider a bi-variate model wherein only stock index is considered as an explanatory variable. The elasticity coefficient on stock index is 1.296 and highly significant in statistical sense. When we add volatility of reserve increment in the model the magnitude of elasticity coefficient with respect to stock index does not change significantly. Although the coefficient on volatility is positive, it is significant only at 7% level. In the remaining three specifications of reserve demand function, only the coefficients on stock index and volatility are statistically significant. These evidences indicate that more than fifty percent of current reserve holdings, which were accumulated during a short span of around 30 months reflect the absorption of speculative capital that were flowing into the stock market. In sum, it is not the growing precaution that had driven the reserve accumulation in India. The RBI having the prime objective of ensuring orderly condition in the foreign exchange market without any specific target for exchange rate has been fighting to minimize the volatility in exchange rate triggered by excessive cross-border capital flows which are highly speculative in nature.
Table 2.5: Long run elasticity estimates (18/11/05 - 18/04/08)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$s$</td>
<td>1.296 (0.00)</td>
<td>1.272 (0.00)</td>
<td>1.155 (0.00)</td>
<td>1.272 (0.00)</td>
<td>1.272 (0.00)</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>0.228 (0.07)</td>
<td>0.261 (0.07)</td>
<td>0.223 (0.04)</td>
<td>0.287 (0.05)</td>
<td></td>
</tr>
<tr>
<td>$r$</td>
<td></td>
<td></td>
<td>0.586 (0.31)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$em$</td>
<td></td>
<td></td>
<td></td>
<td>0.138 (0.15)</td>
<td></td>
</tr>
<tr>
<td>$em^a$</td>
<td></td>
<td></td>
<td></td>
<td>0.219 (0.26)</td>
<td></td>
</tr>
<tr>
<td>$em^d$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.007 (0.97)</td>
</tr>
<tr>
<td>$ecm_{t-1}$</td>
<td>-0.019 (0.01)</td>
<td>-0.021 (0.00)</td>
<td>-0.019 (0.01)</td>
<td>-0.023 (0.00)</td>
<td>-0.018 (0.01)</td>
</tr>
</tbody>
</table>

Note: Figures in [#] indicate the lag order of variables chosen by Akaike Information Criterion and figures in (#) are p-values.

2.5 Concluding observations

There is a general consensus on the view that the unprecedented accumulation of reserves in some emerging countries reflects significant rise in precautionary demand for reserves in response to increased frequency and intensity of banking and financial crises. Some of the recent empirical studies on reserve demand provide evidence in favour of this claim. Nevertheless, it is intriguing to note that India stands as one among the top reserve holding countries. Most of the transactions on capital account are still administered and capital outflows are not as free as capital inflows. Such an asymmetric control over capital flows aimed at preventing sudden withdrawal of capital; hence, it is less probable that the country will face currency crises or speculative attacks. If so, why should the authority build up huge volume of reserves? This paper seeks to answer this question.
The estimates of buffer stock model obtained from autoregressive distributive lag model revealed that the coefficient on incremental reserve volatility is upwardly biased when volatility is measured as rolling average of standard deviation of past reserve increment. Alternatively, we derive volatility from an appropriate GARCH model that provides bias free elasticity estimates. It is interesting to note that the estimated volatility coefficient is much lower than theoretical prediction. The negative coefficient with respect to change in log of nominal Re/$ exchange rate indicate that the RBI leans against wind; hence, the exchange rate intervention during an era of persistent net capital inflows seems to have contributed to the large stockpile of reserve. The empirical evidences further indicate that more than fifty percent of current reserves holdings, which were accumulated during a short span of around thirty months, reflect the absorption of speculative capital that were flowing into the stock market. In sum, it is not the growing precautionary motive that had driven the reserve accumulation in India, rather stock pile of reserves is largely an outcome of the exchange rate policy that aims at ensuring orderly condition in the foreign exchange market without any specific target for exchange rate.