Asymmetric exchange rate intervention and international reserve accumulation in India

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Abstract

The empirical evidence derived from the ARDL approach of Pesaran, Shin and Smith (1996) does not support the widely held view that growing volatility of external transactions has significantly increased reserve demand. Instead, asymmetric exchange rate intervention triggered, perhaps, by concerns about export competitiveness seems to have contributed to large stockpile of reserves.

Keywords: reserve demand; buffer stock model; asymmetric exchange rate intervention.

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1 Introduction

The recent surge in official international reserves holding of emerging market economies (EMEs) 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 has significantly increased the precautionary demand for reserves (Flood and Marion, 2002; Aizenman and Lee, 2005).

However, this claim may not be valid in the presence of administrative controls over capital flows. For instance, in India capital flows are highly restricted and outflows are not as free as inflows (Nayyar, 2000; Miniane, 2004). Such asymmetric control is an integral part of exchange rate management, as it would minimize the probability of sudden reversal of capital flows. Hence, it is hard to believe that the surge in reserve holding reflects precautionary demand. A recent empirical study by Ramachandran (2004) shows that volatility has not played a major role in explaining growing demand for reserves in India. If so, what explains the unprecedented accumulation of reserves?

It is often pointed out that exchange rate intervention policy is triggered by concerns about export competitiveness (Dooley, Folkerts-Landau and Garber, 2003). If this is the case, the authority's response to appreciating pressure on domestic currency is likely to be more forceful than to depreciating pressure of the same magnitude. Such a policy response which aims at strengthening export competitiveness leads to accumulation of reserves over time. We empirically examine whether evidence for such asymmetries exist which differentiates our study from other existing studies.

Section 2 presents the extended version of buffer stock reserve demand equation; section 3 deals with empirical results; and section 4 concludes.

2 The model

We use the buffer stock model of Frenkel and Jovanovic (1981) to explain the growing demand for reserves. This model is found to be very popular in the empirical literature on reserve demand, as their elasticity estimates were remarkably close to their theoretical prediction.[1] The benchmark reserve demand equation is:

$$\log R_t = \beta_0 + \beta_1 \log \sigma_t + \beta_2 \log r_t \ + u_t \qquad \beta_1 \succ 0,\ \beta_2 \prec 0 \tag{1}$$

where R_t is reserves, σ_t is volatility of reserve increment, r_t is opportunity cost of holding reserves and u_t is white noise error . The model assumes that reserve movements follow a random walk process (Wiener process in continuous time period).

We incorporate asymmetric exchange rate intervention by extending equation (1) as follows:

$$\left.\begin{aligned} \log(R_t) &= \beta_0 + \beta_1 \log(\sigma_t) + \beta_2 \log(r_t) + \alpha e_t + u_{st} \\ \log(R_t) &= \beta_0 + \beta_1 \log(\sigma_t) + \beta_2 \log(r_t) + \lambda_1 e_t^a + \lambda_2 e_t^d + u_{at} \end{aligned}\right\} \tag{2}$$

where $e_t = (\Delta \log E_t) \text{ x } 100$ [E is domestic price of one unit of foreign currency]; hence, e_t is percentage change in exchange rate. If $\alpha < 0$ then authorities lean against the wind and exchange rate variation have a symmetric impact on reserve demand. Furthermore, e_t^a and e_t^d are measures of appreciating and depreciating pressure on domestic currency.[2] That is, $e_t^a = d1e_t$ [$d1 = 1$ if $e_t < 0$ and zero otherwise] and $e_t^d = d2e_t$ [$d2 = 1$ if $e_t > 0$ and zero otherwise]. The coefficients λ_1 and λ_2 measure the response of reserve demand to appreciating and depreciating pressure respectively. For example, if $\lambda_1 < 0$ authorities

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[1] The theory predicts that $\beta_1 = 0.5$ and $\beta_2 = -0.25$.

[2] 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."

buy foreign exchange in response to appreciating pressure. Such a policy response in an era of continuous net capital inflows accelerates the accumulation of official reserves.

3 The empirical results

The estimates of reserve demand equations are obtained using weekly data for the period from 05 January 2001 to 12 August 2005[3]. We choose this sample as more than three fourth of current level of reserves (US$ 139.51 billion as on 13th January 2006) has been accumulated during this period. For estimation purpose, reserve is measured as foreign currency assets while the implicit yield on 91-day Treasury bill at cut-off price is used as a proxy for opportunity cost.[4,5] The exchange rate is defined as rupee per US$. The data are collected from various issues of the Reserve Bank of India Bulletin and The Handbook of Statistics on Indian Economy.

The construction of volatility measure (σ) is very crucial in estimating reserve demand equation. Flood and Marion (2002) have demonstrated that defining volatility as rolling standard deviation of reserve increment provides upwardly biased coefficient estimates due to positive skewness in the data. However, Ramachandran (2004) has shown that the use of conditional standard error of reserve increment eliminates such bias. Accordingly, we examine the presence of ARCH effect in reserve increment using LM test. The test statistics consistently reject (not reported) the null hypothesis of no ARCH effect at 1% significance level for different lag specifications. This justifies using conditional standard errors of reserve increment from an appropriate ARCH model (Engle, 1982). Based on the Ljung Box test statistic, we constructed conditional volatility using ARCH (1) process. The OLS estimates of the reserve demand equation (1) is:

$$\begin{gathered}\log R_t = 12.175 + 0.285 \log \sigma_t - 1.651 \log r_t \\ (0.00) \quad (0.00) \qquad (0.00) \quad R^2 = 0.71 \quad F = 289.87 (0.00) \quad D-W = 0.27\end{gathered} \tag{3}$$

[3] This is the minimum frequency at which data on reserve is available for India.

[4] The gold stock, SDRs and Reserve Tranche Position held with the IMF are not included, as they constitute a very negligible proportion of reserves and are not used as an intervention asset.

[5] 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 low and the difference between the domestic and foreign rates are largely influenced by domestic interest rates.

where σ is conditional standard deviation of reserve increment. The p-values in parentheses indicate that the model and the estimated coefficients are significant at 1% level. Although the coefficients have the expected sign, the coefficient on volatility is much lower than the theoretical prediction while the opportunity cost elasticity is larger.[6] However, the D-W statistic (0.27) is lower than R^2 value (0.71) implying that the estimates might be spurious.[7]

Moreover, the standard units root tests (not reported) confirms that R_t follows I (1) process, consistent with the assumption of the buffer stock model. However, the autoregressive conditional standard error- a measure of volatility (σ) and change in exchange rate are I (0) whereas the opportunity cost is I (1) process. Hence, 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 the 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 integration properties of the data. The test yields asymptotically efficient long run estimates irrespective of whether the underlying regressors are I (0) or I (1) process. For instance testing for cointegration among R, σ, and r involves the following steps. First, we need to estimate an unrestricted error correction model of reserves:

$$\begin{aligned}\Delta \log R_t &= aX_t + \sum_{i=1}^{m} b_i \Delta \log R_{t-i} + \sum_{i=0}^{n} c_i \Delta \log \sigma_{t-i} + \sum_{i=0}^{p} d_i \Delta \log r_{t-i} \\ &\quad + \gamma_1 \log R_{t-1} + \gamma_2 \log \sigma_{t-1} + \gamma_3 \log r_{t-1} + \varepsilon_t \end{aligned} \tag{4}$$

[6] The most difficult task in estimating the reserve demand equation is obtaining an appropriate measure of opportunity cost of reserve holding. See Ben-Bassat and Gottlieb (1992) for a debate on opportunity cost measures.

[7] The empirical studies on reserve demand have widely used the buffer stock model of Frenkel and Jovanovic (1981) and estimate the parameters of the model using OLS method. However, the buffer stock model assumes that reserves follow a random walk process in discrete time. If so, estimation of reserve demand equation using OLS method is meaningful if and only if one or all regressors of reserve demand specification follow random walk process and are cointegrated with reserves. Hence, it is essential to examine the integration and cointegration properties of variables in reserve demand function.

where X_t is a vector of deterministic variables; b_i, c_i, d_i are short run dynamic coefficients; γs are long run multiplier; and ε_t is white noise error. Rejecting the null hypothesis $\gamma_1 = \gamma_2 = \gamma_3 = 0$ indicates that there exists long-run relationship among R, σ, and r 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:

$$\log R_t = a_0 + a_1 t + \sum_{i=1}^{q_1} \delta_i \log R_{t-i} + \sum_{i=0}^{q_2} \theta_i \log \sigma_{t-i} + \sum_{i=0}^{q_3} \psi_i \log r_{t-i} + \nu_t \qquad (5)$$

The OLS estimates of equation (5) can be used to obtain the long run coefficients of reserve demand equation. We estimate equation (4) for specifications: $R| \sigma, r$; $R | \sigma, r, e$; and $R | \sigma, r, e^a, e^d$ with a linear trend and a constant as deterministic variables.[8] The F statistics for testing the null hypothesis of no long-run relationships are produced in Table 1. The test statistics for different lag structure across alternative specifications are consistently above the critical values. This confirms that there exists long run relationship among all the variables.

Accordingly, we estimate equation (5) to obtain the long run coefficients while the standard errors are obtained using the delta method. The results in Table 2 indicate that volatility has positive and statistically significant impact on reserve demand. However, the coefficient on volatility is much lower than the theoretical prediction. The coefficient on opportunity cost variable is negative and statistically significant. Moreover, its magnitude is closer to the theoretical prediction unlike OLS estimate of -1.65. In the case of symmetric model, the negative coefficient on percentage change in exchange rate

[8] We consider shorter lags in the short-run dynamic specification of error correction model considering the high frequency of reserve adjustment and found no significant difference in the quality of results for longer lags; hence, we present results for symmetric lags of 2, 4, and 8.

implies that the RBI is leaning against the wind irrespective of whether rupee is under appreciating or depreciating pressure.

Table 1: F statistics for testing cointegration

Symmetric lags	$R/\sigma, r$	$R/\sigma, r, e$	$R/\sigma, r, e^a, e^d$
2	8.205	8.373	8.122
4	10.042	8.786	7.389
8	9.8432	8.710	6.974

The critical bounds for 5 % significance level in the case of three, four and five variable models with constant and a linear trend are 4.903 - 5.872; 4.066 - 5.119; and 3.539 - 4.667 respectively (Pesaran, Shin and Smith, 1996). If $F > F_U$, one can reject $\gamma_1 = \gamma_2 = \gamma_3 = 0$; hence, there is a long-term relationship among variables. If $F < F_L$, one cannot reject $\gamma_1 = \gamma_2 = \gamma_3 = 0$; hence, there is no long-run relationship. Finally, if $F_L < F < F_U$ the inference is inconclusive.

Table 2: Estimates of long run coefficients

Variables	Coefficients of		
	Benchmark model	Symmetric model	Asymmetric model
σ	0.110 (0.03)	0.128 (0.03)	0.113 (0.03)
r	-0.553 (0.00)	-0.581 (0.00)	-0.536 (0.00)
e		-0.183 (0.00)	
e^a			-0.226 (0.00)
e^d			-0.099 (0.14)
c	10.982 (0.00)	10.946 (0.00)	10.939 (0.00)
T	0.005 (0.00)	0.004 (0.00)	0.004 (0.00)
ecm_{t-1}	-0.038 (0.01)	-0.035 (0.00)	0.038 (0.00)

Figures in parentheses are p values. The SBC and AIC criteria suggested ARDL order of (2, 0, 0) for benchmark buffer stock model; (2, 0, 0, 0) for symmetric intervention model; and (2, 0, 0, 0, 0) for asymmetric intervention model.

The striking feature of the results in Table 2 is that reserve responds asymmetrically to exchange rate variations. There is a rise in reserve demand in response to appreciating rupee whereas the reserves do not fall significantly in response to depreciating rupee. This type of asymmetric response to exchange rate changes over time seems to have contributed to the huge accumulation of official reserves in India. The last row of the Table 2 presents the speed of adjustment parameter. The coefficients are significant with expected sign, but the convergence rate is moderate.

Table 3: Predictive accuracy of reserve demand equations

Competing models (mean square errors)	T–values (p values)
Benchmark (0.02847) vs. Symmetric (0.01506)	4.704 (0.00)
Benchmark vs. Asymmetric (0.01227)	5.149 (0.00)
Symmetric vs. Asymmetric	3.485 (0.00)

Since we find cointegration among all the specifications of reserve demand, we examine the superiority of one specification over the other using the predictive accuracy test suggested by Diebold and Mariano (1995). The predicted values of reserves are constructed using the long run coefficients of respective models and the test results are produced in Table 3. The mean square error of benchmark model is the highest while that of asymmetric model is the lowest. The last column provides the t – values to test the null hypothesis that two competing models have equal forecast accuracy. The evidence indicates that the null is rejected in three possible competing reserve demand specifications. The lowest mean square error (and the t – values) observed indicate that the forecast accuracy of asymmetric specification is superior to benchmark and symmetric specification. In sum, the results suggest that asymmetric exchange rate intervention triggered by concerns about India's export competitiveness played a major role in explaining reserve accumulation.

4. Conclusion

The evidence derived from the ARDL approach of Pesaran, Shin and Smith (1996) does not support the view that growing volatility of international transactions has significantly increased reserve demand in India. Instead, asymmetric exchange rate intervention i.e. aggressive purchase in response to appreciating rupee and insignificant response to depreciating rupee seems to have contributed to large stockpile of reserves.

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