International Reserve Accumulation and Money Dynamics: An Empirical Investigation in Indian Context

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ABSTRACT

This paper empirically investigates the extent and effectiveness of sterilization policies of the Reserve Bank of India to offset the monetary expansionary effect of reserve accumulation during the period 1993-2007. The extent of sterilization is measured by examining the neutralization of the effect of reserve accumulation on the monetary base and its effectiveness is investigated by examining the impact of reserve accumulation on domestic interest rates. Using monthly data, a credit reaction function of the Reserve Bank of India is estimated by employing the Vector Autoregressive methodology. The empirical results show that the Reserve Bank of India sterilizes around 90 percent of reserve accumulation and the reserve accumulation does not lead to an increase in the domestic interest rates. Hence, we conclude that the Reserve Bank of India is effectively carried out the sterilized intervention policies, without loosing the monetary policy autonomy, over the study period.

Keywords: International Reserves, Sterilization Coefficient, VAR, Granger Causality, Impulse Response Function.

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1. Introduction

In recent years, there has been a phenomenal increase in international reserves with the central banks of developing countries. The share of developing countries to global reserves has risen dramatically from 30 percent in 1990 to 72 percent in 2007 (IMF 2007). Interestingly the Asian economies are the major reserve holders among developing countries. Since most of these countries follow a managed float exchange rate system, the reserve accumulation arise problems to the central banks in managing exchange rate and monetary targets.

It is argued that the high level of reserve holdings with the central banks can improve the external position of a country and help to maintain the confidence among other countries. However, the reserve accumulation has serious domestic implications, especially in the conduct of monetary policy. The international reserves are part of a country's money supply and hence an increase in reserves leads to an equivalent increase in the domestic money supply. If the capital account is open, then the reserve accumulation ends up with the so called problem of 'impossible trinity'[1]. Under such circumstances, the sterilized intervention[2] helps to maintain an independent monetary policy at least in the short-run (Calvo and Reinhart, 2002).

Though most of the developing countries adopted sterilization policy to control the increase in money supply due to the reserve accumulation, the degree of sterilized intervention and its effectiveness are being questioned when the countries experience 'high capital inflow driven reserve accumulation'. It is argued that sterilization can be difficult to execute and sometimes even self-defeating, as sustained sterilization operation may raise domestic interest rates and stimulate even greater capital inflows and may induce the central bank to accumulate foreign exchange reserves. This process leads to an

[1] The theory of impossible trinity states that no country can follow an independent monetary policy if it follows fixed exchange rate policies and its capital account is open.

[2] This is a policy followed by the central bank to offset the inflationary effect of the reserve accumulation by selling Govt. securities and changing the 'reserve requirement' of the commercial banks etc.

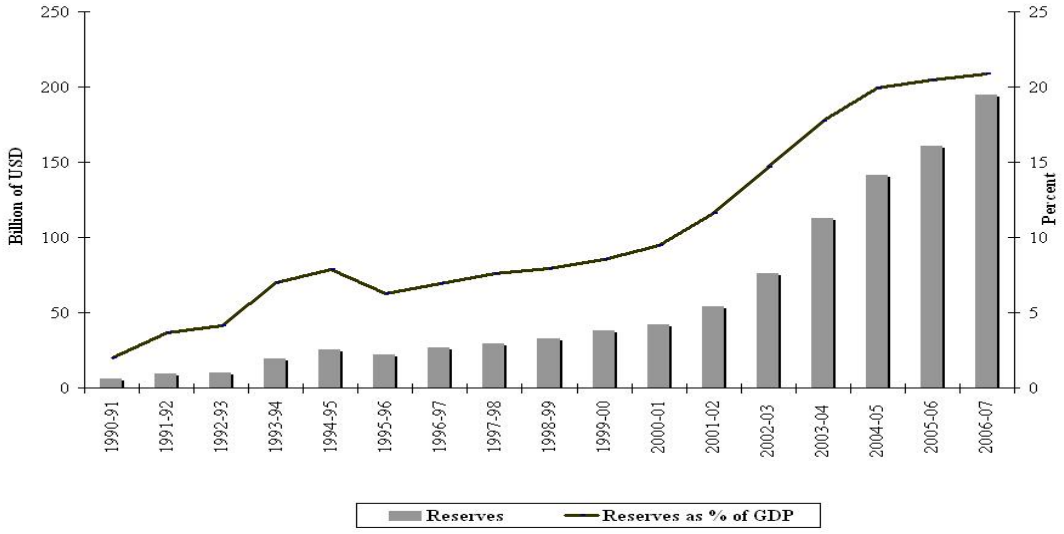
expansionary pressure on domestic money supply, which would in turn could offset the initial monetary tightening through sterilization i.e. reduce the effectiveness of sterilization policy. In addition, this will also increase the cost of sterilization, which is often called 'quasi fiscal cost'[3] (Lee, 1997; Calvo, 1991**)**.

The present paper empirically investigates the behavior of sterilized intervention followed by the Reserve Bank of India (RBI), the central bank of India, during the period 1993-2007. India holds more than 200 billion US dollar as international reserves as of end March 2007 and this level of reserves accounts for more than 20 percent of India's Gross Domestic Product (see Figure 1). It is observed that during the course of reserve accumulation the RBI has followed extensive sterilization policy to offset its expansionary monetary impact. Given the fact that the interest rate offered in India is higher than that of the developed economies, a further increase in domestic interest due to sterilization policy may affect the effectiveness of this policy. The extent of sterilized intervention and its impact on domestic interest rate have not been comprehensively investigated in the Indian context. The present study attempts to examine the extent of sterilization followed by the RBI and the effectiveness of these policies.

The rest of the paper is organized as follows: section 2 deals with evidence of sterilized intervention in India and is followed by empirical model to estimate the sterilized intervention in the section 3. Sections 4 and 5 deal with data sources and econometric methodology. The empirical results are discussed in section 6. Section 7 presents the conclusion.

[3] Quasi-fiscal cost amounts to the interest rate differential between domestic and foreign multiplied by the size of the sterilization.

Figure 1: Trends in International Reserve Holdings in India

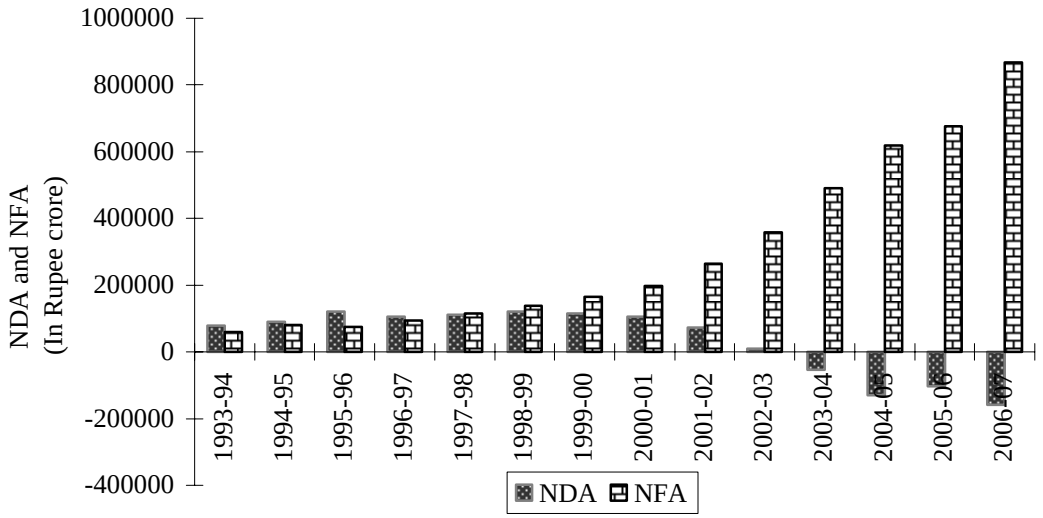


2. Sterilized Intervention in India

An increase in the international reserves directly affects the assets side of balance sheet of the central bank because the total monetary base or reserve money (RM) comprises two assets, namely, net domestic assets (NDA) and net foreign assets (NFA). The purchase of the foreign currency by the central bank to avoid the appreciation of the domestic currency during periods of capital inflows, leads to an increase in NFA and in turn to an equivalent increase in RM, which is known as non-sterilized intervention. At the same time, these monetary expansionary effects of reserve accumulation can be neutralized by reducing the domestic component of monetary base i.e. NDA. This process is known as sterilized intervention and can be implemented through sale of domestic bonds equivalent to the increase in NFA or an increase in 'reserve requirements' of commercial banks.

Figure 2 shows that the RBI reduced NDA considerably to offset the effect of increase in NFA on monetary base and interestingly, the NDA tended to be negative after 2003-04. These are the clear indications of the sterilization activity followed by the RBI to neutralize the inflationary impact of reserve accumulation.

Figure 2: Trends in Change in NDA and NFA



It is interesting to see the dynamics of sterilization operation of the RBI by analyzing the sources of changes in reserve money. Table 1 shows the percentage contribution of the various components of reserve money to the change in the reserve money and which reveal that the percentage contribution of NFA is highly positive in all the years, except 1995-96. This indicates that the reserve money growth is mainly on account of the growth in NFA. At the same time, it is also seen that RBI's credit to the commercial sector (RBICC) is adjusted to offset the increase in NFA till the year 1996-97. This implies that during this period the RBI has sterilized the monetary effect of reserve accumulation by squeezing the availability of credit to the commercial sector. This is consistent with the monetary targeting policy framework followed by the RBI during that period, where, the broad money was projected and bank reserves requirements such as CRR and SLR, were used as instruments of monetary policy. The CRR was continuously revised during this period to manage the availability of credit to the commercial sector (Table 2).

After 1997-98, the increase in NFA is largely offset by the reduction in RBI credit to the Govt., RBICG. This is due to the high open market operation (OMO) followed by the RBI for liquidity management during this period as part of the adoption of multiple indicator approach as a target of monetary policy (Table 2). Under this approach, short-term interest rate is considered as a major instrument of monetary policy, and hence, the liquidity is managed through OMO in the form of outright purchase/sale of govt. securities for liquidity management. The increased sale of govt. securities under OMO to offset the increase in NFA resulted in the reduction of RBI credit to the Govt., RBICG, after 1998-99.

In addition to OMO, the RBI has introduced the Liquidity Adjustment Facility (LAF) in June 2000 to manage the liquidity on a daily basis. This facility consists of Repo[4] and Reverse Repo[5] auctions of government securities to inject and absorb the liquidity from the system. Though the main objective of the LAF is for very short-term liquidity management and to provide stability in the overnight money market, it was widely used for sterilizing the impact of reserve accumulation during the period 2001 to 2003. Subsequently, the RBI introduced Market Stabilization Scheme (MSS) to supplement the LAF to sterilize the monetary impact of reserve accumulation in April 2004. MSS is an arrangement between the Government of India and RBI to absorb the excess liquidity generated due to the reserve accumulation in order to neutralize the monetary impact of capital flows. Under the scheme, RBI issues Treasury Bills/dated government securities by way of auctions and the cost of sterilization is borne by the Government.

During period of high reserve accumulation, the RBI may be required to offer high interest rates to carryout the massive sterilization policies. It can be seen from the table 2 that the RBI has revised the CRR extensively during the early 1995-96 and OMO and Repos thereafter. It is argued that the existence of the high interest rate differential in the developing countries is the major reason for the capital flows and therefore, an increase in the domestic interest rate due to the sterilized intervention in India may attract the capital flows and lead to further accumulation of reserves. This process may offset the

[4] Interest rate for injection of the liquidly
[5] Interest rate for absorption of the liquidly

initial sterilization policy carried by the RBI and thus it may affect the effectiveness of sterilization policy.

Table 1: Movements in the Monetary Base

(Percentage to change in Reserve Money)

	RBICG	**RBICC**	**NFA**	**GCL**	**NMLL**	**RM**
1990-91	148.8	24.8	18.7	0.6	93.1	100
1991-92	**44.0**	-34.0	**92.5**	0.7	3.3	100
1992-93	39.3	33.2	33.7	1.0	7.3	100
1993-94	**3.0**	-14.7	**103.1**	0.5	-7.9	100
1994-95	7.1	26.3	76.1	1.2	10.8	100
1995-96	78.9	34.7	-2.4	0.4	11.6	100
1996-97	**51.2**	-281.4	**374.9**	7.5	52.2	100
1997-98	41.5	7.6	79.7	1.6	30.6	100
1998-99	52.8	31.0	67.0	1.5	52.4	100
1999-00	-20.1	30.8	131.3	3.4	45.5	100
2000-01	24.6	-25.4	137.5	3.4	40.0	100
2001-02	**-4.9**	-27.6	**192.7**	2.9	63.1	100
2002-03	**-101.3**	-20.8	**303.2**	2.2	83.3	100
2003-04	**-112.3**	-4.04	187.0	0.3	-28.9	100
2004-05	**-119.4**	-1.5	**243.9**	0.2	23.1	100
2005-06	31.1	0.6	71.7	1.5	5.0	100
2006-07	**-1.7**	1.46	**142.0**	-0.34	41.4	100

RBICG: RBI credit to government
RBICC: RBI credit to commercial sector including commercial banks
NFA: Net Foreign Assets = Foreign currencies with RBI + Gold
GCL: Govt. currency liability to the public
NMLL: Net non-monetary liabilities of the RBI
RM: Reserve Money (RM = RBIGC+ RBICC+ NFA+ GCL- NMLL)

Table 2: Trends in OMO, CRR and Repos

	OMO Net Purchase	CRR	Repo-Injection	Reverse Repo Absorption
1990-91				
1991-92		15		
1992-93		15		
1993-94		14.5, 14		
1994-95		14.5, 14.75, 15		
1995-96	-530.3	14.5, 14		
1996-97	-10582.7	13.5, 13, 12, 11.5,11, 10.5, 10		
1997-98	-7613.94	9.75, 9.5, 10, 10.5, 10.25		
1998-99	-29668.3	10, 11, 10.5		
1999-00	-30860.9	10, 9.5, 9		
2000-01	-21998.1	8.5, 8, 8.25, 8.5, 8.25, 8		
2001-02	-30334.6	7.5, 5.75, 5.5	9, 8.75, 8.5,8	7, 6.75, 6.5,6
2002-03	-53401.5	5, 4.5	8, 7.5, 7.1	6, 5.75, 5.5, 5
2003-04	-41598	4.5	7	5, 4.5
2004-05	-2899.24	4.75, 5	6	4.5, 4.75,
2005-06	-3912.71	5.25	6, 6.25, 6.5	4.75, 5, 5.25, 5.5
2006-07	-5125.38	5.5, 5.75, 6	6.5, 7, 7.25, 7.5,	5.5, 5.75, 6

The empirical studies in the Indian context examined the extent of sterilized intervention followed by the RBI. The extent of sterilization is analyzed through the statistical significance of sterilization coefficient by estimating a standard credit reaction function of a central bank. The value of sterilization coefficient is expected to lie between -1 and 0 and where -1 implies full sterilization and 0 implies no sterilization. Kohli (2001) estimated the domestic credit reaction function for the period of 1993-2000 by taking NDA as the dependent variable, NFA, and lagged inflation as independent variables and estimated the coefficient of sterilization which found to be -1.09, leading to the conclusion of full sterilized intervention during the period of study. Patnaik (2004) estimated the sterilization coefficient of -0.82 for the period 1993-2003. The index of industrial production (IIP) and Cash Reserve Ratio (CRR) were included as explanatory

variables in the credit reaction function. However, a study by the RBI (2002-03) estimated the coefficient of sterilization as -0.92 for the period 1993-2003.

The above studies offer a range of values on the extent of sterilization by the RBI. However, there is a dearth of studies examining the effectiveness of the sterilization policy. The present context with extensive use of different measures of sterilization operation by the RBI provides an opportunity to analyze the effectiveness of these policies in terms of impact on reserve accumulation on domestic interest rates.

3. Empirical Model

In order to estimate the extent of sterilization, the following credit reaction function of the central bank is estimated.

$$\Delta NDA_t = \gamma_0 + \gamma_1 \Delta NFA_t + \gamma_2 \Delta IIP_t + \gamma_3 \Delta CRR_t + \gamma_4 \Delta ER_t + \varepsilon_t \qquad (1)$$

In equation (1) NDA_t denotes net domestic assets, NFA is the value of net foreign assets and IIP is a measure of output. CRR measures of commercial bank's reserve requirement and ER is the exchange rate [6]. γ_i s are the parameters to be estimated, γ_0 is the intercept term, ε_t is the error term, Δ denotes change and 't' stands for time . All variables are expressed in logarithmic form. The variable definition and its expected signs are discussed below.

Net Domestic Assets (NDA): the depended variable NDA is obtained by subtracting the components of NFA from reserve money (M0). It was observed from the NDA series that some observations in the series contain negative values and therefore, the direct logarithmic transformation is not possible. Hence following, Moreno (1996) the variable NDA is proxied by the difference between log of reserve money and log of net foreign assets[7].

[6] We also tried to incorporate the variables such as real exchange rate and inflation and however, the observed relationships are not theoretically supportive.
[7] Similar method is used by RBI (2002-03) to estimate sterilization coefficient.

Net Foreign Assets (NFA): Generally, the NFA is the defined as the difference between gross foreign reserves and external liabilities. In India, the RBI measures the NFA by subtracting SDR and Reserve Tranche Position in IMF components from total foreign exchange reserves. *NFA* is expected to negatively affect *NDA* when the central banks are engaged in sterilized intervention. The coefficient of *NFA*, γ_1, measures the extent of the sterilization and it takes a value between 0 and -1. When, $\gamma_1 = 0$ it implies absence of sterilization, which means that an increase in reserves leads to an equivalent increase in base money. Conversely, if $\gamma_1 = 1$, then it implies full sterilization of the monetary effect of reserve accumulation. If γ_1 takes a value between 0 and -1 then it implies partial sterilization. The closer the estimate of γ_1 is to -1 the more complete is the sterilization.

Index of Industrial Production (IIP): *IIP* is taken as proxy for output of the economy, due to the non-availability of monthly output series for India[8]. A positive relationship is expected between *NDA* and *IIP* because an increase in output requires high demand for domestic credit.

Cash Reserve Ratio (CRR): this is the percent of demand and time liabilities which commercial banks maintain with the RBI. This is a direct monetary policy instrument which is used by the RBI to manage the availability of credit. An increase in *CRR* is expected to reduce *NDA* implying a negative relationship between the two variables. Since any change in CRR affects the lending rates of the commercial banks, CRR may be considered here as a proxy for the domestic interest rate.

In addition to CRR, the RBI uses market based instruments such as OMO and LAF for liquidity management. Under the LAF, the central bank adjusts Repo and Reverse Repo rates to manage the liquidity condition in the economy, where, Repo is the rate at which banks borrow from the RBI and Reverse Repo is the rate ate which the RBI absorbs liquidity from the system i.e. it represents the interest rate paid to banks for RBI's borrowings. In the present study, 91 days Treasury bill yield rate (TBILL) for OMO and

[8] Though the industrial sector in India contributes to less than 30 percent of GDP, the IIP is the widely used measure to capture the monthly output of the economy, see Patnaik (2004) and RBI (2002-03).

Repo (REPO) and Reverse Repo (RE_REPO) refer for LAF are also used as proxy for interest rates.

Further, the inclusion of the domestic interest rate in the credit reaction function helps to analyze the effectiveness of sterilized intervention by testing whether the increase in NFA resulted in increase in domestic interest rate or not. If the domestic interest rate does not increase then sterilization policy is considered to be effective because the sterilization policy doesn't provide any arbitrage opportunity to the foreign investors to invest in the economy. However, the decline of the domestic interest rate alone cannot lend support of effective sterilization. This is because, if the foreign interest rate declines along with the domestic interest rate, then there is still opportunity for arbitrage due to the positive interest rate differential between domestic and foreign interest rates. Hence, it is preferable to use the interest rate differential to analyze the effectiveness of sterilized intervention. The interest rate differential is measured by taking the deviation between the yield rate of 91 days Treasury bill in India and yield rate of 3 months US Treasury bill.

Exchange Rate (ER): The relationship between exchange rate and domestic credit is ambiguous and empirically determined (Savvides, 1998). An exchange rate deprecation tends to be inflationary and therefore, central bank may pursue a restrictive credit policy which will lead to a reduction in *NDA*. On the other hand, depreciation of domestic currency would increase the cost of servicing external debt and may, therefore, increase the demand for domestic credit. In such case a positive relationship can be expected between these two variables. In the present study the exchange rate is proxied by India Rupee/US Dollar nominal exchange rate and accordingly a rise in the exchange rate indicates depreciation and decline indicates an appreciation of India Rupee.

4. Data

The credit reaction function is estimated using monthly data from 1993:04 to 2007:04. The data are collected from the RBI publications namely Handbook of Statistics on Indian Economy and monthly bulletin for the various years. The US three month Treasury-Bill rate is drawn from the website of Federal Reserve System,

www.federalreserve.gov. The variables such as *NDA* and *NFA* are expressed in crores of Rupees. Since the present study uses four alternatives proxies for interest rate we estimate a credit reaction function for each of these proxies of interest rate. The interest rate such as Repo and Reverse Repo are available only from June 2000 onwards and therefore, a separate the credit reaction function is estimated using these variables for the period 2001:04 to 2007:04.

5. Econometric Methodology

To estimate the credit reaction function, we use the most widely used technique in the field of measuring monetary policy reaction, i.e. Vector Autoregressive methodology (VAR). A problem in estimating the credit reaction functions is the potential endogeneity of the NFA variable and the possibility of reverse causation when central bank follows a sterilization policy. Kouri and Porter (1974) showed that NDA will affect NFA also. Therefore, the earlier studies employed two stage least square methods to overcome the problem of endogeneity of NDA (Kouri and Porter.1974; Mille and Askin, 1976; Kamas, 1986; Celasun et al, 1999; Brissimis et all, 2002). However, the developments in the times series econometrics namely, VAR method, helps to overcome the problem of endoginity and to analyze the extent of sterilization in a time varying framework (Takagi, and Esaka, 1999; Christensen, 2004; Chang, 2005, Ouyang et al, 2007). The VAR method not only enables us to find the causal relationships between reserves and other variables in system but also to generate the responses of each variable in the model due to the reserve accumulation. A brief description about the tests conducted to carryout the estimation is following.

5.1 Testing for Stationarity

Before estimating credit reaction function (Equation 1), it is important to check the order of integration of the each variable in the model. Since we use VAR method to estimate the credit reaction function, it requires that all variables in the system are

stationary in levels. In this study the Augmented Dickey-Fuller (1981) and Phillip-Perron (1988) unit root tests are used to examine the order of integration.

5.2 Vector Autoregressive Model

The credit reaction function is estimated using VAR methodology. The unrestricted VAR was introduced by Sims (1980) as a better alternative to the traditional structural models. The VAR is commonly used for forecasting systems of interrelated time series and for analyzing the dynamic impact of random disturbances on the system of variables. The VAR methodology is preferred to traditional structural method for a number of reasons. First, it does not depend on prior assumptions on the structure of the economy and allows all variables in the systems to be endogenous. Second, it helps to find the dynamic interrelationship between variables in the system by generating responses of variables to the innovations of other variables.

VAR is a multivariate time series analysis, in which a variable Y_1, is stated as a function of both the past history of Y_1 or its lagged values and the lagged values of other variables $(Y_2, Y_3, ..., Y_n)$ that influence Y_1. The model is viewed as the reduced form of structural equation models that have uniform set of the lagged endogenous variables of every equation as regressors.

Let Y_t be the vector of five stationary endogenous variables (NDA, NFA, IIP, CRR, ER) with lag of order 1. The VAR can be written in the following matrix form as

$$\begin{bmatrix} NDA_t \\ NFA_t \\ IIP_t \\ CRR_t \\ ER_t \end{bmatrix} = \begin{bmatrix} \beta_{10} \\ \beta_{20} \\ \beta_{30} \\ \beta_{40} \\ \beta_{50} \end{bmatrix} + \begin{pmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & \gamma_{14} & \gamma_{15} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \gamma_{24} & \gamma_{25} \\ \gamma_{31} & \gamma_{32} & \gamma_{33} & \gamma_{34} & \gamma_{35} \\ \gamma_{41} & \gamma_{42} & \gamma_{43} & \gamma_{44} & \gamma_{45} \\ \gamma_{51} & \gamma_{52} & \gamma_{53} & \gamma_{45} & \gamma_{55} \end{pmatrix} \begin{bmatrix} NDA_{t-1} \\ NFA_{t-1} \\ IIP_{t-1} \\ CRR_{t-1} \\ ER_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix} \quad (2)$$

$$Y_{t0} = \beta_0 + \gamma Y_{t-1} + \varepsilon_t \quad (3)$$

Where β is the deterministic constant term, γ is the parameter and ε_t is the white noise random error term assumed to have zero mean, constant variance and serially uncorrelated. In general, VAR model which lag order of ρ can be expressed as

$$Y_t = \beta_0 + \sum_{i=1}^{\rho} \gamma_i Y_{t-i} + \varepsilon_t \qquad (4)$$

All variables in the right-hand side of the equations in the VAR system have a common lag length. Therefore, the model may be over parameterized and may lead to erosion of degrees of freedom. In such situations, it is important to select an appropriate lag length that can avoid misspecification and over-parameterization. The present paper follows two widely used criteria such as Akaike Information Criterion (AIC) and Schwartz Bayesian Criterion (SBC) in the present analysis. It is argued that the estimated coefficients of the VAR model are difficult to interpret due to its a-theoretical nature and the large number of parameters to be estimated (Brooks, 2002). Therefore, three sets of statistics of VAR such a Granger Causality/Block Exogeneity Test, Variance Decomposition and Impulse Response Function are analyzed for the purpose of deriving inferences.

5.2.1 Granger Causality

To test the direction of causality between variables in the VAR system we use the causality test developed by Granger (1969). If X_t is said to be Granger causes a time series Y_t then the past values of X_t should help to forecast future values of Y_t after controlling for the past values of Y_t. The VAR framework allows testing for Granger causality among variables in the system.

$$\begin{aligned} Y_t &= \alpha_1 + \sum_{i=1}^{m} \beta_i Y_{t-i} + \sum_{i=1}^{m} \lambda_i X_{t-i} + \varepsilon_t^y \\ X_t &= \alpha_2 + \sum_{i=1}^{m} \delta_i X_{t-i} + \sum_{i=1}^{m} \phi_i Y_{t-i} + \varepsilon_t^x \end{aligned} \qquad (5)$$

The null hypothesis that X_t does not Granger cause Y_t can be tested by H_0: $\lambda_i = 0$ for all *i* s. Similarly, the null that Y_t does not Granger cause X_t can be tested by H_0: $\phi_i = 0$ for all *i*s. F-test is used to test the joint significance of the lags on the explanatory variables.

However, if VAR includes more than two variables then the block exogeneity test is useful in detecting the causality among variables. In the case of 3 variables X_t, Y_t and Z_t, and testing whether X_t Granger cause either Y_t or Z_t, the block exogeneity test restricts all lags of X_t in the Y_t and Z_t to be equal to zero. Then this cross equation restriction is tested using likelihood ratio test. This can be done by estimating an unrestricted model of Y_t and Z_t equations using lagged values of X_t, Y_t and Z_t and obtain variance/covariance matrix of residuals $\sum_u$. Then a restricted model is re-estimated by excluding the values of X_t and obtaining variance/covariance matrix of residuals $\sum_r$. Then find the likelihood test statistic is found as follows.

$$(T-c)(\log|\Sigma_r| - \log|\Sigma_u|) \qquad (6)$$

This statistic follows a chi-square distribution with degrees of freedom equal to 2ρ, where ρ is the lag order of X_t, T is the number of observations and c is the number of parameters estimated in each equation of the unrestricted system.

5.2.2 Variance Decomposition

The decomposition of variance measures the percentage of a variable's forecast error variance that is attributable to a shock from a variable in the system. Variance decomposition analysis provides information about the percentage of variation in the forecast error of a variable explained by its own innovations and by innovations in other variables. If a variable is exogenous with respect to the other variables in the system, then own innovations will explain all forecast error variance.

5.2.3 Impulse Response Function

The impulse response function is used to trace out the responsiveness of the variable to shock to each variable in the VAR system and this is carried out by a unit shock applied to the errors of each variable. If the system of equations is stable, then any shock should reduce to zero, whereas an unstable system would produce an explosive time path.

Consider a simple bivariate VAR (1) model:

$$\begin{aligned} Y_t &= \alpha_1 + \beta_1 Y_{t-1} + \lambda_1 X_{t-1} + \varepsilon_t^y \\ X_t &= \alpha_2 + \delta_1 X_{t-1} + \phi_1 Y_{t-1} + \varepsilon_t^x \end{aligned} \tag{7}$$

A change in ε_t^y will instantaneously change Y_t and thus this would lead to a change in X_t and also Y_t in the next period. Hence impulse response function helps to examine how long and to what extent the variables respond to the shock in a given equation. Generally the impulse response functions are derived from the moving average representation of the autoregressive system and is expressed as

$$Y_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \tag{8}$$

Where Y_t is an $n \times 1$ vector of variables to be estimated and the coefficients of A_i represents a $n \times i$ matrix of the coefficients of the lagged variables in the system. And ε_{t-i} is a linear combination of current and past one-step-ahead forecast errors or innovations, representing the unexpected portion of the system. Since impulse responses are highly non-linear functions of the estimated parameters, confidence bands are constructed around the mean response. Responses are considered statistically significant at the 95% confidence level when the upper and lower bands carry the same sign.

6. Empirical Results

6.1 Descriptive Statistics

The summery statistics of the variables is reported in the table 3 and where Jarque-Bera statistic are statistically significant for all variables except for IIP, TBILL and REPO, which implies these variables are not normal. The formal tests for stationarity

such as ADF and PP are conducted to understand the integration properties of the variables and are reported in the table 4. The ADF and PP tests show that the null hypothesis of stationarity is rejected in levels for all variables and accepted in first differences. This indicates that all variables are non-stationary or I(1) in its levels and stationary at its first-differences. For the present analysis, all variables are taken in their first difference mainly due to two reasons. First, the literature shows that the variables included in the credit reaction function such as NDA and NFA are in change form rather than in level form. Secondly, the VAR assumes that the variables under consideration should be stationary. Therefore, all non-stationary variables are converted into stationary form by taking first differences (indicated in D_X).

Table: 3 DESCRIPTIVE STATISTICS

	NDA	NFA	IIP	ER	CRR	TBILL	IRD_ TBILL	REPO	Reverse REPO
Observations	168	169	169	169	169	169	169	73	73
Mean	0.404	12.128	5.061	3.707	2.095	2.003	1.249	1.951	1.681
Std. Dev.	0.450	0.9017	0.257	0.152	0.435	0.292	0.477	0.123	0.129
Skewness	-0.134	0.096	0.015	-0.669	-0.0279	0.026	-0.565	0.186	0.064
Kurtosis	1.841	1.904	2.307	1.931	1.479	2.272	3.180	1.833	1.757
Jarque -Bera	9.897	8.708	3.382	20.671	16.300	3.748	9.222	4.559	4.747
Probability	0.007	0.012	0.184	0.000	0.000	0.153	0.009	0.102	0.093

NOTE: The Jarque-Bera test is a test of the null hypothesis of normality in which the skewness and kurtosis of the series is compared to the normal distribution.

Table: 4 UNIT ROOT TESTS

	ADF Test Statistic		**PP Test Statistic**	
	Levels	**First Difference**	**Levels**	**First Difference**
NDA	-1.66	-12.75*	-1.66	-12.19*
NFA	-1.19	-2.72*	-1.06	-9.23*
IIP	0.731	-4.59*	-0.89	6.78*
ER	0.997	-5.32*	1.26	-9.49*
CRR	-1.39	-11.76*	-1.14	-11.76
TBILL	-0.45	-4.55*	-0.60	-12.22*
IRD_TBILL	-1.35	-11.17*	-1.34	-13.80*
REPO	-0.45	-4.08*	-0.69	-8.16*
Reverse Repo	-0.42	-4.23*	-0.81	-7.57*

*, ** and *** denote rejection of unit root at 1, 5, 10 percent respectively

6.2 Vector Autoregressive Model

The credit reaction function is estimated using an unrestricted VAR model including 11 centered seasonal dummy variables[9] in the VAR system to capture the seasonal variation in the series. These dummy variables are considered as exogenous variables in the VAR system. As a preliminary step, an appropriate lag length is selected following standard lag selection criteria such as AIC, SBC and LR. Table 5 shows that the all lag selection criteria unanimously indicate to an optimum lag of one.

Table 5: VAR Lag Order Selection Criteria

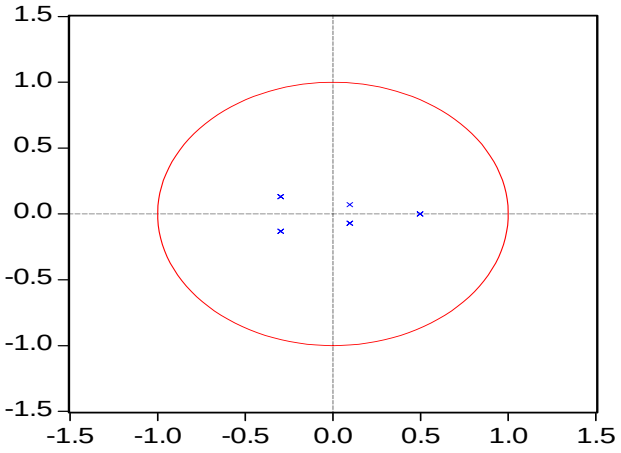
Lag	LR	AIC	SBC
0	NA	-22.62114	-21.47279
1	279.0477*	-24.24841*	-22.62158*
2	28.86829	-24.14553	-22.04023
3	28.29571	-24.04614	-21.46235
4	29.14255	-23.96149	-20.89922
5	17.77501	-23.79428	-20.25353
6	16.87297	-23.62551	-19.60629

* indicates lag order selected by the criterion, LR: sequential modified LR test statistic, AIC: Akaike information criterion, SBC: Schwarz information criterion

Furthermore, the stability of the VAR is tested using AR root graph which shows the inverse roots of the AR polynomial (Lütkepohl, 1991). The estimated VAR is stable and stationary if all roots have modulus less than one and lie inside the unit circle. If the VAR is not stable, certain results, such as standard errors of impulse response, would not be valid. The figure 3 shows that all AR roots are inside the unit circle and indicate the estimated VAR is stable (stationary).

[9] The reason to use the centered seasonal dummy variable is that a standard 0-1 dummy variable will affect both the mean and the trend of the level series in VAR system but the centered seasonal dummy variable can shift the mean without contributing to the trend. The centered seasonal dummies sum up to zero over time.

Figure 3: Inverse Roots of AR Characteristic Polynomial



6.2.2 Granger Causality Test

The direction of causality among variables is tested using Granger causality/Block exogeneity test and the results are reported in table 6. It shows that domestic credit (D_NDA) is caused by the foreign assets (D_NFA) but not the other way around. This implies that any change in the domestic money supply does not affect the foreign exchange reserves. One of the major reasons for the non-responsiveness of NFA to NDA is the high regulatory laws on capital outflows in India. This supports the unidirectional causality from NFA to NDA. It can also be seen that ER and CRR cause NDA. The causality from CRR to NDA indicates that the change in commercial banks' reserve requirement may help to control the domestic credit. The causation from ER to NFA indicates that movements in exchange rate influence the reserve movement. It is also shown that CRR causes ER which indicates that the movements in CRR affect the exchange rate movements.

In addition, the causality test also reveals that NDA causes output IIP and CRR causes ER. At the same time the CRR is found to be not caused by any variable in the system. This may be due to its exogenous nature, or its movements are completely determined by the central bank. Similarly, ER is found to be caused only by CRR.

Table 6: Granger Causality/Block Exogeneity Wald Tests

Dependent variable:	D_NDA	D_NFA	D_IIP	D_CRR	D_ER
D_NDA	-	1.448	3.69***	0.007	1.89
D_NFA	351.17*	-	0.366	0.023	0.02
D_IIP	1.511	1.002	-	0.020	0.38
D_ER	4.57**	10.47*	0.688	0.241	
D_CRR	8.68*	0.332	0.084	-	7.08*
All	400.73*	13.30*	4.65	0.266	8.93***

Note: Wald test follows chi-square statistics with 2 df. *, ** and *** denote statistical significance at 1, 5 and 10 percent respectively

6.2.2 Variance Decomposition

Table 7 presents the forecast error variance decompositions of domestic credit using VAR model. This indicates that the foreign asset shocks dominate over other disturbances in explaining variation in domestic credit. It explains around 65 percentage of variation in domestic credit and it implies that a substantial part of domestic credit movements represents a response to fluctuations in foreign exchange reserves holdings with the central bank.

Table 7: Variance Decomposition of NDA

Period	D_NDA	D_NFA	D_IIP	D_CRR	D_ER
1	99.64	0.11	0.00	0.00	0.24
2	28.53	68.74	0.23	1.63	0.85
3	27.32	65.65	0.92	1.57	4.52
4	27.02	65.24	1.05	1.75	4.92
5	26.93	65.18	1.07	1.77	5.02
6	26.92	65.15	1.07	1.78	5.05
7	26.91	65.15	1.07	1.78	5.06
8	26.91	65.15	1.07	1.79	5.06
9	26.91	65.15	1.07	1.79	5.06
10	26.914	65.15	1.07	1.79	5.0

6.2.3 Impulse Response Function

The previous section on causality has shown the direction of causality among variable, however, it does not indicate the nature of causal relationship in terms of signs

of the relationship and its duration. The impulse response function helps to identify the nature of the relationships and duration of the response of the variable due to the one unit innovation in an endogenous variable.

Response of NDA

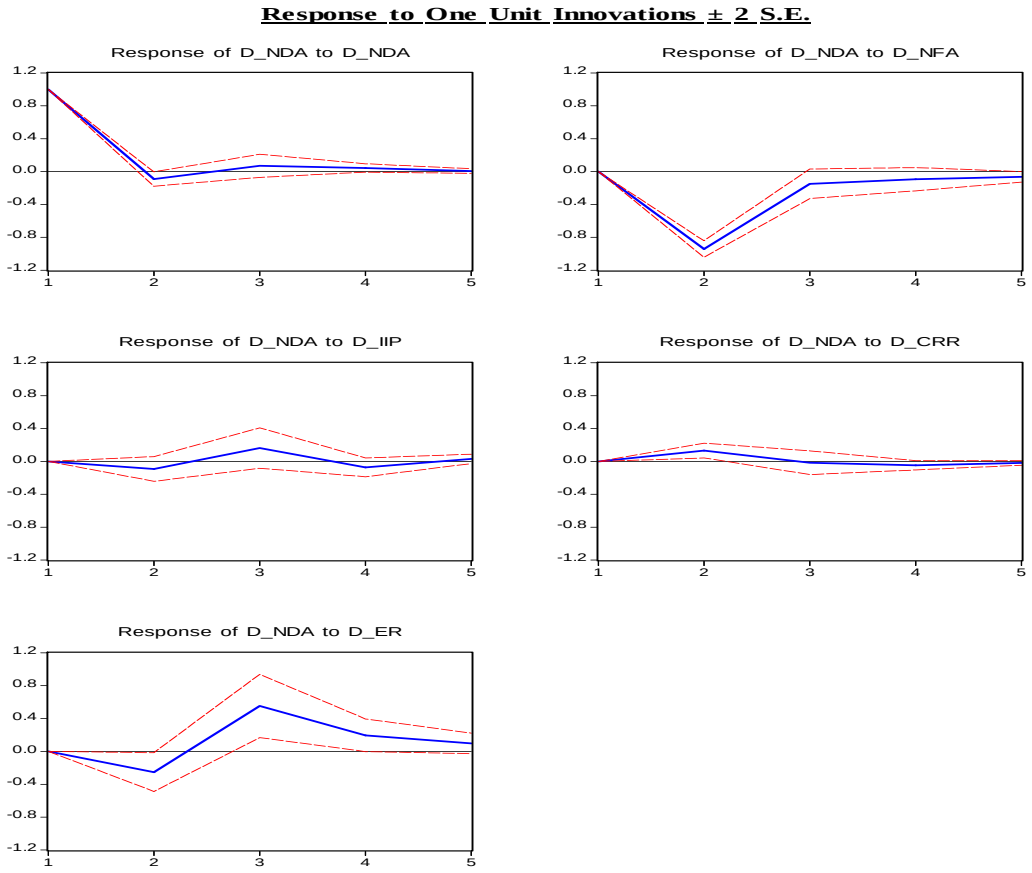
Figure 4 shows the impulse response of NDA with respect in one unit shock to other endogenous variables in the VAR system. The dotted lines represent a two standard deviation band around the estimates of impulse response. The effects can be significant if the band excludes zero. A one unit shock or one unit rise in NFA leads to a significant reduction of NDA to -0.9 units at the end of first month. This indicates that the RBI sterilizes the reserve accumulation by around 90 percent in the 1st month. However, the sterilization operation declines during the second month and turns to zero by the end of the same month. The high sterilization coefficient of -0.9 indicates the central bank's high monetary control during the periods of reserve accumulation.

An increase in exchange rate, i.e. a depreciation of domestic currency, leads to a reduction in NDA during the first month. Though the effect does not seem to be highly significant, the reduction can be attributed to the fact that the depreciation of the domestic currency turns to be inflationary and may, therefore prompt the central bank to follow a restrictive credit policy. However the response of NDA to ER starts increasing at the beginning of second month and turns to be positive and significant till the end of the third month. This may be due to an increase in demand for domestic credit from the private and public sectors to meet the high external debt servicing due to the depreciation (Savvides, 1998).

It is also seen that the NDA does not respond significantly due to a shock in CRR and IIP. Moreover, the CRR is found to be a positive effect on NDA, which contradicts the proposition that an increase in reserve requirement leads to a reduction in domestic credit. The increase in NDA due to an increase in CRR may be attributed to the extensive use of alternative measures such as OMO and LAF for liquidity management during the

most of study periods. This has reduced the RBI's reliance on direct monetary policy instrument, namely CRR[10].

Figure 4: Response of NDA



Response of NFA

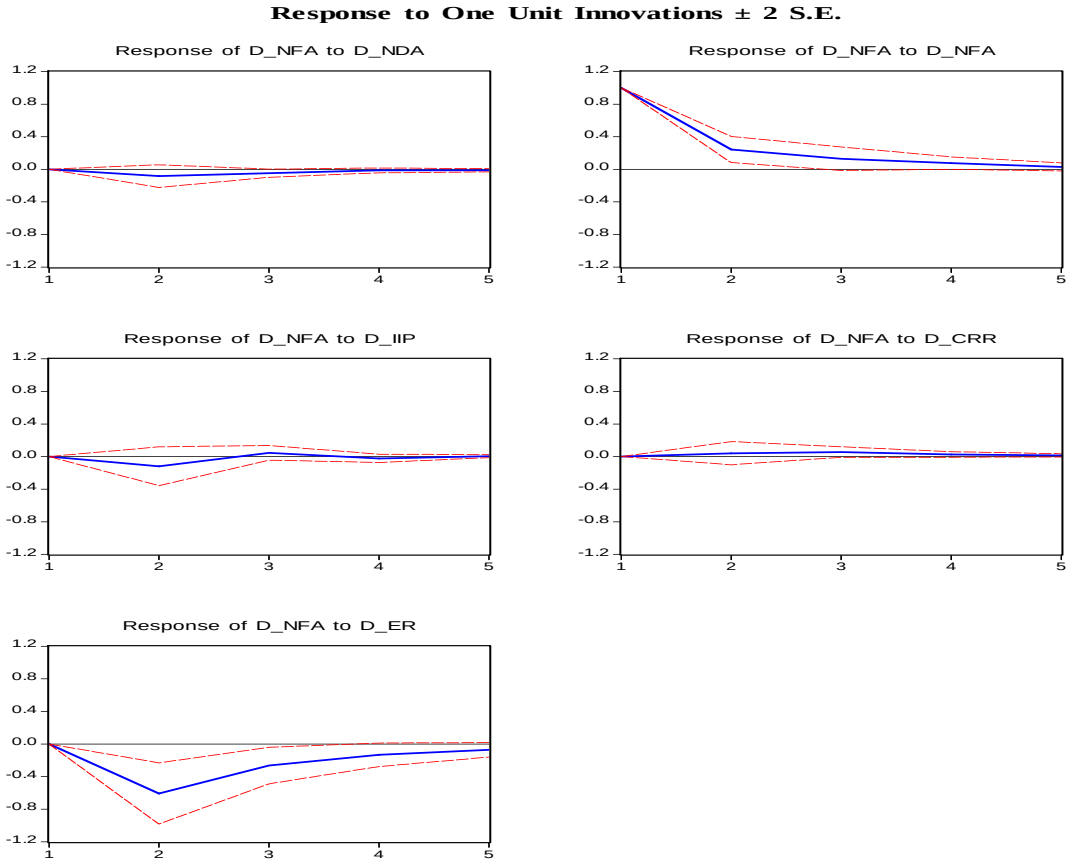
Figure 5 shows that the response of NFA to NDA, IIP and CRR is small and insignificant. The non-responsiveness of NFA to an increase in NDA reveals that an increase in domestic credit due to expansionary monetary policy does not lead to a reduction in foreign exchange reserves.

A rise in ER or a depreciation of domestic currency is associated with a decline in NFA during the subsequent months. It can also be argued alternatively that, a reduction

[10] "The LAF enabled the RBI to de-emphasize targeting of bank reserves and focus increasing on interest rate. This has helped in reducing the CRR without engendering increasing liquidity pressure" (Mohan, 2005).

or an appreciation of the domestic currency leads to an increase in NFA. The latter condition is more relevant in the present context because India has experienced high capital inflows rather than outflows during the period of study. In this context, the Rupee appreciation can lead to an increase in reserves with the RBI due to its asymmetric intervention policy or 'lean against the wind' policy during the period of appreciation of Rupee (Ramachandran and Srenivasanm, 2007). This finding supports the argument that the mercantilist policies of the RBI better influence the reserve accumulation in India (Prabheesh et al, 2009).

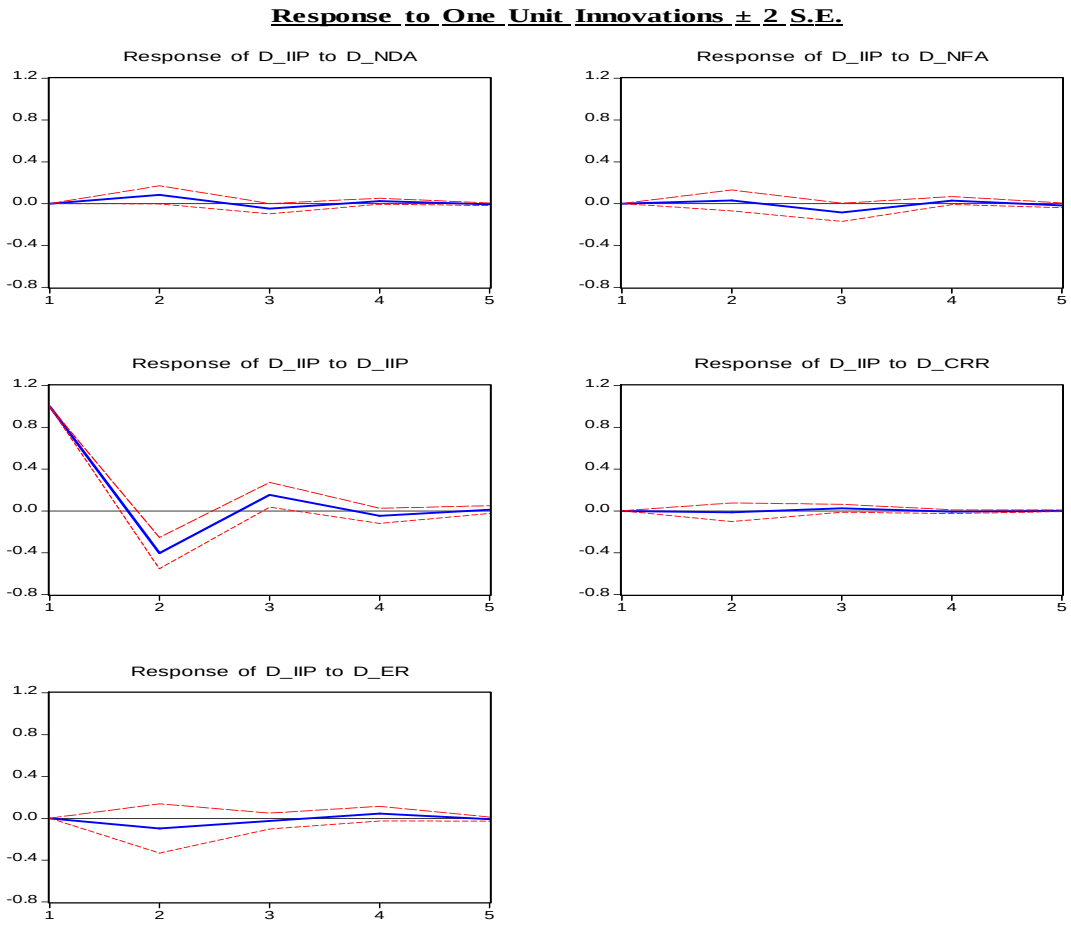
Figure 5: Response of NFA



Response of IIP

Figure 6 shows that the response of IIP with respect to NFA, CRR and ER and it is found that the responses are small and insignificant. However, an increase in NDA leads to a small increase in IIP in the first month which can be attributed to the high credit availability owing to an increase in output.

Figure 6: Response of IIP

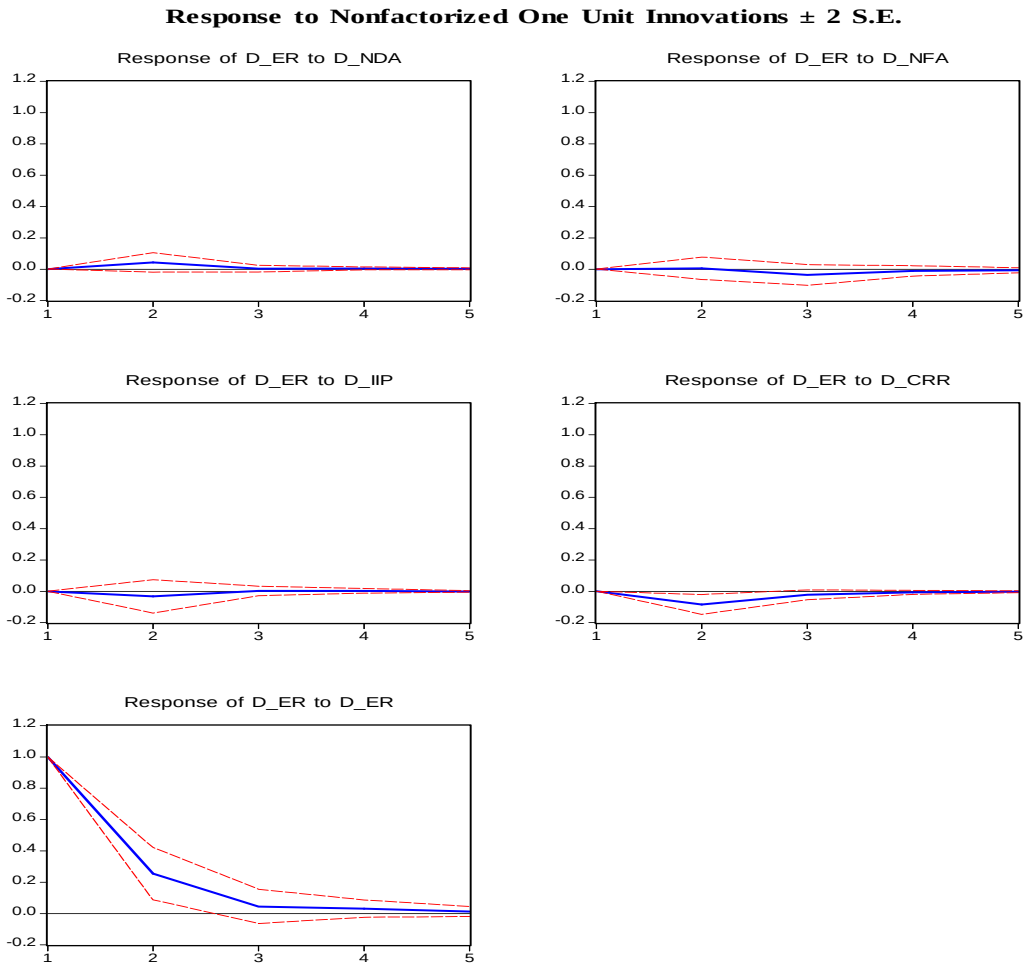


Response of ER

It is observed from the figure 7 that the ER does not respond significantly to a shock in NDA, NFA and IIP. However, the exchange rate responds negatively or

appreciates with an increase in CRR. This may be because an increase in CRR leads to an increase in the interest rate differential which may attract capital flows to the economy and thereby put a pressure on domestic currency causing it to appreciate.

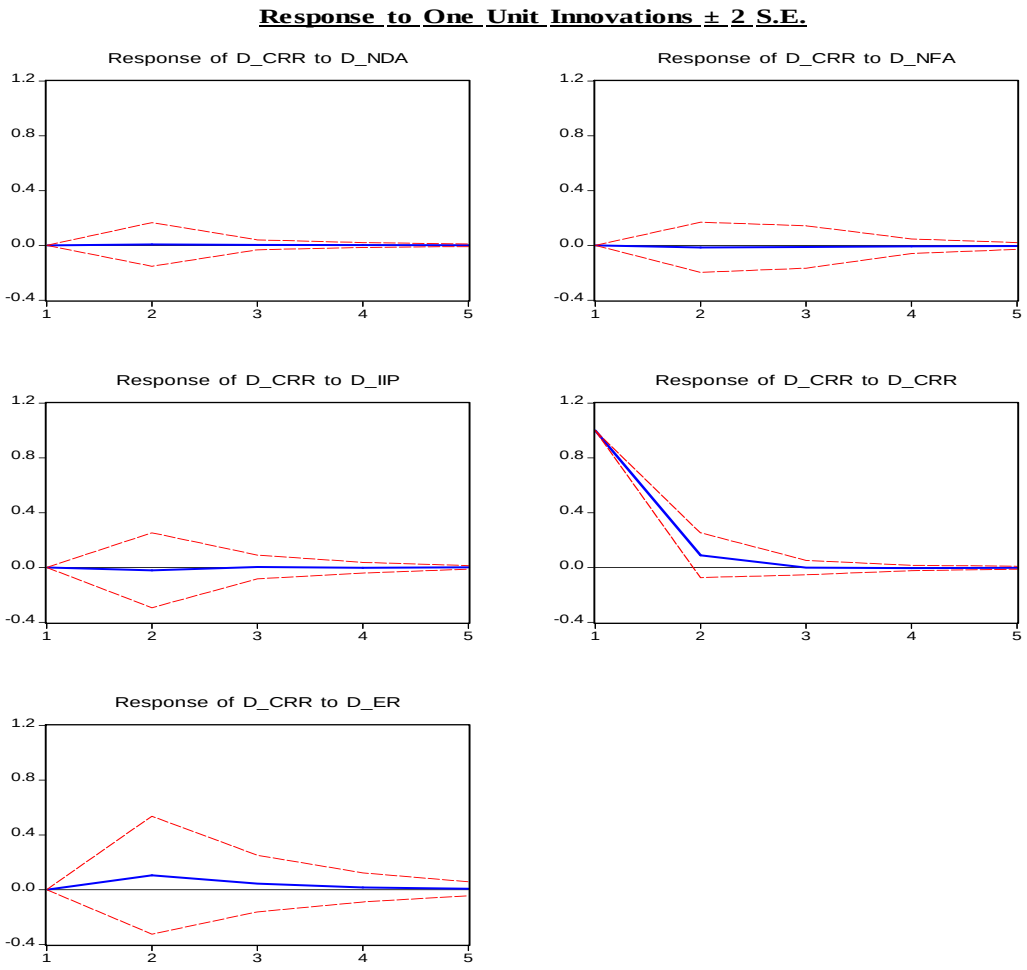
Figure 7: Response of ER



Response of CRR

It is observed that the CRR does not respond to any other variables in the system (Figure 8). This can be attributed to the exogenous nature of the CRR in the system. A shock to NFA leads to neither an increase nor a decrease in the domestic interest rate, CRR, implying that the RBI does not increase the domestic interest rate to carryout the sterilization policy to offset the monetary impact of the reserve accumulation.

Figure 8: Response of CRR



Response of Other Interest Rates to Reserve Accumulation

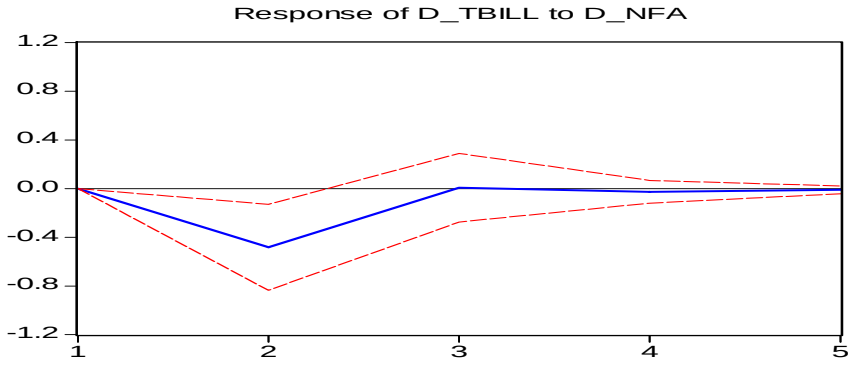
The response of T-bill rate, interest rate differentials and Repo rates to the reserve accumulation is discussed below.

Response of Treasury Bill rate to Reserve Accumulation

We estimated a credit reaction function which includes Treasury bill rate as a proxy for domestic interest rate instead of CRR for the same period 1993:04 to 2007:04, using VAR model. The impulse response function of T-BILL to NFA is shown in the

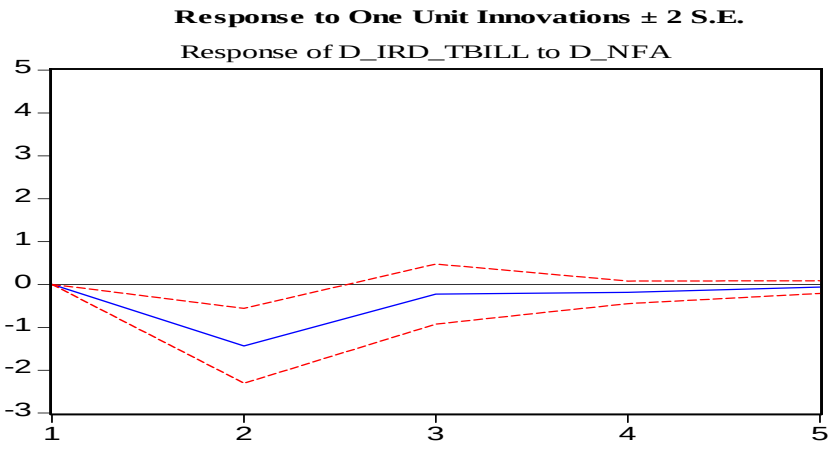
figure 9. It is interesting to see that a rise in NFA leads to a significant decline in the T-bill rate during the first month. This finding challenges the argument that the central bank is required to keep the domestic interest rate at a higher level to carryout the sterilization policy. This shows that the RBI was able to reduce the Treasury bill rate when it engaged in OMO during the period of high reserve accumulation. This can be supported by the argument that the effect of sterilization on domestic interest rate is determined by the nature of source shocks which induce the capital inflows (Frankel, 1994). If the capital inflows are driven by external shock, .i.e. a reduction in foreign interest rates, then the sterilization operations can be carried out by reducing the domestic interest rate as long as there exist a positive interest rate differential between domestic and foreign interest rate.

Figure 9: Response of T-bill to NFA



Similarly, a credit reaction function which includes interest rate differential is estimated for the same period and the impulse response of interest rate differential (D_IRD_TBILL) due to the reserve accumulation is shown in the Figure 10. This indicates that the gap between global and Indian interest rate is declining due to reserve accumulation. This indicates that there is no scope for interest rate arbitrage opportunity for foreign capital to flow in due to sterilization policies.

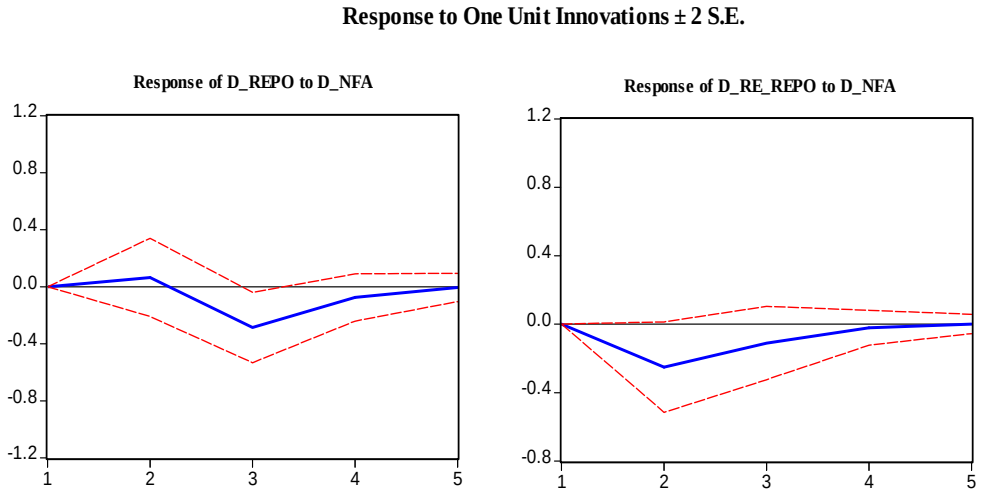
Figure 10: Response of IRD T-bill to NFA



Response of Repo rates to Reserve Accumulation

In order to find the effect of reserve accumulation on Repo interest rates, we plug in Repo and Reverse Repo rates as a proxy of domestic interest rate in the credit reaction function and estimated the same using VAR methodology. Since Repo rates under LAF programme was introduced in June 2000, the credit reaction function is estimated for the period 2000:04 to 2007:04. The estimated impulse response function of Repo rates to NFA is shown in the figure 11. The figure of response of Reverse Repo (RE_REPO) to NFA shows that an increase in NFA leads to a decline in the Reverse Repo rate in the subsequent periods. This implies that domestic interest rate does not increase due to the sterilization. The effect of Repo due to the shock on NFA is not found to be significant because this interest rate is used for injecting the money supply during the period of low liquidity.

Figure 11: Response of Repo and Reverse Repo to NFA



Given the above findings from the impulse response function, the efficacy of sterilized intervention can be analyzed by verifying the following causality channel. An increase in foreign assets reduces the domestic credit through sterilized intervention and high sterilization leads to an increase in domestic interest rate. An increase in domestic interest rate may attract capital inflows and thereby put a pressure on the domestic currency to appreciate. The intervention of the central bank in the foreign exchange market to resist the appreciation may further lead to an increase in foreign exchange reserves and so on. The empirical findings support all above links except the causality from foreign assets to domestic interest rate. This helps the RBI to carryout the sterilization policy effectively; otherwise capital flows due to the rise in domestic interest rate would increase the monetary base and offset the initial sterilization policy. The sterilized intervention does not lead to an increase in domestic interest rate rather it leads to a reduction. Similarly, the interest rate differential also shows a declining response implying that there is no scope for interest rate arbitrage opportunity for foreign capital to flow in due to sterilization policies. Therefore, it can be concluded that the RBI effectively sterilizes the reserve accumulation in order to offset it expansionary effect on monetary base during the period of study.

7. CONCLUSION

This paper has empirically analyzed the extent and effectiveness of sterilized intervention policy followed by the RBI to offset the impact of reserve accumulation on monetary base. The extent of sterilized intervention is analyzed by estimating a credit reaction function of the central bank for the period 1993:04 to 2007:04 using the VAR methodology.

The empirical result of Granger causality test revels that the foreign assets causes the domestic credit but there is no reserves causality. This indicates that the domestic monetary sector in India does not affect the BoP position. This can be attributed to the high restrictions on capital outflow from India. The overall causality results show that foreign assets cause domestic assets; interest rate causes exchange rate; and exchange rate cause foreign assets. The test does not support the causality from domestic credit to interest rate and foreign credit to interest rate.

The impulse response function shows that a one unit increase in foreign exchange reserves leads to a reduction of domestic credit by approximately 0.9 units. This indicates that around 90 percent of the reserve accumulation is sterilized by the RBI. At the same time, an increase in domestic credit does not have any effect on foreign exchange reserves. The high sterilization and low sensitivity of foreign assets to domestic assets indicate high monetary policy autonomy of the RBI during the reserve accumulation. It is also found that an increase in domestic interest rate leads to appreciation of the domestic currency due to capital inflows. An exchange rate appreciation of domestic currency leads to reserve accumulation, which indicates the RBI resists the Rupee from appreciating during capital inflows. This supports the 'mercantilist policies' argument of reserve accumulation.

The study considers alternative proxies for interest rates to analyze the effect of reserve accumulation on domestic interest rates. CRR, the direct monetary control measure, does not show any increase due to the reserve accumulation. However, the other interest rates such as Treasury bill rate, interest rate differentials and Reverse Repo rate show a declining trend due to reserve accumulation. The reduction in these interest rates may be attributed to the 'push factors' driven capital flows to India. This non-increasing

pressure on domestic interest rate due to reserve accumulation helps the RBI to carryout the sterilization policy effectively during the period of study.

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