# Macroeconomic Stress Testing and the Resilience of the Indian Banking System: A Focus on Credit Risk

Tanima Niyogi Sinha Roy and Basabi Bhattacharya

South Calcutta Girls' College, Calcutta University, Kolkata, India,
Jadavpur University, Kolkata, India

16. March 2011

# Macroeconomic Stress Testing and the Resilience of the Indian Banking System: A Focus on Credit Risk

**Tanima Niyogi Sinha Roy**

**Associate Professor, Department of Economics, South Calcutta Girls' College,**

**Calcutta University, Kolkata, India,**

**&**

**Basabi Bhattacharya**

**Professor, Financial Economics, Department of Economics, Jadavpur University,**

**Kolkata, and Regional Director, Professional Risk Managers' International**

**Association (PRMIA), Kolkata Chapter**

**Paper presented at the Second International Finance Conference, Indian Institute of Management, Kolkata, India, January 10-12, 2011**

# Macroeconomic Stress Testing and the Resilience of the Indian Banking System: A Focus on Credit Risk


## Abstract

The paper undertakes a macroprudential analysis of the credit risk of Public Sector Banks during the liberalization period. Using the Vector Autoregression methodology, the paper investigates the dynamic impact of changes in the macroeconomic variables on the default rate, the Financial Stability Indicator of banks by simulating interactions among all the variables included in the model. Feedback effects from the banking sector to the real economy are also estimated. The impact of variations in different Monetary Policy Instruments such as Bank Rate, Repo Rate and Reverse Repo Rate on the asset quality of banks is examined using three alternative baseline models. Impulse Response Functions of the estimated models are augmented by conducting sensitivity and scenario stress testing exercises to assess the banking sector's vulnerability to credit risk in the face of hypothetically generated adverse macroeconomic shocks.

Results indicate the absence of cyclicality and pro-cyclicality of the default rate. Adverse shocks to output gap, Real Effective Exchange Rate appreciation above its trend value, inflation rate and policy-induced monetary tightening significantly affect bank asset quality. Of the three policy rates, Bank Rate affects bank soundness with a lag and is more persistent while the two short-term rates impact default rate instantaneously but is much less persistent. Scenario stress tests reveal default rate of Public Sector Banks could increase on an average from 4% to 7% depending on the type of hypothetical macroeconomic scenario generated. An average buffer capital of 3% accumulated during the period under consideration could thus be inadequate for nearly twice the amount of Non-Performing Assets generated if macroeconomic conditions worsened.

An important policy implication of the paper is that as the Indian economy moves gradually to Full Capital Account Convertibility, the banking sector is likely to come under increased stress in view of the exchange rate volatility with adverse repercussions on interest rates and bank default rates. In this emerging scenario, monetary policy stance thus emerges as an important precondition for banking stability. The study also highlights the inadequacy of existing capital reserves should macroeconomic conditions deteriorate and the urgency to strengthen the buffer capital position.



**JEL Codes**: G21, E52

**Keywords**: Banks, Macro Prudential analysis, Stress test

# Macroeconomic Stress Testing and the Resilience of the Indian Banking System: A Focus on Credit Risk

## Section 1: Introduction

The increasing occurrence of banking crisis spanning the last two decades has contributed to the growth of a new area of research broadly known as Macroprudential analysis which delves into the relation between macroeconomic variables and Financial Stability Indicators (FSIs).[1] Macroprudential analysis has also focused on the ability of banks to withstand macroeconomic shocks based on stress tests in several developing and developed countries in the globalizing era. Macroeconomic stress testing has thus become an important tool for financial stability analysis. Assuming credit risk to be one of the most dominant risk categories for banks in India, this paper is an application of macroeconomic stress testing of the default rate of banks using the Vector Autoregression (VAR) methodology to test the soundness of the Indian banking system.

With the implementation of the Narasimham Committee recommendations on banking reforms, a new era has been ushered in the Indian banking sector. Our banks have gradually emerged as stronger entities in the contemporary deregulated and liberalizing environment. They have managed to reduce their bad loans and are focusing on better lending practices. In spite of this improving landscape it is of great significance to know how the effects of the changing macroeconomic scenario and monetary policy stances work upon the financial health of banks as the Indian economy integrates with the global economy. Considering the need for such a study for India, the paper employs a Recursive Vector AutoRegression (RVAR) model and makes an attempt to explore the

[1] FSIs are aggregated micro-prudential indicators used by supervisors to assess bank soundness.

macroeconomic determinants of the asset quality of the Indian banking sector. The contribution of this paper lies in using an unrestricted VAR model for the analysis of the impact of real, financial and monetary policy shocks on the banking system and the feedback effects. Though there are several techniques to assess the vulnerability of a financial system to exceptional but plausible macroeconomic shocks, this paper has followed the simple approach of augmenting the estimated Impulse Response Functions (IRFs) of the endogenous variables of the estimated VAR model with stress testing exercises.

The remaining paper is arranged as follows: Section 2 provides a brief review of the literature that has underlined the role of macroeconomic variables in explaining the asset quality of banks and has performed stress tests to assess the impact of worsening macroeconomic conditions on bank loan quality. Section 3 deals with some of the macroeconomic changes and policy shifts in the contemporary Indian economy and their expected effects on the credit risk of PSBs. Data sources and methodology are discussed in Section 4. Empirical results are stated and analyzed in Section 5. Finally Section 6 concludes the study and offers some policy implications.

**Section 2: Present State of Art**

There exists an elaborate body of research on the role of bank-specific and macroeconomic factors in influencing banking sector fragility for both advanced and emerging market economies. While bank-specific factors are found to have contributed towards the lack of strong and vibrant banking systems in many economies, macroeconomic disturbances such as business fluctuations and adverse movements in interest rates and exchange rates are revealed to have underlined some of the major systemic banking crises in the 1990s. Based on the growing significance of role of macroeconomic factors in causing banking crisis, there has been an increasing emphasis on the study of interactions between macroeconomic trends and banking fragility. This has led to the development of macroprudential analysis which makes an important contribution in assessing the macroeconomic causes and the soundness and vulnerabilities of financial systems to macroeconomic shocks.

***Cyclicality and pro-cyclicality of bank asset quality****:* Economic expansion which is associated with an increase in corporate profits and household incomes enables borrowers to be in a better position to service bank loans leading to reduction in bad loans. But when recession sets in, the converse usually occurs. This is known as cyclicality of bank lending. When asset quality deteriorates due to economic slowdowns there is likely to be a second round effect from the banking sector to the real economy. The pressure to maintain minimum capital adequacy due to enhanced credit risk shrinks credit supply and further amplifies the business cycles and bad loans in bank books. This is referred to as the pro-cyclicality of bank loans. Cross-country studies find economic recessions have been one of the major causes of banking crisis (Demirguc–Kunt & Detragiache, 1998; Kaminsky & Reinhart, 1999; Hardy & Pazarbasioglu, 1999). Evidence on cyclicality of bank asset quality is also found in some country-specific studies. Salas & Saurina (2002) find significant role of economic downturns in increasing problem loans in Spanish banks. Meyer & Yeager (2001) find that the loan quality of local banks in US is affected by local economic slowdowns. According to Shu (2002), bad loans as a proportion of total loans of banks decrease with high economic growth in Hong Kong. However, a few studies have refuted the cyclicality hypothesis. Jordan & Rosengren (2002) observe that only a very few banks failed in the US in the 2001 recession. Lindhe (2000) found the annual GDP growth to be positive during the Swedish banking crisis.

Increasingly a large number of studies have employed VAR approach to focus on the impact of business cycles on bad debts of banks. Gambera (2000) finds farm income and state annual product have significant influence on bank loan quality in the US. Quagliariello (2003) confirms the cyclicality of write-offs to total loans for Italian banks.[2] Some papers have documented the impact of output gap on bank balance sheets. Bank failures increase (or decrease) with increase (or decrease) in output gap (Lindhe, 2000 ; Pain, 2003 Hoggarth, Logan & Zicchino, 2005 & Amediku, 2007).[3] Recently some studies have investigated the feedback effect from the banks to the real economy using the VAR approach. Marcucci & Quagliariello (2005) find evidence of both cyclicality and pro-cyclicality of asset quality for Italian banks. According to Hoggarth et al (2005) there is cyclicality of aggregate write-offs, but no feedback effect from UK banks to the real economy. In contrast, Baboucek & Jancar (2005) find no substantiation of the cyclicality hypothesis of Salas & Saurina (2002) find significant role of economic downturns in increasing problem loans in Spanish banks. Meyer & Yeager (2001) find that the loan quality of local banks in US is affected by local economic slowdowns. According to Shu (2002), bad loans as a proportion of total loans of banks decrease with high economic growth in Hong Kong. However, a few studies have refuted the cyclicality hypothesis. Jordan & Rosengren (2002) observe that only a very few banks failed in the US in the 2001 recession. Lindhe (2000) found the annual GDP growth to be positive during the Swedish banking crisis.

---

[2] NPAs and write-offs (bank losses net of recoveries) are used interchangeably as indicators for explaining the asset quality of banks.
[3] Output gap is the difference between potential and actual output.

Increasingly a large number of studies have employed VAR approach to focus on the impact of business cycles on bad debts of banks. Gambera (2000) finds farm income and state annual product have significant influence on bank loan quality in the US. Quagliariello (2003) confirms the cyclicality of write-offs to total loans for Italian banks.[4] Some papers have documented the impact of output gap on bank balance sheets. Bank failures increase (or decrease) with increase (or decrease) in output gap (Lindhe, 2000 ; Pain, 2003 Hoggarth, Logan & Zicchino, 2005 & Amediku, 2007).[5] Recently some studies have investigated the feedback effect from the banks to the real economy using the VAR approach. Marcucci & Quagliariello (2005) find evidence of both cyclicality and pro-cyclicality of asset quality for Italian banks. According to Hoggarth et al(2005) there is cyclicality of aggregate write-offs, but no feedback effect from UK banks. In contrast, Baboucek & Jancar (2005) finds no corroboration of the cyclicality of Non Performing Assets (NPAs) but confirm pro-cyclicality hypothesis for banks in Czech economy. Filaso (2007) on the other hand, find evidence of weak pro-cyclicality for the Italian banking sector.[6]

***Monetary Policy and bank asset quality***: Since the seminal contribution of Sims (1980), the use of the VAR approach for the empirical investigation of monetary policy shocks has gained momentum. Graeve et al (2008) find a monetary contraction by one standard deviation leads to a significant though small increase in the probability of banking distress in Germany. The effect is however substantially low if capitalization is high. but

[4] NPAs and write-offs (bank losses net of recoveries) are used interchangeably as indicators for explaining the asset quality of banks.
[5] Output gap is the difference between potential and actual output.
[6] They believe fall in output can undermine the solidity of the banking system only if the contraction in output is far more severe than any previous recession.

confirm pro-cyclicality for banks in Czech economy. Filaso (2007) on the other hand, find evidence of weak pro-cyclicality for the Italian banking sector.[7]

***Monetary Policy and bank asset quality***: Since the seminal contribution of Sims (1980), the use of the VAR approach for the empirical investigation of monetary policy shocks has gained momentum. Graeve et al (2008) finds a monetary contraction by one standard deviation leads to a significant though small increase in the probability of banking distress in Germany. The effect is however substantially low if capitalization is high. Filaso (2007) finds bank soundness indicators display minor variations as monetary policy conditions are tightened for countering financial crisis.

***Impact of other macroeconomic factors on bank asset quality:*** A large number of studies have emphasized the prominent influence of interest rates in explaining bank asset quality. Clair (2004) and Lindhe (2000) assert that credit quality is adversely affected by increase in nominal interest rates. Demirguc-Kunt & Detragiache (1998) and Gizycki (2001) find aggregate credit risk to vary with real interest rates. Shu (2002) finds that bad loans decline as consumer price inflation and property price inflation increase. He also finds credit portfolios of banks are also affected by appreciation of nominal exchange rates due to increasing foreign loan defaults.

***Stress testing macroeconomic shocks and their impact on bank loan quality*** : The IMF and the World Bank formally introduced macro-prudential stress tests as a key element of IMF member countries have competed or have been undergoing Financial Sector Assessment Program (FSAP) which was developed in recognition of important multi-faceted interlinkages between a country's financial system and its economy. The purpose

[7] They believe fall in output can undermine the solidity of the banking system only if the contraction in output is far more severe than any previous recession.

of FSAP involving stress tests is to assess the resilience of banks to macroeconomic shocks which is of central importance to financial stability. Stress tests permit a forward-looking analysis to assess the vulnerability of a banking system in particular, to either a major fall in exchange rate, large increase in interest rate, a very sharp and prolonged contraction in the economy or combination of these shocks. Stress testing simulations are performed under exceptional but plausible events to assess vulnerability of loan quality to adverse macroeconomic shocks. IRFs of VAR models have been popularly used to conduct stress tests (Baboucek & Jancar, 2005; Filosa, 2007; Tracey, 2005 and Amediku, 2007). Stress tests using VAR models outperform other forms of stress tests by estimating changes in Non-Performing Loans as a result of macroeconomic shocks distinct from idiosyncratic shocks, by supporting links to well established macroeconomic theories and monetary policy and facilitating stress testing of the stability of the banking system both in the form of sensitivity analysis of scenario analysis (Amediku, 2007, p 5-6).

The purpose of this paper is to use a RVAR model to a) empirically investigate the dynamics between default rate of Public Sector Banks (PSBs) and key macroeconomic variables and compare the effects of different policy rates on bank asset quality b) perform stress tests to assess the banking sector's vulnerability to credit risk and determine the early signals for deterioration of loan quality.

**Section 3: Macroeconomic Changes and Banks' Asset Quality: Theoretical Underpinnings and the Contemporary Indian Economy**

Since economic liberalization in 1991, gradual changes in the macroeconomic environment are expected to work upon the balance sheets of banks. During the 1990s, there have been periodic fluctuations in the growth rate of output in the Indian economy.

There were two protracted economic downturns and NPA levels were soaring in the mid-1990s. The influence of banks on output variations is reflected in the bank credit-GDP ratio.

The twin objectives of monetary policy in India that have evolved over the years are price stability and ensuring adequate flow of credit to facilitate economic growth. In recent years financial stability has been added as yet another objective of monetary policy with top priority. During the 1970s and 1980s, in the era of fiscal dominance in the Indian economy, market-oriented interest rates had little relevance. Direct instruments like administered interest rate ceilings, bank credit ceilings, reserve requirements and priority sector lending functioned as the key instruments of monetary management. Since 1991, a host of interest rates emerged as significant signals of monetary policy stance in India. Indirect instruments have replaced the direct instruments.

In this new scenario, Bank Rate as a Monetary Policy Instrument (MPI) has become very significant for the entire financial system since its reactivation in the 1997-98. During 1997-2003, the Bank Rate was changed 14 times of which 8 changes took place during 1997-99 and remaining 7 changes occurred during 2000-2003 (Insert Table 1 here). The growing significance of the Bank Rate as a MPI during this period is thus quite evident. The Bank Rate acts as an important benchmark for determination of other interest rates such as PLR (Prime Lending Rate), Sub-PLR and Benchmark-PLR (BPLR) charged by banks from the ultimate borrowers. From Sept 1998 to March 2004, RBI has estimated the interest rate pass-through effect for PLR to be 0.61, which means that for every 100 basis points (bps) increase in the Bank Rate, PLR increases by 61 bps.[8] Thus every time

[8] Report on Currency and Finance, 2003-04, Chapter 7, p 203

the Bank Rate is adjusted, it has important repercussions on commercial bank lending rates and asset quality is likely to be impacted.

In the past few years, short-term interest rates such as Repo Rate and Reverse Repo Rate have played a crucial role in RBI monetary policy stance and have thus emerged as dynamic indicators of interest rates (Insert Table 2 here). Since the introduction of Liquidity Adjustment Facility (LAF) in June 2000, the RBI has been injecting liquidity in the system through Repos and absorbing liquidity from the system on a daily basis through Reverse Repos (Insert Table 3 here).[9]

The RBI cannot afford the luxury of adopting inflation targeting as the single main objective of monetary policy in India.[10] The multiple objectives of our monetary policy include growth, price and financial stability. In India the emphasis is currently more on managing inflation expectations. Price stability is maintained through various fiscal, monetary and administrative measures. In this controlled inflationary regime there is not much variation between real and nominal interest rates. The RBI tolerance level of inflation is in the range of 5-5.5%. When headline inflation (Wholesale Price Index, WPI) exceeds the tolerance limit, RBI pursues monetary tightening to rein in inflationary pressures. Supply side shocks, poor level of intermediation between producer and consumer, presence of strong demand pull factors and rising oil prices account for the rising inflationary trend in India. These pressures exert a critical influence on the RBI monetary policy stance and RBI adjusts the policy interest rates (Repo Rate, Reverse Repo Rate or Bank Rate) to reach an acceptable level of inflation. Policy interest rates also adjust to suck out excess liquidity and counter the expansionary impact of sudden

[9] In 2007-08 the objective of monetary policy has been unidirectional to reduce inflation. For this two instruments were used the Repo/Reverse Repo Rates and the CRR. The first was to directly affect the cost of borrowing while the second was to reduce the quantum of lendable resources.

[10] 'RBI Roots for Managing Inflation Expectation' *Economic Times* 18.06.07

spurts in liquidity from the system caused by heavy capital inflows. The rise in interest rates is likely to aggravate the NPA problem in all sectors including retail credit such as home loans, car loans, personal unsecured loans and corporate loans.

From full convertibility on the current account in 1991 to gradual relaxation in the capital account, the exchange rate policy has undergone significant changes. The increasing domestic and external financial integration has led the monetary policy stance to be influenced by exchange rate fluctuations via its effect on inflation. In recent times this has been one of the most important features of short-term monetary policy adjustments in India.

There is a large empirical literature on the causes of NPAs in the Indian banking sector. Rajaraman, et al (1999) find operating environment and regional exposure of banks play a significant role in explaining the inter-bank variations for the year 1996-97. Another study by Rajaraman and Vashishtha (2002) reveal that levels of operating efficiency explain the higher than average NPAs for a group of banks. Ranjan & Dhal (2003) find that terms of credit, bank size and macroeconomic shocks influence bank asset quality. However, none of the studies in the Indian context have focused on the dynamic interlinkages between macroeconomic shocks and bank asset quality.

Asset quality measured by NPAs is one of the leading indicators of the financial health of PSBs in India. Since financial liberalization in India, banks have widened their operations beyond their traditional roles of lending and accepting deposits and have entered into new lines of business. Consequently they have become more vulnerable to market risks (viz equity risk, exchange rate risk, interest rate risk), operational risks and even off -balance sheet risks. However credit risk still largely explains banking fragility in India. Its predominance is reflected in the composition of Capital Adequacy Ratio where 70% of capital is allocated for credit risk and 30% for market risk and operational risk. A lion's share of gross NPA of Scheduled Commercial Banks is concentrated solely in PSBs. This paper thus focuses on PSBs alone. (Insert Table 3 here).[11]

**Section 4: Data Sources and Methodology**

The period for the study extends from 1995-2007. Default rate (DR) has been used as the FSI in this exercise.[12] Besides, a few of macroeconomic, monetary and financial variables have been selected cautiously based on econometric considerations of constructing a parsimonious VAR model. These are output gap, Bank Rate/ Repo Rate/Reverse Repo Rate, Consumer Price Inflation and Real Effective Exchange Rate.

Default rate (**DR**) is based on gross NPAs and gross advances.[13] The data on CPI (1982=100) and Real Effective Exchange Rate (REER, 1993-94=100) are available on a monthly basis. The monthly data on Consumer Price Inflation (CPI, 1981-82=100) has been shifted to the base year 1993-94 to maintain conformity with other variables. To remove the seasonality present in GDP and CPI data, seasonal adjustments based on the Moving Average method is made in each case. Output gap (**OG_GDP)** is the difference between the log of the Hodrick Prescott (HP) filtered GDP series and the log of the GDP series.[14] The resulting series after first logarithmic differencing of seasonally adjusted CPI is the Inflation Rate **(INF)**. The REER deviation from its trend **(R_T**) is the

---

[11] Gross NPAs as % of gross advances for PSBs after touching an all time high of 24.8 % in 1993-94 gradually declined to 5.53% in 2004-05 which was quite high by international standards.

[12] IMF (2006) includes Non-Performing Loans in its set of FSIs for Macroprudential analysis.

[13] The default rate in month ' t' is the ratio of incremental gross NPAs in month ' t' to performing loans in month ' t-1'. Performing loans in a certain period is the difference between gross advances and gross NPAs in that period. The definition of default rate adopted in this paper is similar to that of Quagliariello & Marcucci (2003, p 28). The reason for not using Net NPAs and net advances in the calculation of default rate is because larger provisioning for bad debts may lead to lower Net NPAs whereas the gross NPA figure could actually be rising.

[14] Output gap is the deviation of actual output from potential output that is sustainable in the long run. Since sustainable output cannot be observed directly, Hodrick Prescott (HP) filtered series from eviews5 software is used to estimate the potential output.

difference between the HP trend value of the REER and the REER itself**.** The policy rates are the Bank Rate **(B),** Repo Rate **(RR)** and Reverse Repo Rate **(RRR).** The data for all the variables have been obtained from RBI website www.rbi.org.in (Insert Table 4 here). Three baseline models are estimated using three alternative policy rates. For the period 1997-2003 a RVAR model is developed using Bank Rate as the MPI. For the post-LAF period that is 2001-2007 where the short-term rates viz the Repo Rate and Reverse Repo Rate are frequently used to convey RBI monetary policy signals two alternative RVAR models are estimated.

In this paper the RVAR model is employed as the variables used are a mix of real and financial variables. VARs perform well not only in capturing the data generating process of macroeconomic aggregates but also in capturing the contemporaneous and lagged relation between real economy and banking sector without imposing any apriori theorization (Graeve et al , 2008, p7). The relevant shocks are identified by the Granger causality tests and the response of the system to these shocks is analyzed by the IRFs and Forecast Error Variance Decomposition (FEVD). Before explaining the detailed methodology below, the stationarity properties of the time series data and the determination of the lag order of the VAR model are discussed.

**Stationary Tests of Endogenous Variables**

Several unit root tests such as Augmented Dickey Fuller (ADF, 1979), Phillips-Perron ( PP, 1988), Generalized Least Squares (GLS) de-trended Dickey-Fuller test ( by Elliot, Rothenberg, and Stock, 1996) henceforth known as DF-GLS test and Kwiatkowski, Phillips, Schmidt & Shin ( KPSS,1993) tests have been used to check for the stationarity of the variables.

Conventional unit root tests are known to lose power dramatically against stationary alternatives with a low order moving average process: a characterization that fits well to a number of macroeconomic time series. Along the lines of the ADF test, a more powerful variant is the DF-GLS test proposed by Elliott, Rothenberg and Stock (ERS, 1996). In the ADF approach either a constant or a constant and linear time trend are included to take into account the deterministic components of the data. ERS propose a simple modification of the ADF in which data are de-trended before the unit root test is conducted.

Main criticism of the ADF and PP unit root tests is that the power of these tests are low if the process is stationary but has a root close to the non-stationary boundary. These also have low power in small samples. To overcome this issue Kwaitkowski, Phillips, Schmidt & Shin (1993) have developed a unit root test that has the null hypothesis of stationarity and the alternative hypothesis of non-stationarity.

**Determination of Optimal Lag Length**

The VAR model is estimated using symmetric lags indicating the same lag length for all variables in all the equations of the model. Symmetric lag VAR model is easily estimated since the specification of all equations of the model are the same and estimation by OLS yields efficient estimates. On the issue of the lag-length selection, a maximum of 12 lags is considered and five criteria namely Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) and Hannan & Quinn Information Criterion (HQIC) are considered. The smallest value for each criterion corresponding to a certain lag length is chosen as the lag length for that criterion. The choice of appropriate lag order of the VAR model is based on these criteria and the diagnostic tests that test for the presence of autocorrelation and heteroskadasticity in the residuals.

**Recursive VAR**

In a recursive dynamic structural equation model, the ordering of the variables is very crucial. The first variable is a function of lagged values of all variables including itself, the second variable is a function of contemporaneous values of first variable and lagged values of all variables and so on. The variables in a RVAR structure are ordered according to their speed of reaction to a particular shock. The financial variables such as policy interest rate, inflation rate and exchange rate are ordered here at the end of the RVAR implying that they react instantaneously to shocks to real side variables. In contrast the real variables such as default rate and the output growth rate placed at the beginning of RVAR respond to shocks in financial variables only after a lag. The output growth rate is ordered after the Default Rate reflecting that business cycles affect bank asset quality after a lag. Our RVAR model includes the following endogenous variables in this exact order i.e. deviation of the REER from its trend value (R_T), Inflation rate (INF), Bank Rate (B), Output Gap (OG_GDP) and Default Rate that is DR ← OG_GDP ← B ← INF ← R_T.

The two other alternative RVAR model orderings using Repo Rate and Reverse Repo Rate are as follows:

DR ← OG_GDP ← RR ← INF ← R_T.

DR ← OG_GDP ← RRR ← INF ← R_T.

Consider the following equations

$$DR_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} DR_{t-i} + \sum_{i=1}^{k} \alpha_{2i} OG\_GDP_{t-i} + \sum_{i=1}^{k} \alpha_{3i} \mathrm{B}_{t-i} + \sum_{i=1}^{k} \alpha_{4i} INF_{t-i} + \sum_{i=1}^{k} \alpha_{5i} R\_T_{t-i} + \varepsilon_{1t} \quad \ldots\ldots(1)$$

$$OG\_GDP_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} DR_{t-i} + \sum_{i=1}^{k} \beta_{2i} OG\_GDP_{t-i} + \sum_{i=1}^{k} \beta_{3i} \mathrm{B}_{t-i} + \sum_{i=1}^{k} \beta_{4i} INF_{t-i} + \sum_{i=1}^{k} \beta_{5i} R\_T_{t-i} + \beta_6 DR_t + \varepsilon_{2t} \quad \ldots\ldots(2)$$

$$\mathrm{B}_t = \phi_0 + \sum_{i=1}^{k} \phi_{1i} DR_{t-i} + \sum_{i=1}^{k} \phi_{2i} OG\_GDP_{t-i} + \sum_{i=1}^{k} \phi_{3i} \mathrm{B}_{t-i} + \sum_{i=1}^{k} \phi_{4i} INF_{t-i} + \sum_{i=1}^{k} \phi_{5i} R\_T_{t-i} + \phi_6 DR_t + \phi_7 OG\_GDP_t + \varepsilon_{3t} \quad \ldots\ldots(3)$$

$$INF_t = \gamma_0 + \sum_{i=1}^{k} \gamma_{1i} DR_{t-i} + \sum_{i=1}^{k} \gamma_{2i} OG\_GDP_{t-i} + \sum_{i=1}^{k} \gamma_{3i} \mathrm{B}_{t-i} + \sum_{i=1}^{k} \gamma_{4i} INF_{t-i} + \sum_{i=1}^{k} \gamma_{5i} R\_T_{t-i} + \gamma_6 DR_t + \gamma_7 OG\_GDP_t + \gamma_8 \mathrm{B}_t + \varepsilon_{4t} \quad \ldots\ldots(4)$$

$$R\_T_t = \eta_0 + \sum_{i=1}^{k} \eta_{1i} DR_{t-i} + \sum_{i=1}^{k} \eta_{2i} OG\_GDP_{t-i} + \sum_{i=1}^{k} \eta_{3i} \mathrm{B}_{t-i} + \sum_{i=1}^{k} \eta_{4i} INF_{t-i} + \sum_{i=1}^{k} \eta_{5i} R\_T_{t-i} + \eta_6 DR_t + \eta_7 OG\_GDP_t + \eta_8 \mathrm{B}_t + \eta_9 I_t + \varepsilon_{5t} \quad \ldots\ldots(5)$$

In the above equations k represents the lag length. The first equation shows the effect on default rate due to past innovations to it and to all other variables. The second equation shows the impact on output gap due to current and past shocks to default rate and past shocks to all other variables. The third equation shows the impact on Bank Rate due to current and past innovations in default rate and output gap and past innovations in all other variables. The fourth equation shows the effects on inflation rate due to current and past shocks to default rate, output gap and Bank Rate and past shocks to the remaining variables. Finally the last equation shows the effects on deviation of the REER from its trend value due to past shocks to itself and current and past shocks to default rate, output gap, Bank Rate and inflation rate.

**Granger Causality Tests**

A variable x is said to *Granger cause* a variable y if past values of x are useful for predicting values of y**.** Consider the first equation of the five -variable VAR with a lag order of k for the recursive ordering DR ← OG_GDP ← B ← INF ← R_T

Consider equation (1)

$$DR_t = \alpha_0 + \sum_{i=1}^{k}\alpha_{1i}DR_{t-i} + \sum_{i=1}^{k}\alpha_{2i}OG\_GDP_{t-i} + \sum_{i=1}^{k}\alpha_{3i}\mathrm{B}_{t-i} + \sum_{i=1}^{k}\alpha_{4i}INF_{t-i} + \sum_{i=1}^{k}\alpha_{5i}R\_T_{t-i} + \varepsilon_{1t}$$

$$= \alpha_0 + \alpha_{11}DR_{t-1} + .... + \alpha_{1k}DR_{t-k} + \alpha_{21}OG\_GDP_{t-1} + .... + \alpha_{2k}OG\_GDP_{t-k} + \alpha_{31}B_{t-1} + ..... + \alpha_{3k}B_{t-k} + ..$$
$$. + \alpha_{41}INF_{t-1} + .... + \alpha_{4k}INF_{t-k} + \alpha_{51}R\_T_{t-1} + ... + \alpha_{5k}R\_T_{t-k} + \varepsilon_{1t}$$

In this case there are five null hypotheses against five alternative hypotheses.

a) DR Granger causes DR if $H_0 : \alpha_{11} = \alpha_{12} = ....... = \alpha_{1k} = 0$ is rejected against $H_A$**:** at least one $\alpha_{1i} \neq 0$

b) OG_GDP Granger causes DR if $H_0 : \alpha_{21} = \alpha_{22} = ....... = \alpha_{2k} = 0$ is rejected against $H_A$ : at least one $\alpha_{2i} \neq 0$

c) B Granger causes DR if $H_0 : \alpha_{31} = \alpha_{32} = ....... = \alpha_{3k} = 0$ is rejected against $H_A$**:** at least one $\alpha_{3i} \neq 0$

d) INF Granger causes DR if $H_0 : \alpha_{41} = \alpha_{42} = ....... = \alpha_{4k} = 0$ is rejected against $H_A$ : at least one $\alpha_{4i} \neq 0$

e) R_T Granger cause DR if $H_0 : \alpha_{51} = \alpha_{52} = ....... = \alpha_{5k} = 0$ is rejected against $H_A$ : at least one $\alpha_{5i} \neq 0$

These tests show the p-values associated with the F-test for testing whether the relevant set of coefficients are 0 or not. Rejection of $H_0$ through the standard F-test attests to the inclusion of a particular variable in the inclusion of another variable.

**Impulse Response Functions**

An IRF traces the dynamic response of current and future values of each of the variables to a one-unit increase in current value of one of the VAR errors within two standard error bands. Consider the 5 equations corresponding to the recursive VAR. A change in $\varepsilon_{1t}$, will immediately change values of current 'DR'. It will also change all future values of 'OG_GDP', 'B', 'INF' and 'R_T' since lagged 'DR' appears in all five equations. This is the interpretation of the IRF when the innovations $\varepsilon_{1t}, \varepsilon_{2t}$, $\varepsilon_{3t}$ $\varepsilon_{4t}$ and $\varepsilon_{5t}$ are uncorrelated. But the innovations are not usually uncorrelated. Cholesky decomposition takes care of correlated errors via orthogonalised IRF where errors are made completely independent so that the covariance matrix of the resulting innovations is diagonal. However one serious problem with orthogonalised IRF is that it is not invariant with respect to the ordering of the variables. Pesaran & Shin (1998) have developed the generalized IRF analysis, which is invariant with respect to the ordering of variables**.** Since Cholesky decomposition is sensitive to a particular kind of ordering, the VAR model has been reordered and results have been checked to see whether there are any notable differences. If there are no significant changes in the results it will mean our results are robust and there is no further need for applying the generalized IRF methodology.

**Forecast Variance Decomposition Analysis**

FEVD computes the forecast error variance decomposition which provides the proportion of the total forecast-error variance of each variable that is caused by each of the shocks or disturbances in the system. The FEVD table gives information about the relative importance of each random innovation on a particular variable. For the variable that comes first in the VAR ordering the only source of one period ahead variation is its own innovation and the first number is always 100. The decomposition of variance thus critically depends on the ordering of equations.

**Section 5: Estimation Results:**

Considering the change in the definition of NPAs from 180-day norm to 90-day norm from April 2004, the Chow breakpoint test is applied to detect the presence of an endogenous structural break in the gross NPA series.[15] Results show there is no significant structural break on that specified date (Insert Table 5 here). The general descriptive statistics of all the endogenous variables are given below (Insert Table 6 and Chart 1 here). The multicollinearity matrix shows poor pair-wise correlations among the regressors indicating basically independent variables (Insert Table 7 here**).**

We have conducted the empirical exercises on two periods respectively. The results are presented for the period 1997-2003 during which the Bank Rate functioned as an active Monetary Policy Instrument and for 2001 to 2007 where the short-term rates viz the Repo Rate and the Reverse Repo Rate operated as signals of RBI monetary policy stances.

***1997-2003***

[15] To move towards international best practices and impart greater transparency, it was decided to classify loans as non-performing where the interest and/or installment of principal remain overdue for a period of more than 90 days from the year 2004.

AIC, SIC and HQIC along with sequential LR tests and FPE are reported for all the endogenous variables. Numbers in bold indicate the minimum along each column and correspond to the lag chosen by each criteria. For this exercise, a lag of three months is chosen as the order of the VAR model (Insert Table 8 here). This choice of this lag order is also consistent with the LM test and White test indicating the absence of autocorrelation and heteroskadasticity respectively, in the residuals. The results of the correlation residual matrix indicate the absence of any high correlation among any pair of residuals (Insert Table 9 here). The unit root tests reveal that the default rate, output gap, REER deviation from its trend and the inflation rate are stationary with trend and constant term. None of the policy rates such as the Bank Rate, Reverse Repo Rate or Repo Rate are stationary. Further the rates have not been log differenced, as many observations will be reduced to zero making them meaningless (Insert Table 10 here). We have followed here the basic idea of Sims, Stock and Watson (1990) that for VARs with some non-stationary variables there is some loss in efficiency but not consistency. However, even if there is loss in efficiency Sims (1980) recommended against differencing the variables since the objective of VAR analysis is to study inter-relationship among variables and not determine efficient estimates.

The default rate equation in the baseline model has a modest explanatory power with an adjusted $R^2$-statistics of 76%.[16] The result for Durbin Watson test for residual autocorrelation shows a value of nearly 2. All the coefficients have their expected sign in the default rate equation. The coefficient for output gap, Bank Rate and inflation rate have positive signs while the coefficient of REER deviation from trend is negative. The

[16] Results are not shown here due to space constraint.

roots of the characteristic polynomial reveal, no root lies outside the unit circle. VAR, thus satisfies the stability condition and is stationary (Insert Chart 2 and Table 11 here).

Preliminary indications on the interactions among the variables suggest the following. The null hypothesis of Granger causality is not rejected for cyclicality of the default rate or for any feedback effect from the banking sector to the real economy. This is perhaps comprehensible as the time lag of three months may not be sufficient for any discernible interaction between the real sector and the banking sector. The lagged effect of central bank's steady dose of monetary tightening is also expected to weigh on bank asset quality via lending rates. Results indicate the Bank Rate Granger cause the default rate as expected via lending rates. Inflation rate and the appreciation of the REER over its trend value also Granger cause the default rate. Other results show the default rate Granger cause Bank Rate and inflation rate , the policy rate is Granger caused by the inflation rate while REER appreciation over its trend value and inflation rate Granger cause each other (Insert Table 12 here).

The chart on IRFs reflect the Cholesky decomposition and are sensitive to the particular kind of recursive ordering already stated (Insert Chart 3 here). Each variable responds to a unit shock equal to one standard deviation in all the variables including it. IRFs always assume positive (increase) shocks to a variable. Each response is produced via interaction among all the variables included in the VAR model. In this exercise simulations have been performed for a sufficiently long period of 5 years to detect the response pattern as interactions among the variables prominently occur only at a significantly long period.

The standard characteristic of the IRFs is that the effect of the shocks die down gradually and move very close to 0 as shown over a period of 60 months.[17]

The response of default rate to itself is positive but the effects eventually disappear. The IRF gives evidence of the feedback effect from the banks to the real economy for a period of two months as output gap increases. Loan quality is significantly affected following a monetary policy impulse after a lag via rise in lending rates and increases persistently from the 3rd month to nearly 1% over 12-month period, declining thereafter.[18] The response of the default rate is positive and persistent increasing up to 3% following an inflationary shock and dying down subsequently. As REER appreciates above its trend value slowdown in exports occurs and this affects the default rate with a time lag. The IRF shows due to positive innovation in rate of change of REER the response of default rate falls for 4 months and then increases. During the period under consideration it is observed as REER appreciated due to heavy capital inflows, the RBI raised its policy interest rate to restrict inflation and eventually this led to loan defaults in future. This has been proved in this analysis through Granger Causality tests and IRFs.

The IRFs also support many other basic economic hypotheses. Increase in output gap causes decrease in inflation rate, increase in Bank Rate following inflationary shock , fall in inflation rate following monetary policy shock, increase in inflation rate as REER appreciates sharply above its trend value after a time lag and finally REER appreciation causes deceleration in output growth.

[17] The IRF graphs however show response of variables to shocks over a period of 12 months

[18] In this essay there is no distinction among banks based on their financial health. Not all banks react by pulling up their lending rates in the event of a policy rate hike. It is expected that adequately capitalized banks react to a much lower degree than banks with a low capital scenario. Thus from the monetary policy perspective the financial health of banks in the transmission of monetary policy shocks has been ignored in this analysis. This is one shortcoming of this analysis.

The column standard error is the forecast error of the variable for each forecast horizon (Insert Table 13 here). The remaining columns show the % of variance due to each innovation. Each row adds up to 100. FEVD for default rate show 12 months ahead 56.32%, 1.30%, 3.57, 20.39% and 18.40% of forecast error in default rate are explained by itself, output gap, Bank Rate, inflation rate and REER appreciation above its trend value respectively. Policy interest rate change is quickly transmitted to default rate via rise in lending rates. 5 years ahead almost 9% of forecast error of default rate is explained by Bank Rate alone.

The sensitivity of the responses gained within the framework of impulse response analysis are tested for robustness by re-ordering of the variables . When we changed the positions of the variables in the original model we find results of the baseline model are invariant to the new ordering.

### *2001-2007*

Since we want to compare the impact of the policy rates on bank asset quality we present the IRFs for the post-LAF period during 2001-2007 when Repo Rate and Reverse Repo Rate were actively used as signals of monetary policy stances by the RBI. The VAR model corresponding to each of these policy rates has an optimal lag order of 1 respectively. LM test and White test indicate the absence of autocorrelation and heteroskadasticity in the residuals at this lag order. Default rate responds almost instantaneously to shock in Repo Rate or Reverse Repo Rate (Insert Charts 4 and 5 here). Default rate increases persistently up till the fourth month to 0.025% in response to shock in Repo Rate and slowly dies down. Shock to Reverse Repo Rate however causes the default rate to rise to 0.05% in the second month and thereafter falls successively.

Comparing these results with the earlier result, it is clear that while asset quality is slowly impaired, is more substantial and takes a long time to recover following a shock to the Bank Rate, bank soundness respond more quickly, is less significantly affected and recovers more rapidly following shocks to the short-term policy rates.

**Results of Stress Testing Default Risk: Sensitivity and Scenario analysis**

Stress testing exercises are conducted for the baseline VAR model estimated during the period 1997-2003 when Bank Rate was the major active MPI. The Jarque-Bera statistics for the time series of endogenous variables during that period indicate that they do not follow normal distribution. Further since all these variables are leptokurtic the occurrence of fat-tailed events is far more probable than the normality assumption. It is known that shocks equal to 2 or 3 standard deviations fall on the 95% or 99% quantiles of the empirical distributions of the time series. Using the $99^{th}$ quantile approach uses the information in the time series both in order to determine the relatively large shocks and to limit the magnitude with respect to the maxima of the time series. The shocks are generated for the different variables (Insert Table 14 here). If we take into account the $99^{th}$ quantile, the response of default rate to all the endogenous variables including itself are produced from the standard impulse response analysis for various months (Insert Table 15 here). Acceleration in default rate causes it to rise by 5%, 6-months ahead and subsides thereafter. The response to inflation rate is also about the same. Though response to rise in the Bank Rate is a bit delayed it rises by about 5%, 12-months ahead but dies down later. The most delayed effect of default rate occurs in response to output gap. However the response is much lower compared to the other impulses. The most prominent early warning signals of worsening loan quality are thus the default rate itself, followed by changes in policy interest rate and growth of consumer price inflation.

Three scenarios are considered (Insert Table 16 here). The first scenario ('a')combines positive shock to Bank Rate and inflation rate. The second scenario ('b') combines impulses to Bank Rate, inflation rate and output gap. The third scenario ('c') combines REER appreciation above its trend value, inflation rate and Bank Rate. The three scenarios show default rate of PSBs can rise by 4% to 7% if such adverse conditions actually exist in the economy.

The pertinent question that can now be raised is whether PSBs are resilient enough to counter such adversities. During 1996-97 to 2002-03, PSBs have build up some amount of buffer capital of an average of 3% which can insulate them from extreme shocks. However as the stress tests reveal, default rate may rise from 4 % to 7% in extreme adverse scenarios , the average buffer CAR of 3% above the 9% stipulated level may be inadequate (Insert Chart 6 here)

Adverse monetary shocks, inflation rate and output gap may impair the soundness and profitability of Indian PSBs, the dominant segment of our banking system. Thus banks should use all possible means to accumulate more reserves as preparedness for more adverse times to come in future

**Section 6: Conclusions and Policy Implications**

This paper applies VAR methodology to stress test the Indian PSBs. It estimates the changes in macroeconomic variables on the default rate of the banking industry and provides a dynamic statistical interpretation of the macroprudential concept of credit risk created by simulating interactions between all the variables included in the model. The empirical findings are in conformity with the theoretical assumptions underlying the investigated transmission and with the empirical findings presented in the VAR literature.

There is no evidence of any cyclical and pro-cyclical patterns between banks' default rate and output gap. Similar results are obtained as the output gap replaces Index of Industrial Production (IIP). Default rate responds very positively to inflationary shocks. As REER appreciates (assuming capital inflows) inflation follows soon after and policy interest rates rise to contain inflation and stabilize the exchange rates leading to deterioration of bank asset quality. Exchange rate shocks are thus likely to enhance future credit risk of PSBs. This finding is also a reflection of the impossible trinity of independent monetary policy, capital flows and exchange rates.

There is an important implication of the result of increase in the policy interest rate and its transmission to the bank default rate via pass-through effects to the lending rates. Shocks to Bank Rate affects the default rate the most compared to Repo Rate and Reverse Repo Rate. These findings suggest that bank default rate is influenced by external disturbances through the nexus of exchange rates and domestic interest rates.

The paper has also made another important contribution to literature. The resilience of PSBs has been tested by generating adverse macroeconomic scenarios. It has been found based on the IRFs of the RVAR model used in this study that default rate of PSBs can increase on an average from 4% to 7% depending on the type of scenario. Buffer capital of an average of 3% accumulated during 1996-97 to 2002-03 may not be sufficient from the nearly twice the amount of NPAs generated in the face of the most unfavourable macroeconomic scenarios during that period.

# REFERENCES

**Amediku, Settor (2007),** "Stress Tests of the Ghanaian Banking Sector: A VAR Approach, Monetary Policy Analysis and Financial Stability Department, Bank of Ghana, Working Paper/Bank Of Ghana (BOG)-2006/02, 1-37 www.bog.gov.gh

**Baboucek, Ivan and Martin Jancar (2005),** " A VAR Analysis of the Effects of Macroeconomic Shocks to the Quality of the Aggregate Loan Portfolio of the Czech Banking Sector." *Czech National Bank Working Paper Series* No. 1/2005, 1- 68, www.cnb.cz/en/research

*Basic Statistical Returns,* various issues www.rbi.org.in

**Clair, Robert St (2004),** "Macroeconomic Determinants of Banking Financial Performance and Resilience in Singapore" Macroeconomic Surveillance Department , *Monetary Authority of Singapore (MAS) Staff paper* No 38 ,1-34, www.mas.gov.sg/masmcm

**Demirguc kunt , Asli and Enrica Detragiache** (1998 ) " The Determinants of Banking Crises in Developing and Developed Countries ", *IMF Staff Papers* , Volume 45 , No. 1, 1-29 www.imf.org/external/pubs/ft/staffp/1998

**Dickey, D.A. and W.A. Fuller (1979).** "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, 74, 427–431.

**Elliot, G., T.J Rothenberg and J.H Stock (1996**), "Efficient Tests for an Autoregressive Unit Root", *Econometrica*, Vol. 64, 813–826.

**Filosa, Renato (2007),** "Stress testing of the Italian Banking System: a VAR Approach", *Heterogeneity and Monetary Policy,* No. 0703, 1-46

**Financial Soundness Indicators Compilation Guide (2006) www.imf.org**

**Gambera, Michele** (2000) "Simple Forecasts of Bank Loan Quality in the Business cycle" *Emerging Issues Series, Federal Reserve Bank of Chicago*(S &R -2000-3), 1-31, www.chicagofed.org/publications

**Gandolfo, Giancarlo (1981),** ***Qualitative Analysis and Econometric Estimation of Continuous Time Dynamic Models,*** North Holland, Amsterdam.

**Graeve, Ferre de; Thomas Kick & Michael Koetter (2008) ,** 'Monetary Policy and Bank Distress: an Integrated Micro-macro Approach ' *Deutsche Bundesbank Discussion Paper Series* 2 : Banking and Financial Studies No.03/2008

**Gyzycki, Marianne (2001),** "The Effect of Macroeconomic Conditions on Banks' Risk and Profitability" , *Reserve Bank of Australia Research Discussion Paper 2001-06*, 1-40, www.rba.gov.au/rdp

*Handbook of Statistics on Indian Economy,* various issues www.rbi.org.in

*Handbook of Monetary Statistics on Indian Economy*, various issues www.rbi.org.in

**Hardy , Daniel C and Ceyla Pazarbasioglu** (1999) " Determinants and Leading Indicators of Banking Crises : Further Evidence .Washington DC , IMF Staff Papers, Volume 46, No. 3, 1-12, www.imf.org/external/pubs//ft/staffp

**Hoggarth , Glen , Steffen Sorensen & Lea Zicchino** (2005), 'Stress Tests of UK Banks Using a VAR Approach', *Bank of England Working Paper* , No.282, 1-44 www.bankofengland.co.uk/publications/wp282

**Jordan, John S. and Eric. S Rosengren** (2002), "Economic Cycles and Bank Health", Federal Reserve Bank of Boston, 1-28 www.bos.frb.org/bankinfo/conevent/slowdown/jordanrosen.

**Kaminsky , Graciela L and Carmen M. Reinhart (1999),** "The Twin Crises: The Causes of Banking and Balance-of -Payments Problems', *American Economic Review*, Vol 89 , 473- 500, http:// home.gwu.edu/graciela

**Kwiatkowski, Denis, Peter C. B. Phillips, Peter Schmidt & Yongcheol Shin (1992).** "Testing the Null Hypothesis of Stationary against the Alternative of a Unit Root," *Journal of Econometrics,* 54, 159-178.

**Lindhe, Lena** (2000), "Macroeconomic Indicators of Credit Risk in Business Lending". *Sveriges Riksbank Economic Review* 1/2000*,* 1-15, www.riksbank.com

**Marcucci, Juri and Mario Quagliariello** (2005), "Is Bank Portfolio Riskiness Procyclical? Evidence from Italy Using a Vector Autoregression. " *University of York, Discussion Papers in Economics,* No. 2005/09, 1-45**,** www.york.ac.uk/depts/econ

**Meyer, Andrew P. and Timothy J. Yeager (2001),** "Are Small Rural Banks Vulnerable to Local Economic Downturns?" *Federal Reserve Bank of St Louis Working Paper.* March/April 2001, 1-14 www.stlouisfed.org

**Phillips, P.C.B. and P. Perron (1988).** "Testing for a Unit Root in Time Series Regression," *Biometrika*, 75, 335–346

**Pesaran, M.H and Shin Y** (1998), "Generalized Impulse Response Analysis in Linear Multivariate Models", *Economic Letters* , Vol 58, 17-29

**Quagliariello, Mario (2003),** 'Are Macroeconomic Indicators Useful in Predicting Bank Loan Quality? Evidence from Italy' http://www-users.york.ac.uk/mq102/mpa_en.pdf.

**Ranjan, Rajiv and Sarat Chandra Dhal** (2003), "Non Performing Loans and Terms of Credit of Public Sector Banks in India: An Empirical Assessment" . *RBI Occasional Papers* , Volume 24 , No 3 . Winter, 1 -41 www.rbi.org.in

**Rajaraman, Indira, Sumon Bhaumik and Namita Bhatia** (1999), 'NPA Variations Across Indian Commercial Banks', *Economic & Political Weekly (EPW)* , January 16-23 , 161-168

**Rajaraman, Indira and Garima Vashistha** (2002), 'Non-Performing Loans of PSU Banks Some Panel results', *Economic & Political Weekly (EPW)*, February 2, 1-7

**Reddy, Y. V. (2004),** 'Credit Policy, Systems and Culture', *Reserve Bank of India Bulletin*, March., 303-311, **www.rbi.org.in**

*Report on Currency and Finance* , 2003-04 www.rbi.org.in

**Salas, V and J Saurina (2002),** 'Credit Risk in Two Institutional Regimes: Spanish Commercial and Savings Banks', *Journal of Financial Services Research.* Volume 22, No. 3*,* 203-224 www.papers.ssrm.com

**Shu Chang (2002)**, 'The Impact of Macro Economic Environment on the Asset quality of Hong Kong's Banking Sector', Hong Kong Monetary Authority (HKMA) www.bis.org/publ

**Sims, C. (1980),** "Macroeconomics and Reality", *Econometrica*, Vol. 48, No. 1, 1-48

**Sims, C. A., J. H. Stock and M. W. Watson (1990),** 'Inference in Linear Time Series Models with some Unit Roots', *Econometrica*, Vol. 58, No. 1, 113-144

**Sy, Amadou N.R(2007),** 'Capital Account Convertibility and Risk Management in India' *IMF Working paper* /07/251 **www.imf.org**

**Tracey, Marlon ( 2007 )** 'A VAR Analysis of the Effects of Macroeconomic Shocks on Banking Sector Loan Quality in Jamaica', 1-38 http://www.boj.org.jm/uploads

## TABLES

### Table 1: Frequency of Bank Rate Change

| Period | Frequency of Bank Rate Change | Range |
|---|---|---|
| **1950s** | 2 | 3.0-4.0 |
| **1960s** | 4 | 4.0-6.0 |
| **1970s** | 3 | 5.0-9.0 |
| **1980s** | 1 | 9.0-10.0 |
| **1990s** | 10 | 8.0-12.0 |
| **April 1997- March 2003** | 14 | 6.25-11.00 |
| **March 2003- March 2008** | Nil | 6.25 |

Source: Handbook of Statistics on Indian Economy, various issues

### Table 2: Frequency of Repo Rate and Reverse Repo Rate Change

| | REPO RATE | | REVERSE REPO RATE | |
|---|---|---|---|---|
| | FREQUENCY | RANGE | FREQUENCY | RANGE |
| **2000-01** | 21 | 9.00-15.00 | 26 | 7.00-15..50 |
| **2001-02** | 3 | 8.00-8.75 | 3 | 6.00-6.75 |
| **2002-03** | 3 | 7.00-7.50 | 3 | 5.00-5.75 |
| **2003-04** | 1 | 6.00 | 1 | 4.50 |
| **2004-05** | NIL | 6.00 | 1 | 4.75 |
| **2005-06** | 2 | 6.25-6.50 | 3 | 5.00-5.50 |
| **2006-07** | 5 | 6.75-7.75 | 2 | 5.75-6.00 |
| **2007-08** | Nil | 7.75 | Nil | 6.00 |

Source: Handbook of Statistics on Indian Economy, various issues

### Table 3: Share of Gross NPAs by Bank Groups (1996-97 to 2007-08)

| Year | 1996-97 | 1997-98 | 1998-99 | 1999-00 | 2000-01 | 2001-02 | 2002-03 | 2003-04 | 2004-05 | 2005-06 | 2006-07 | 2007-08 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PSBs** | 92 .13 | 89.84 | 88.06 | 87.60 | 85.63 | 79.64 | 76.92 | 79.42 | 80.97 | 18.94 | 77.18 | 71.84 |
| **Private banks** | 5.37 | 6.27 | 7.93 | 8.11 | 950 | 16.44 | 18.96 | 15.94 | 15.10 | 15.29 | 18.33 | 23.08 |
| **Foreign banks** | 2.50 | 3.89 | 4.01 | 4.30 | 4.86 | 3.92 | 4.11 | 4.64 | 3.92 | 3.77 | 4.48 | 5.08 |

Source: Handbook of Statistics on Indian Economy, various issues

### Table 4: Data Sources of Variables in Unrestricted VAR Model

| | VARIABLE | Symbol | Data Source |
|---|---|---|---|
| 1 | Default rate constructed from gross NPA and gross advances. | DR | Handbook of Statistics on Indian Economy 2009-10 |
| 2 | Output gap (difference between log of seasonally adjusted GDP from its Hodrick Prescott filtered trend) | OG_GDP | Handbook of Statistics on Indian Economy 2009-10 |
| 4 | Consumer Price Index (CPI) for Industrial workers. (Base year 1982=100 shifted to 1993-94=100) | INF | Handbook of Statistics on Indian Economy 2009-10 |

| | | | |
|---|---|---|---|
| 5 | REER deviation from trend value is the difference 36–currency trade-based Real Effective Exchange Rate index (Base year 1993-94=100) | R_T | Handbook of Statistics on Indian Economy 2009-10 |
| 6 | Bank Rate | B | Handbook of Statistics on Indian Economy 2009-10 |
| 7 | Repo Rate | RR | Handbook of Statistics on Indian Economy 2009-10 |
| 8 | Reverse Repo Rate | RRR | Handbook of Statistics on Indian Economy 2009-10 |

**Table 5. Chow Breakpoint Test on the Default Rate series (Breakpoint April 2004)**

| | | | |
|---|---|---|---|
| **F-statistic** | 1.026641 | Probability | 0.360695 |
| **Log likelihood ratio** | 2.093482 | Probability | 0.351080 |

**Table 6: Descriptive Statistics of Time Series of Endogenous Variables in RVAR Model**

| | A | OG_GDP | B | RR | RRR | INF | R_T |
|---|---|---|---|---|---|---|---|
| **Mean** | 0.033 | 6.02E-05 | 0.080 | 7.187 | 5.479 | 0.486 | 0.0517 |
| **Median** | 0.010 | 0.001 | 0.070 | 7.000 | 5.500 | 0.406 | 0.071 |
| **Maximum** | 0.606 | 0.104 | 0.120 | 9.000 | 6.750 | 3.512 | 8.522 |
| **Minimum** | -0.153 | -0.107 | 0.060 | 6.000 | 4.387 | -1.782 | -6.038 |
| **Std. Dev.** | 0.103 | 0.037 | 0.023 | 0.933 | 0.694 | 0.669 | 2.581 |
| **Skewness** | 2.391 | -0.045 | 0.780 | 0.208 | -0.020 | 0.829 | 0.267 |
| **Kurtosis** | 12.42 | 3.734 | 2.062 | 1.819 | 1.746 | 6.330 | 3.254 |
| **Jarque-Bera** | 715.7 | 3.519 | 21.23 | 5.285 | 5.311 | 88.85 | 3.249 |
| **Probability** | 0.000 | 0.102 | 0.000 | 0.071 | 0.070 | 0.000 | 0.324 |
| **Observations** | 154 | 154 | 154 | 81 | 81 | 154 | 154 |

**Table 7: Correlation Matrix of Variables in RVAR Model**

| | DR | OG_GDP | B | RR | RRR | INF | R_T |
|---|---|---|---|---|---|---|---|
| **DR** | 1.000 | -0.017 | 0.396 | 0.455 | 0.541 | 0.070 | -0.1212 |
| **OG_GDP** | -0.109 | -0.005 | 0.088 | -0.070 | -0.027 | 0.070 | -0.124 |
| **B** | 0.397 | -0.026 | 1.000 | 0.688 | 0.621 | 0.038 | -0.179 |
| **RR** | 0.455 | -0.024 | 0.6888 | 1.000 | 0.807 | 0.039 | -0.125 |
| **RRR** | 0.542 | -0.110 | 0.6218 | 0.807 | 1.000 | 0.090 | -0.018 |
| **INF** | 0.070 | 0.122 | 0.038 | 0.039 | 0.091 | 1.000 | 0.064 |
| **R_T** | -0.121 | 0.064 | -0.179 | -0.125 | -0.018 | 0.064 | 1.000 |

**Table 8: Optimal Lag length of RVAR model**

| Lag | LogL | LR | FPE | AIC | SIC | HQIC |
|---|---|---|---|---|---|---|
| **0** | 337.3626 | NA | 6.38e-09 | -4.681164 | -4.577085 | -4.638870 |
| **1** | 898.2382 | 1074.353 | 3.36e-12 | -12.22871 | -11.60424 | -11.97495 |
| **2** | 969.3133 | 131.1387 | 1.76e-12 | -12.87765 | -11.73279 | **-12.41243** |
| **3** | 999.9580 | 54.38353 | 1.63e-12 | -12.95716 | **-11.85190** | -12.28046 |
| **4** | 1037.757 | 64.41720 | 1.37e-12 | -13.13742 | -10.95177 | -12.24926 |
| **5** | 1067.525 | 48.63607 | 1.29e-12 | -13.20458 | -10.49854 | -12.10496 |
| **6** | 1085.923 | 28.76291 | 1.44e-12 | -13.11159 | -9.885162 | -11.80050 |
| **7** | 1115.877 | 44.72014 | 1.37e-12 | -13.18137 | -9.434545 | -11.65881 |
| **8** | 1135.141 | 27.40352 | 1.53e-12 | -13.10058 | -8.833362 | -11.36655 |
| **9** | 1154.940 | 26.77042 | 1.71e-12 | -13.02732 | -8.239716 | -11.08183 |
| **10** | 1191.251 | 46.53992 | 1.53e-12 | -13.18664 | -7.878639 | -11.02968 |
| **11** | 1227.608 | 44.03766 | 1.38e-12 | **-13.34659** | -7.518200 | -10.97817 |
| **12** | 1243.975 | 18.67232 | 1.67e-12 | -13.22500 | -6.876218 | -10.64511 |

## Table 9: Residual Correlation Matrix

| | DR | OG_HP | B | INF | R_T |
|---|---|---|---|---|---|
| **DR** | 1.000000 | 0.078601 | 0.172676 | 0.028174 | 0.098388 |
| **OG_GDP** | 0.078601 | 1.000000 | 0.016087 | 0.127937 | 0.042464 |
| **B** | 0.172676 | 0.016087 | 1.000000 | -0.202969 | 0.259626 |
| **I** | 0.028174 | 0.127937 | -0.202969 | 1.000000 | -0.113784 |
| **R_T** | 0.098388 | 0.042464 | 0.259626 | -0.113784 | 1.000000 |

## Table 10: Results of Unit root tests

| | Order of integration | ADF (Intercept & trend) | DF-GLS (Intercept & trend) | PP (Intercept & trend) | KPSS (Intercept & trend) |
|---|---|---|---|---|---|
| **DR** | I(0) | -4.72 | -3.92 | -5.38 | 0.32 |
| **OG_GDP** | I(0) | -8.34 | -6.41 | -5.18 | 0.03 |
| **B** | I(0) | -1.98 | -2.06 | -1.48 | 1.58 |
| **RR** | I(0) | -2.10 | -1.88 | -1.72 | 0.91 |
| **RRR** | I(0) | -3.46 | -3.48 | -2.83 | 0.14 |
| **INF** | I(0) | -7.28 | -7.03 | -9.28 | 0.06 |
| **R_T** | I(0) | -3.46 | -3.48 | -2.83 | 0.14 |

Note: Critical values of ADF & PP tests are -4.01, -3. 43 _-3.15, at 1%, 5% and 10% significance levels
Critical values of DF--GLS test are -3.52, -2.97 & -2.68 at 1%, 5% and 10% significance levels
Critical values of KPSS test are 0.216, 0.146 & 0.119, at 1%, 5% and 10% significance levels

## Table 11: Stability condition in VAR

| ROOT | MODULUS |
|---|---|
| 0.944640 | 0.944640 |
| 0.826758 - 0.148843i | 0.840050 |
| 0.826758 + 0.148843i | 0.840050 |
| 0.635294 - 0.413210i | 0.757853 |
| 0.635294 + 0.413210i | 0.757853 |
| 0.281255 - 0.679442i | 0.735354 |

| | |
|---|---|
| 0.281255 + 0.679442i | 0.735354 |
| -0.423090 | 0.423090 |
| 0.249919 - 0.169115i | 0.301760 |
| 0.249919 + 0.169115i | 0.301760 |

**Table 12: Results of Granger Causality Tests (3 lags)**

| NULL HYPOTHESIS | F-TEST | SIGNIFICANCE LEVEL | COMMENT |
|---|---|---|---|
| **1) Default Rate versus Output Gap** | | | |
| i) OG_GDP does not Granger cause DR | 0.026 | 0.99402 | Do not reject $H_0$ |
| ii) DR does not Granger cause OG_GDP | 0.081 | 0.96998 | Do not reject $H_0$ |
| **2) Default Rate versus Bank Rate** | | | |
| i) B does not Granger cause DR | 5.293 | 0.00241 | **Reject** $H_0$ |
| ii) DR does not Granger cause B | 3.497 | 0.02001 | **Reject** $H_0$ |
| **3) Default Rate versus Inflation Rate** | | | |
| i) INF does not Granger cause DR | 10.966 | 5.6E-06 | **Reject** $H_0$ |
| ii) DR does not Granger cause INF | 3.5113 | 0.01967 | **Reject** $H_0$ |
| **4) Default Rate versus deviation of REER from its HP trend** | | | |
| i) R_T does not Granger cause DR | 1.48 | 0.02645 | **Reject** $H_0$ |
| ii) DR does not Granger cause R_T | 0.546 | 0.65189 | Do not reject $H_0$ |
| **5) Output Gap versus Bank Rate** | | | |
| i) B does not Granger cause OG_GDP | 1.554 | 0.20832 | Do not reject $H_0$ |
| ii) OG_GDP does not Granger cause B | 1.611 | 0.19454 | Do not reject $H_0$ |
| **6) Output Gap versus Inflation rate** | | | |
| i) INF does not Granger cause OG_GDP | 0.171 | 0.91502 | Do not reject $H_0$ |
| ii) OG_GDP does not Granger cause INF | 0.455 | 071459 | Do not reject $H_0$ |
| **7) Output Gap versus deviation of REER from its HP trend** | | | |
| i) R_T does not Granger cause OG_GDP | 0.8611 | 0.46560 | Do not reject $H_0$ |
| ii)OG_GDP does not Granger cause R_T | 0.264 | 0.43275 | Do not reject $H_0$ |
| **8) Bank Rate versus Inflation Rate** | | | |
| i) INF does not Granger cause B | 2.766 | 0.04830 | **Reject** $H_0$ |
| ii) B does not Granger cause INF | 0.7458 | 0. 52856 | Do not reject $H_0$ |
| **9) Bank Rate versus deviation of REER from its HP trend** | | | |
| i) R_T does not Granger cause B | 0.1200 | 0.94802 | Do not reject $H_0$ |
| ii) B does not Granger **cause R_T** | 0.5584 | 064423 | Do not reject $H_0$ |
| **10)Inflation rate versus deviation of REER from its HP trend** | | | |
| i) R_T does not Granger cause INF | 5.848 | 0.00128 | **Reject** $H_0$ |
| ii) I does not Granger cause R_T | 3.054 | 0.03419 | **Reject** $H_0$ |

Bold significance levels indicate significance at the usual levels

**Table 13 : Results on Forecast Error Variance Decomposition**

**Decomposition of Forecast error variance of DR as explained by the effect of shocks**

| Step Ahead | S.E | DR | OG_GDP | B | INF | R_T |
|---|---|---|---|---|---|---|
| 1 | 0.053282 | 100.0000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| 3 | 0.074182 | 77.68623 | 0.067897 | 1.172441 | 15.32973 | 5.743701 |
| 6 | 0.089875 | 61.52935 | 0.619590 | 1.291011 | 23.47592 | 13.08412 |
| 9 | 0.094766 | 58.94139 | 0.677475 | 1.845128 | 21.57348 | 16.96252 |
| 12 | 0.097655 | 56.32567 | 1.308919 | 3.569571 | 20.39191 | 18.40394 |
| 60 | 0.103554 | 51.74728 | 2.583039 | 9.136343 | 18.34081 | 18.19252 |

**Decomposition of Forecast Error Variance of OG_GDP as explained by effect of shocks**

| Step Ahead | S.E | DR | OG_GDP | B | INF | R_T |
|---|---|---|---|---|---|---|
| 1 | 0.009748 | 0.617805 | 99.38219 | 0.000000 | 0.000000 | 0.000000 |
| 3 | 0.019395 | 0.554549 | 95.57987 | 2.079487 | 1.550351 | 0.235746 |
| 6 | 0.020706 | 0.737643 | 92.10904 | 2.563976 | 4.253995 | 0.335344 |
| 9 | 0.021591 | 0.776273 | 90.34187 | 4.407513 | 4.007417 | 0.466928 |
| 12 | 0.021705 | 0.942267 | 89.63837 | 4.791309 | 4.160344 | 0.467706 |
| 60 | 0.021799 | 1.258484 | 89.05060 | 4.922336 | 4.220656 | 0.547921 |

**Decomposition of Forecast Error Variance of B as explained by effect of shocks**

| Step Ahead | S.E | DR | OG_GDP | B | INF | R_T |
|---|---|---|---|---|---|---|
| 1 | 0.002862 | 2.981705 | 0.000636 | 97.01766 | 0.000000 | 0.000000 |
| 3 | 0.005795 | 16.42451 | 0.111828 | 80.76685 | 1.249493 | 1.447317 |
| 6 | 0.008016 | 18.47465 | 4.563234 | 70.67835 | 3.505213 | 2.778552 |
| 9 | 0.009563 | 20.69232 | 6.864525 | 64.33545 | 4.491432 | 3.616270 |
| 12 | 0.010429 | 22.65070 | 6.516396 | 60.51618 | 5.555987 | 4.760739 |
| 60 | 0.012276 | 24.43290 | 6.705621 | 55.38974 | 5.790497 | 7.681244 |

**Decomposition of Forecast Error Variance of INF as explained by effect of shocks**

| Step Ahead | S.E | DR | OG_GDP | B | INF | R_T |
|---|---|---|---|---|---|---|
| 1 | 0.648868 | 0.079376 | 1.59044 | 4.465908 | 93.86427 | 0.000000 |
| 3 | 0.756873 | 3.120364 | 1.19132 | 3.795647 | 91.49705 | 0.395608 |
| 6 | 0.807264 | 8.147587 | 2.09533 | 3.941841 | 85.23758 | 0.577660 |
| 9 | 0.820427 | 8.443796 | 2.15615 | 3.976667 | 84.33737 | 1.086005 |
| 12 | 0.824272 | 8.669275 | 2.19811 | 4.020089 | 83.72034 | 1.392179 |
| 60 | 0.830901 | 8.818785 | 2.33116 | 4.667752 | 82.43744 | 1.744857 |

**Decomposition of Forecast Error Variance R_T as explained by effect of shocks**

| Step Ahead | S.E | DR | OG_GDP | B | INF | R_T |
|---|---|---|---|---|---|---|
| 1 | 1.116568 | 0.968015 | 0.121371 | 6.063834 | 0.505908 | 92.34087 |
| 3 | 1.818634 | 1.497635 | 8.145723 | 3.829049 | 6.539628 | 79.98796 |
| 6 | 2.263577 | 5.807114 | 13.51151 | 3.992628 | 13.57874 | 63.11001 |
| 9 | 2.440053 | 8.825651 | 13.20368 | 5.881393 | 16.68006 | 55.40921 |
| 12 | 2.510120 | 10.07188 | 12.89555 | 6.968179 | 17.64851 | 52.41588 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **60** | 2.541191 | 10.36768 | 12.76896 | 7.519695 | 17.63654 | 51.70712 |

**Table 14: Generation of Extreme Macroeconomic Shocks**

| | DR | OG_GDP | B | INF | R_T |
|---|---|---|---|---|---|
| **$95^{th}$ quantile** | 0.228 | 0.034 | 0.12 | 1.99 | 3.62 |
| **$99^{th}$ quantile** | 0.308 | 0.048 | 0.11 | 2.75 | 5.54 |
| **Standard deviation** | 0.560 | 0.021 | 0.016 | 0.78 | 2.59 |
| **95th quantile / std deviation** | 0.407 | 1.619 | 6.875 | 2.55 | 1.39 |
| **99th quantile / std deviation** | 0.550 | 2.285 | 7.500 | 3.52 | 2.13 |

Note: Values are in percentage

**Table 15: Sensitivity Stress Tests: Stressed Response of Default Rate ($99^{th}$ quantile)**

| | DR | OG_GDP | B | INF | R_T |
|---|---|---|---|---|---|
| **12** | 0.141 | -2.085 | 4.131 | 2.383 | -1.427 |
| **24** | -0.429 | 1.240 | 3.750 | 2.078 | -0.968 |
| **36** | -0.179 | 1.081 | 2.981 | 1.700 | -0.771 |

Note: Responses are in percentage points

**Table 16: Scenario Stress Tests : Stressed Response of Default Rate**

| | Scenario 'a' | Scenario 'b' | Scenario 'c' |
|---|---|---|---|
| 12 | 6.514 | 4.429 | 4.132 |
| 24 | 5.828 | 7.068 | 6.538 |
| 36 | 6.514 | 5.762 | 4.784 |

# CHARTS

## Chart 1: TIME PATHS OF ENDOGENOUS VARIABLES

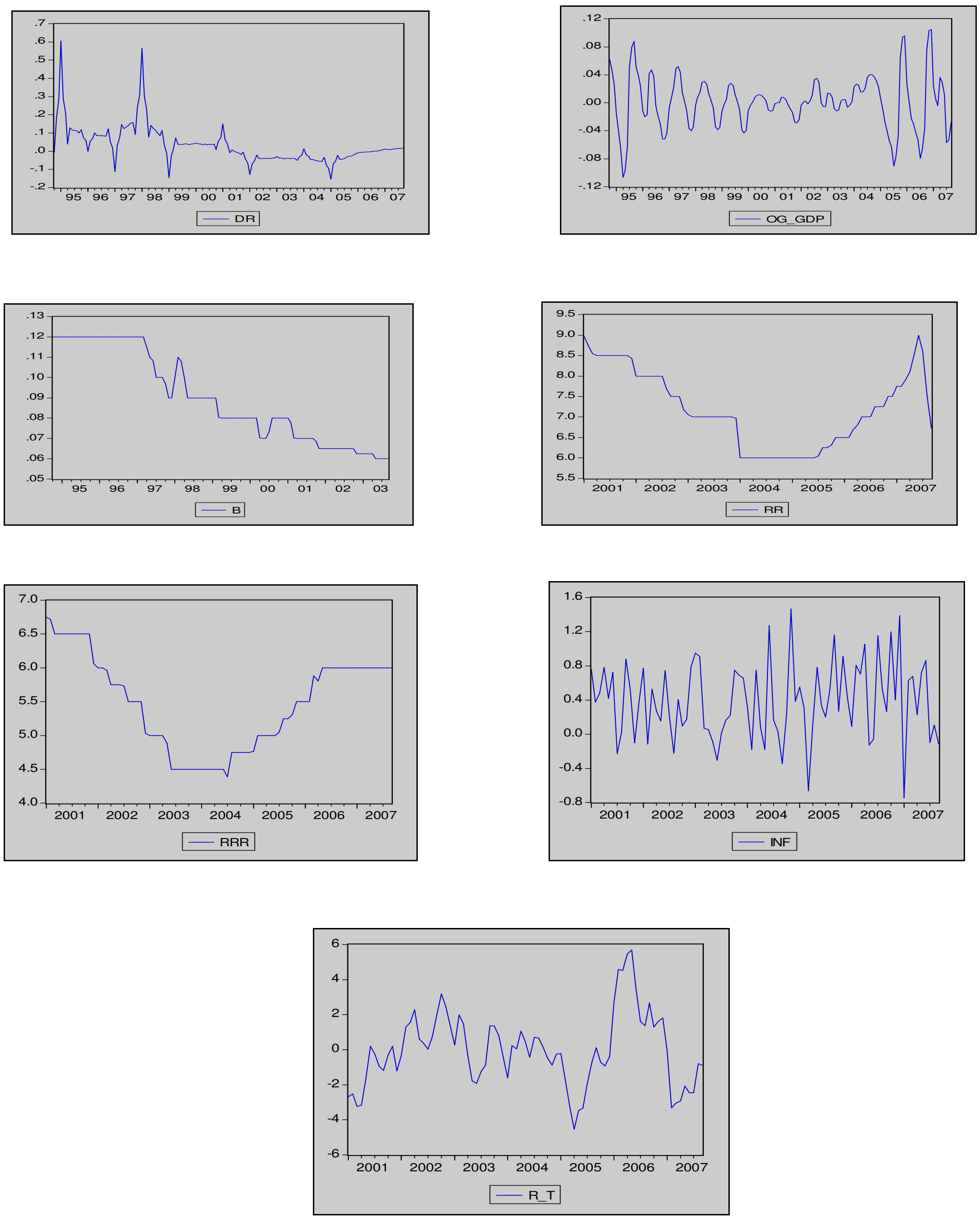


**Chart 2: STATIONARY VAR**

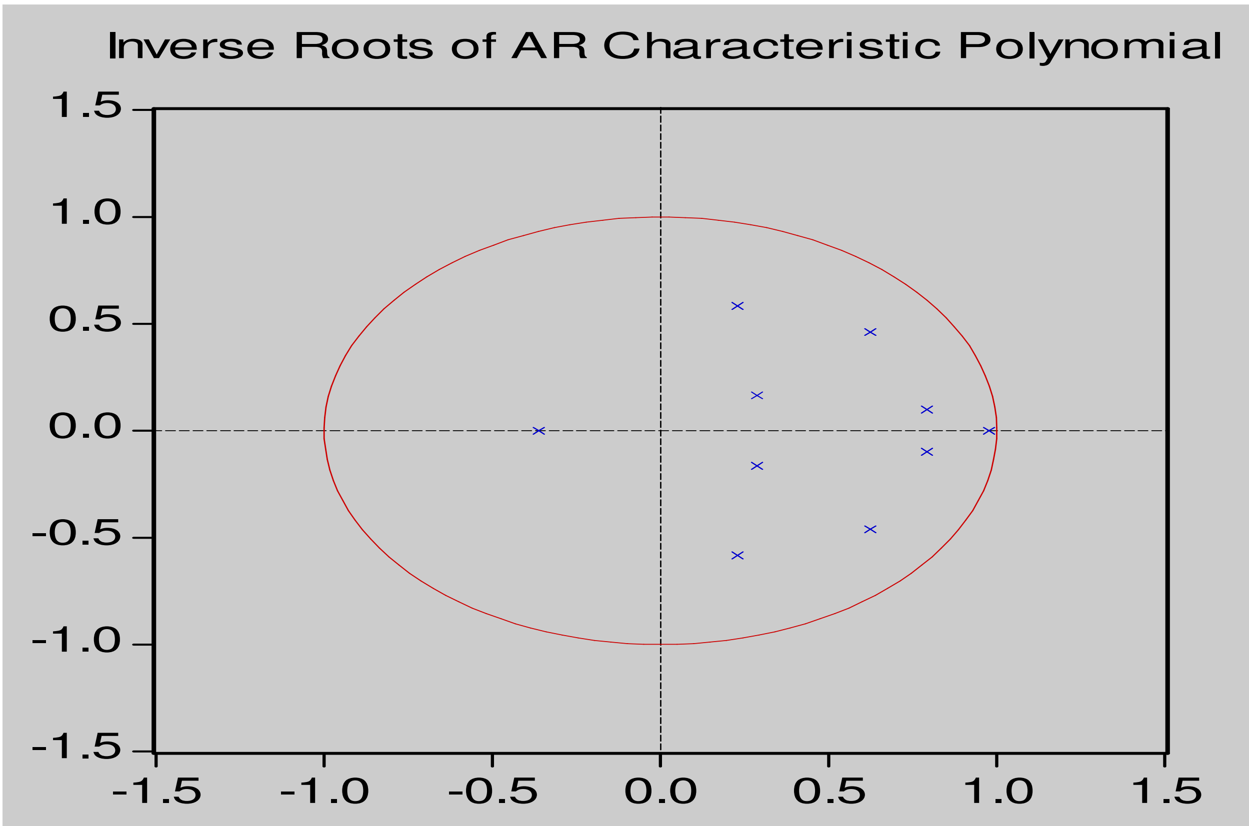


**CHART 3: GRAPHS OF IMPULSE RESPONSE FUNCTIONS USING BANK RATE AS THE MONETARY POLICY INSRUMENT**

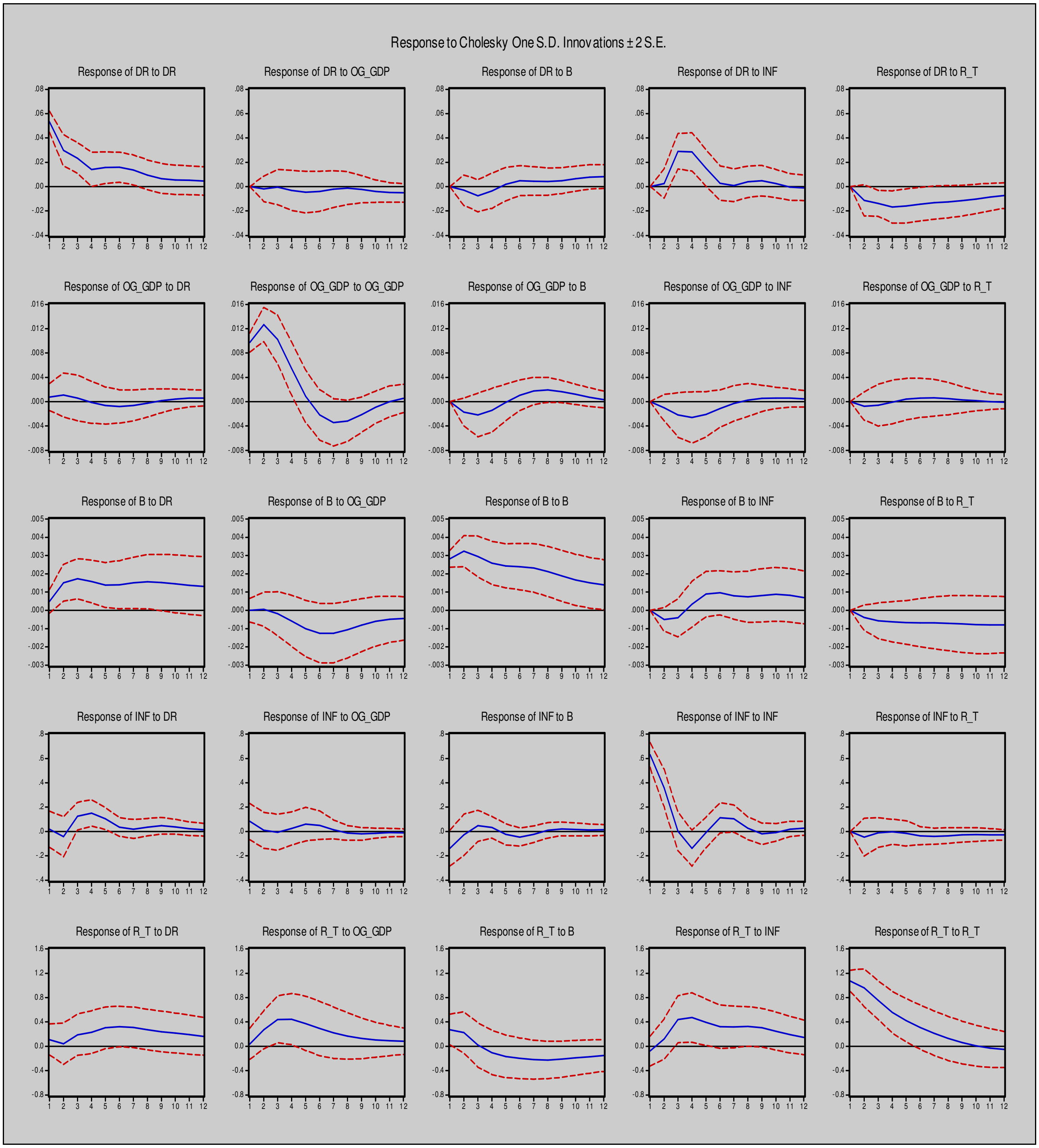


**CHART 4: GRAPHS OF IMPULSE RESPONSE FUNCTIONS USING REPO RATE AS THE MONETARY POLICY INSRUMENT**

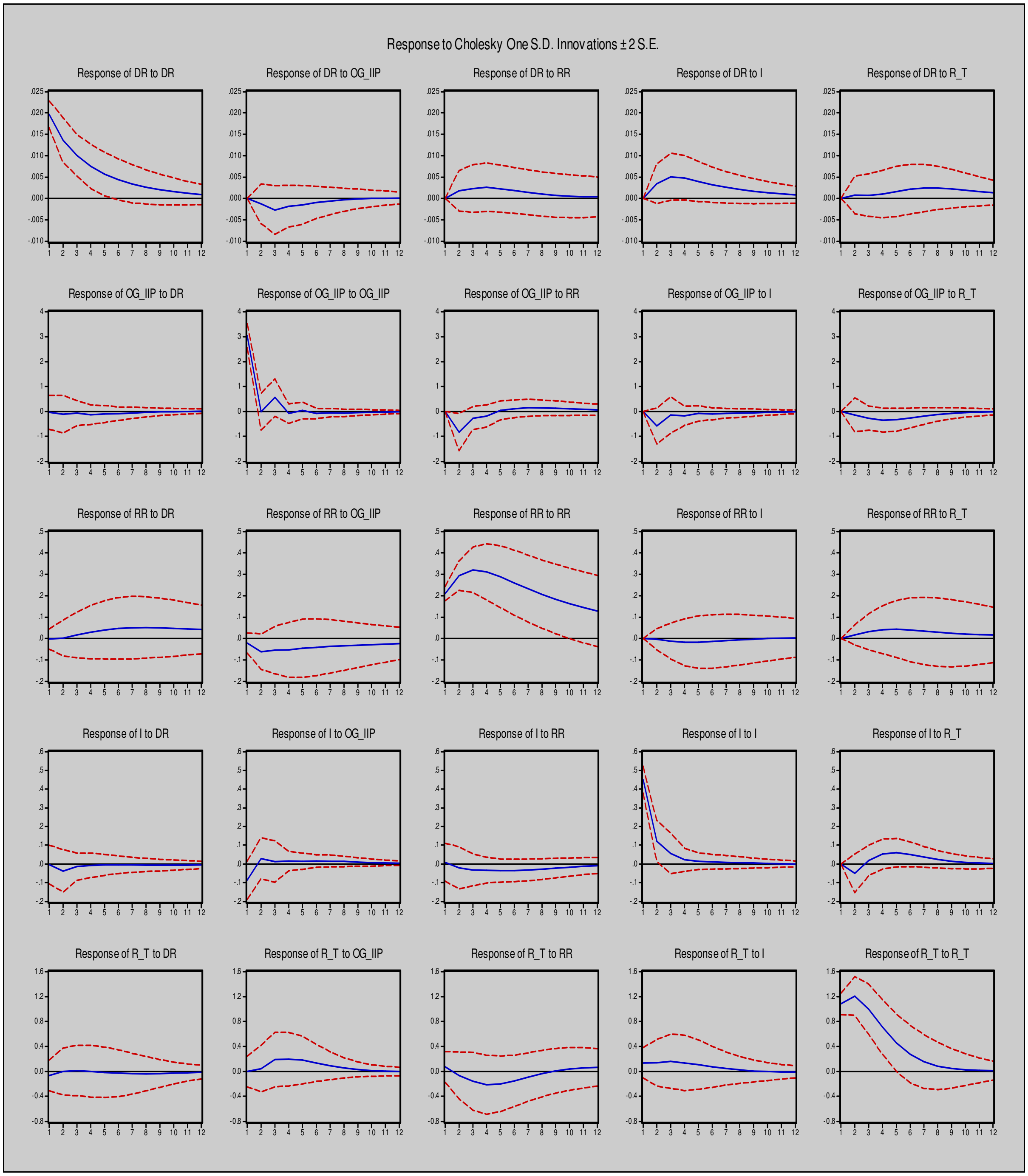
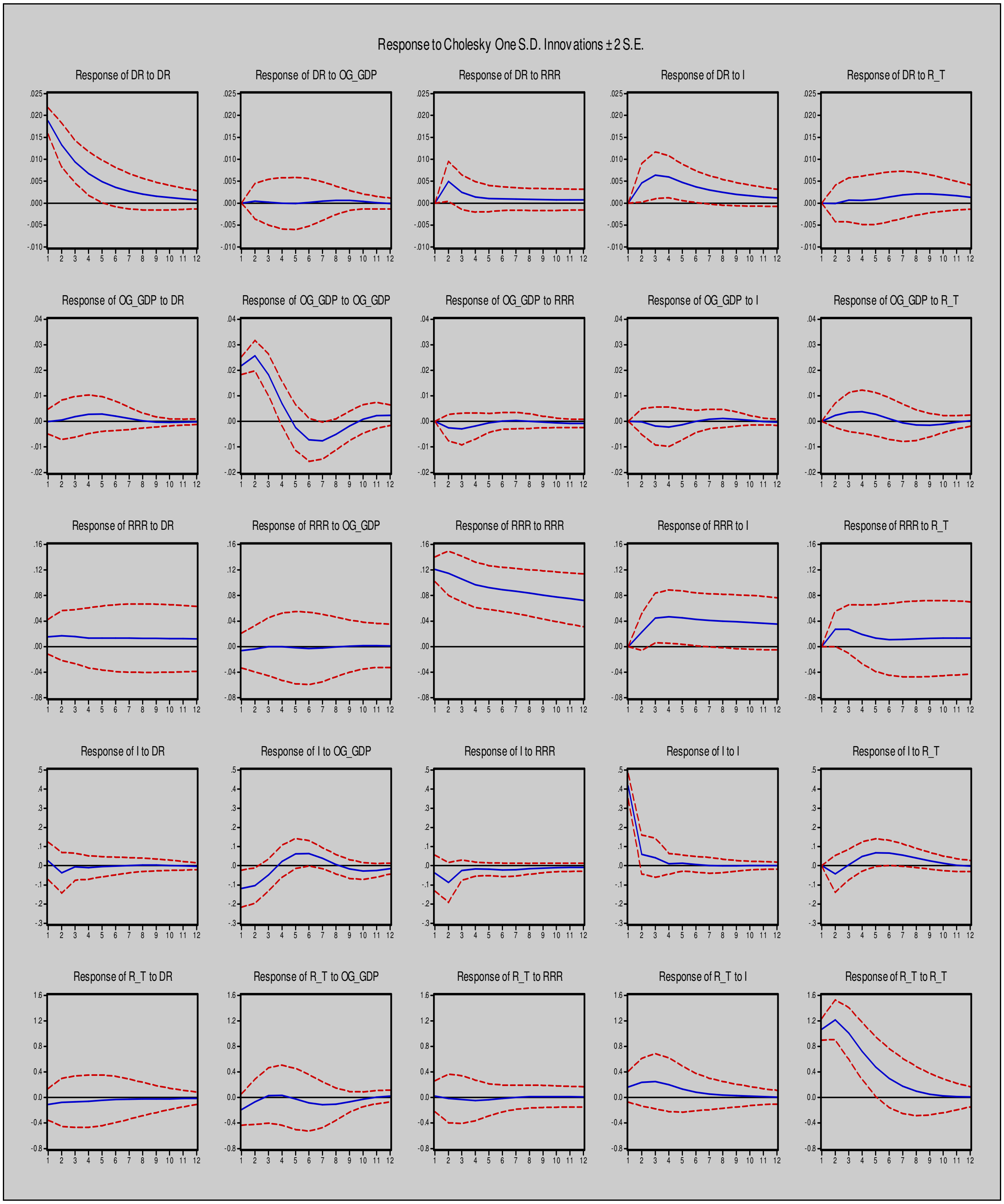


**CHART 5: GRAPHS OF IMPULSE RESPONSE FUNCTIONS USING REVERSE REPO RATE AS THE MONETARY POLICY INSRUMENT**



## Chart 6 : BUFFER CAR OF PUBLIC SECTOR BANKS