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A VAR Model of Monetary Policy and Hypothetical Case of Inflation Targeting in India

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Abstract:

The empirical VAR literature on identification and measurement of the impact of monetary policy shocks on the real side of the economy is fairly comprehensive for developed economies but very limited for emerging and transition economies. In this study, we propose an identification scheme, for a developing economy taking India as a case study, which is able to capture the monetary transmission mechanism without giving rise to any empirical anomalies. We use a VAR approach with recursive contemporaneous restrictions and identify monetary policy shocks by modelling the reaction function of the central bank and structure of the economy. The effect of monetary policy shocks on the exchange rate and other macroeconomic variables is consistent with the predictions of a broad set of theoretical models. This set-up is used to build a hypothetical case of inflation targeting where the monetary policy instrument is set after looking at the current values of inflation only. This is in contrast with the 'multiple indicator approach' currently followed by Reserve Bank of India. This hypothetical scenario of inflation targeting suggests a sharper response of the interest rate (monetary policy instrument) to shocks and strengthening of the exchange rate channel in transmission of interest rate impulses. This study also provides some useful implications on the type of theoretical framework which can be used to model the evolution of monetary policy for a developing economy like India.

Keywords: India, Inflation Targeting, Monetary policy, VAR

JEL codes: E52, E58, E47

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1. Introduction

The monetary policy framework in India has undergone various transformations since the beginning of the planning period in 1951. The monetary policy framework, at the beginning of the planning period, could be best described as "controlled expansion" of the money supply. It was determined mainly by the fiscal stance. It was being formulated against the backdrop of large budget deficits. The main task of the Reserve Bank of India (RBI) was to contain the adverse effects of monetization[3]. India switched to a monetary targeting framework in the mid 1980s. Monetary Targeting was pursued in a very flexible manner with a 'feedback' from the real sector of the economy. This was necessary partly because of the high level of government borrowings and administered interest rates. The two core objectives of monetary policy were maintaining price stability and provision of adequate credit to the productive sectors of the economy.

The policy environment, framework and strategies underwent a distinct change in the early 1990s when India adopted economic reforms in 1991 after a balance of payment crisis. Monetary policy had to deal with traditional issues along with the new issues brought about by the changed economic policy environment. Deregulation and liberalization of financial markets cast doubt on the appropriateness of exclusive reliance on money as the only intermediate target in the late 1990s. The expansion of money supply emanating from monetization of the government deficit and rising capital inflows rendered the control of monetary aggregates more difficult. The gradual opening up of the Indian economy from the 1990s also increased the upward risks to domestic inflation. This emanated from large capital inflows in the economy and a host of other global factors to which domestic inflation was increasingly becoming more responsive. The transition of economic policies from a controlled to liberalized but regulated regime has been reflected in the changes in monetary management in India. The monetary policy framework in India changed from 'pure monetary

[3] Monetization of the deficit is the increase in net RBI credit to the government which, in turn, is the increase in the RBI's holding of government dated securities, 91-day treasury bills and rupee coins for changes in cash balances with the Reserve Bank.

targeting strategy' to a 'Multiple Indicator Approach (MPA)' in 1998-1999[4]. Though, the basic objectives of monetary policy of price stability and ensuring availability of credit to productive sectors have remained intact, the underlying operating procedures have undergone significant changes. Besides, broad money which remains an information variable, a host of macroeconomic indicators including interest rates or rates of return in different markets are used for drawing policy perspectives. The main attributes of monetary policy in India from the mid 1980s to present are summarized in the table 1:

Table 1: Main Attributes of Monetary policy In India

Attribute	Mid 1980s to 1998-99	1998-99 to Present
Objectives	1)Price Stability 2)Ensuring adequate flow of credit to productive sectors of the economy	
Transmission Mechanism (or Intermediate target)	Monetary Targeting with annual growth in broad money (M_3) as intermediate target	Multiple Indicator approach with rate of returns in different markets (namely money, capital, currency, external etc.) as intermediate target
Operating Procedure (Instruments)	Direct instruments namely interest rate regulations, selective credit control and Cash Reserve Ratio (CRR)	Indirect instruments namely repo operations[5] under Liquidity Management Facility (LAF) and Open Market Operations(OMO)

The monetary management in India has been credible so far but the increased integration of the Indian economy into the world economy after 2000 has lead to transmission of uncertainties related to world financial and oil markets, into the domestic (Indian) economy, hence, making the macroeconomic environment more unpredictable. The monetary framework in India has to adjust to the world of rapid capital inflows and outflows. In this changed scenario, the MPA of monetary policy, which is currently followed by the Reserve Bank of India (RBI), does not seem to work effectively. The multiplicity of objectives leads

[4] Though, the 'multiple indicator approach' was formally adopted in April 1998, the change in the operating procedure of monetary policy was visible after 1995 only as our analysis in the next section suggests.

[5] Repo operations entail lending (or borrowing) money by RBI to banks against approved securities to meet their day-to-day requirement or to fill the short-term gap. These operations are overnight operations. The 'repo rate' is the rate at which RBI lends money to banks and the 'reverse repo rate' is the rate at which RBI borrows money from banks.

to inherent conflict among such objectives in this environment. This approach is creating a conflict between exchange rate stabilization and inflation stabilization leaving the market confused as which variable the RBI will choose to defend[6]. This changed scenario calls for a change to the monetary policy framework to ensure it is transparent and forward-looking with accountability on the part of the central Bank. Inflation targeting by its very nature, encompasses all these properties.

Mishra and Mishra (2009) analyzed the preconditions for inflation targeting in India and assessed its suitability as a monetary policy framework for India. They built sector specific Vector Autoregression (VAR) models and suggested that the Indian economy satisfies the preconditions for inflation targeting. Extending the analysis of Mishra and Mishra (2009) this paper builds a short run comprehensive VAR model of monetary policy for the Indian economy to model a hypothetical inflation targeting monetary policy regime for India.

The VAR model presented is subjected to monetary policy shocks as different models respond differently to monetary policy shocks. The response of major macroeconomic variables to these shocks will help us determine the type of theoretical model, which can explain all the possible interrelationships among macroeconomic variables and thus fit the framework of the Indian economy better among the variety of models available. Moreover given the theoretical consistency of responses of various macroeconomic variables to monetary shocks, we can conduct the hypothetical experiment of inflation targeting in the above specified VAR model[7].

Since, the variables are simultaneously determined over time, an identification assumption on contemporaneous causality is required to be able to isolate monetary policy shocks. We assume that the policy shock is orthogonal to the variables RBI considers while setting its policy instrument. This is referred to as the *recursiveness* assumption. The economic implication of the recursiveness assumption is that time t variables in the RBI's information set do not respond to time t realizations of monetary policy shocks.

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[6] To see how refer, for example, to D'souza(2003) and Shah (2007)

[7] This approach is based on Lucas' methodology (see, Christiano et al., 1999).

The empirical VAR literature on identification and measurement of the impact of monetary policy shocks on macroeconomic and financial variables is fairly comprehensive for developed economies but very limited for emerging and transition economies. In this study, we made an attempt towards addressing this situation by taking India as a case study. This study contributes to the literature in several ways; first, it suggests an identification scheme which is able to the capture monetary transmission mechanism for a developing economy like India; secondly, it gives preliminary evidence on how an inflation targeting regime would work for India; and lastly, it will provide implications for the theoretical model which can be used to model monetary policy evolution for a developing economy like India.

The rest of this paper is organized as follows: Section 2 reviews the literature related to the effects of monetary policy shocks; section 3 presents a brief discussion of the VAR and structural VAR methodology as employed in the paper; section 4 outlines structure of the VAR model and the description of the variables included in the model; section 5 presents empirical results and their discussion and section 6 concludes.

2. Review of Literature

2.1 Effects of Monetary Policy Shocks: The Recursive Approach

Much of the work on identification of monetary policy shocks has centred on U.S. economy. The studies could be classified on the basis of policy instruments, whose innovations could be called monetary policy shocks. McCallum (1983) and Bernanke and Blinder (1992) chose federal funds rate to be the monetary policy instrument. Bernanke and Blinder (1992) found that the funds rate is the good indicator of monetary policy actions and is superior to both monetary aggregates and other interest rates in the economy. In their framework nonpolicy variables (output, price etc.) are ordered before the policy variables (money supply, interest rates etc.). Their study highlights the stylized fact that nominal interest rates are good forecasters of real variables in the economy.[8]

[8] They found that federal funds rate as the best informative variable.

Another set of studies, by Eichenbaum (1992) and Christiano and Eichenbaum (1992) suggested that innovations to non-borrowed reserves primarily reflect shocks to monetary policy, while innovations to broader monetary aggregates reflect shock to money demand. Strogin (1995) suggested a new measure to identify monetary policy shocks. He argued that the main difficulty in identifying monetary policy from monetary aggregate is that a significant portion of the variance in reserve data is due to the Federal Reserve's accommodation of innovations in the demand for reserves rather than policy induced supply innovations. He utilized the linear representation of the Federal Reserve's operating procedures, which include both the level of total reserves and the mix of borrowed and non-borrowed reserves supplied by the Federal Reserve to identify exogenous disturbance to monetary policy net of accommodation.

The next important question in the literature on monetary policy shocks is the effect of these shocks on various aspects of the real economy. Bernanke and Blinder (1992) found that monetary transmission works partly by affecting bank assets (loans) as well as bank liabilities (deposits). Christiano and Eichenbaum (1995) analyzed the liquidity effects of monetary policy shocks for the US economy and found that conventional wisdom holds. This means that unanticipated expansionary monetary policy shocks cause a persistent decrease in real and nominal interest rates. Gertler and Gilchrist (1994) analyzed the response of small versus large manufacturing firms to monetary policy for the U.S. economy. They tried to investigate how financial factors stemming from the presence of capital market imperfections may enhance the effect of monetary policy. They also make use of the innovations in the federal funds rate to identify monetary policy disturbances. Their identification approach again was based on the fact that monetary policy may adjust to current movements in output and inflation but its effects operate with a lag.

Eichenbaum and Evans (1995) extended the interest rate effects of monetary policy in closed economy settings to an open economy setting. They investigated the effects of U.S. monetary policy shocks on the exchange rate. In their identification scheme, like Gertler and Gilchrist (1994), the monetary policy variable is set after looking at output and inflation while these variables in turn react to monetary policy with a lag. They found that contractionary shock to U.S. monetary policy led to a sharp persistent appreciation of U.S. nominal and real exchange rate and also a sharp persistent decrease between foreign and U.S. interest rates. Their finding challenged the predictions of international Real Business Cycle (RBC) models in which money is introduced simply by adding a cash-in-advance constraint or playing a transaction role.

Christiano, Eichenbaum and Evans (1996), assess the impact of a monetary policy shock on the net funds raised by the different sectors of the economy. They found that following a contractionary shock to monetary policy, net funds raised in the financial market by the business sector increases for a year and after that the recession induced by the policy shock gains momentum and the net funds raised by business sector begins to fall. They argued that existing models of business cycle fails to capture this fact. This implies that frictions embodied in these models are not sufficient to take account of the fact of the rise in net funds by the business sector after a contractionary monetary policy shock. Thus these models provide incomplete explanation of the monetary transmission mechanism.

2.2 Effects of Monetary Policy Shocks: The Non-Recursive Approach

The approach to identify the effects of monetary policy shocks assuming recursiveness corresponds to a notion that economic variables within certain period are determined in a block recursive way. This implies that variables denoting a 'Goods Market'(non policy variables like output, employment, prices etc) are determined first, then the central bank sets its policy instrument and after that the remaining variables in the money market (policy variables like interest rates, credit money supply etc) are determined. Thus abandoning the recursiveness assumption implies dropping the assumption that the central bank only looks at the variables that are predetermined relative to monetary policy shock.

Sims (1986) argued that VAR models can be used for policy analysis. He explains that any decision making model employs some identifying assumptions but these identifying assumptions in econometric policy making models are not certain. The VAR models have the advantage of modelling the uncertainty embedded in their identifying assumptions. He examined a six variable quarterly post-war model of the U.S. economy. He presented two different identifications of this VAR system. The first identification hinges upon the idea that the monetary authority and the banks can see interest rates and indicators of movements in monetary aggregates immediately but can react to remaining variables in the economy after a delay. The main identifying restriction imposed on the model is that money stock innovations enter only in money supply and demand and monetary shock affects other variables in the system only via interest rate. In the next alternative identifying scheme money stock innovations are allowed to enter the price equation. This restriction means the disturbances coming from the price equation can be interpreted as money demand shocks. Sims work showed that simple extension of Wold causal chain ordering could give important insights about the dynamics of the structure of the economy. He also commented that the inferences from conventional macroeconometric modelling, which ignores the endogenity of policy instruments, are likely to be misleading.

Gorden and Leeper (1994) argued that the empirical research about the dynamic impact of monetary policy is based on some extreme economic assumptions of elasticity of supply and demand functions of reserves when policy shocks are identified with innovations in reserves or the short-term nominal interest rate. These assumptions require researchers to treat either reserves or interest rates as predetermined. This avoids the problem of modelling both policy and private behaviour simultaneously as the result of supply and demand interactions. They estimated the behaviour of the monetary authority and financial institutions in separate models for the reserve market and M2 market. The model identifies monetary policy shocks that generate dynamic responses of variables in line with the predictions of traditional monetary analysis. An expansionary monetary policy shock shifts the supply curve of reserves upward but keeps the demand curve unchanged. Thus the short-term interest rate falls (a liquidity effect); monetary aggregates, price level output rise and unemployment falls.

Sims and Zha (1998) assumed that there are no predetermined variables in monetary authorities' reaction function. The only contemporaneous variables which Fed sees while setting its policy instrument (S_t) are a producer's price index for crude materials and monetary aggregate. In contrast, Leeper, Sims and Zha (1996) assumed that not all the variables that central bank looks at while setting its policy instrument are predetermined but the subset of goods market variables are predetermined. They estimated VAR models of various dimensions[9]. They concluded, "Most movements in monetary policy instruments are responses to the state of the economy, not random deviations from the usual patterns of behaviour of the monetary authorities" Leeper, Sims and Zha (1996 p.58). VAR analysis of monetary policy has encountered some empirical puzzles which are in conflict with the

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[9] For details of the identification restrictions, refer to Leeper, E.M., Sims, C.A. And Zha, T.(1996)

theories of monetary transmission. In the next few subsections, we will outline the main puzzles and their possible solution as proposed in the literature.

2.3 Effects of Monetary Policy Shocks: Some Puzzles in the Literature

The empirical literature that has dealt with the effects of monetary policy shocks has found evidence of several anomalies in both open and closed economy settings. These puzzles as summarized by Kim and Roubini (2000 p.562) are as follows[10]:

- *The liquidity puzzle.* When monetary policy shocks are identified as innovations in monetary aggregates (such as M0, M1 and M2), such innovations appear to be associated with increases rather than decreases in nominal interest rates.
- *The price puzzle.* When monetary policy shocks are identified with innovations in interest rates, the responses of output and money supply are correct as a monetary tightening (an increase in interest rates) is associated with a fall in the money supply and output. However, the response of the price level is wrong as monetary tightening associated with an increase in the price level rather than a decrease.
- *The exchange rate puzzle.* While a positive innovation in interest rates in the United States is associated with an impact appreciation of the US $ relative to the other G-7 currencies, such monetary contraction in the other G-7 countries are often associated with an impact depreciation of their currency relative to US $.
- *The forward discount bias puzzle.* If the uncovered interest parity holds, a positive innovation in domestic interest rates relative to foreign ones should lead to a persistent depreciation of the domestic currency over time after the impact appreciation, as the positive interest rate differential implies an expected depreciation of the currency. However, the evidence suggests that positive interest differentials on domestic assets are associated with persistent appreciations of the domestic currency (for periods up to two years after the initial monetary policy shock).

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[10] For a discussion of the literature that has encountered the mentioned puzzles and their possible solution refers to Kim and Roubini (2000).

Many studies in the empirical literature have attempted to deal with these puzzles and provided suggestions to explain them. Sims (1992) suggested that innovations in the short-term interest rate are a better indicator of change in monetary policy, as monetary aggregates may not currently represent changes in monetary policy in the presence of demand shocks. But this suggestion led to the price puzzle. Sims conjectured that evidence of the price puzzle might be explained by the fact that the information set of the central bank while setting up its policy instrument does not contain information on future inflation. Christiano, Eichenbaum and Evans (1996) and Sims and Zha (1998) showed that the inclusion of current and lagged values of commodity prices in the Fed's information set was able to solve the price puzzle.

Grilli and Roubini (1995) attempted to explain and solve the exchange rate puzzle for non U.S. G-7 countries. Their explanation of the exchange rate puzzle for non U.S. G-7 countries was similar to that of Sims' explanation for solving the price puzzle for the U.S. They suggested that the inclusion of a better proxy for expected inflation might be helpful in solving the exchange rate puzzle. They suggested, "Movements in long term interest rates might be capturing quite well agent's expectations about long term inflationary trends. Then, a good proxy of the degree of tightness of monetary policy might be the differential between short-term and long-term interest rates" Grilli and Roubini (1995 p.6). The substitution of short-term interest rate with the differential between the short and long-term interest rate was able to solve the exchange rate puzzle for non U.S. G-7 countries[11] in their 7 variable VAR system.

Cushman and Zha (1997), on the other hand, argued that puzzling response of various macro economic variables like exchange rate to interest rate innovations in non U.S. G-7 countries is due to the fact that their economic structure is different from U.S. economy as they are smaller compared to the U.S. economy. Thus the identification scheme of monetary policy for these economies should account for it. They estimated a structural VAR model which incorporates the features of a small open economy. They applied this model to Canadian economy and identified monetary policy shocks, which are consistent with standard theory and highlight the exchange rate as a transmission channel.

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[11] Exchange rate puzzle was solved for France, Germany, Japan, Canada and the UK but not for Italy.

Kim and Roubini (2000) extended the structural VAR approach of Sims and Zha (1995) to an open economy. Their identification was successful in solving the liquidity and exchange rate puzzle and also the forward discount bias puzzle to some extent for non U.S. G-7 countries. They assumed that the monetary authority sets the interest rate after observing the current values of money, the exchange rate and the world price of oil but not the current values of output, price level and U.S. federal funds rate. They assumed a conventional money demand function where demand for money depends on real income and nominal interest rate. World price of oil and U.S interest rate are made contemporaneously exogenous to any variable in the domestic economy. Exchange rate is assumed to be contemporaneously affected by all the variables in the system. Their identification scheme was able to produce monetary impulses, which do not exhibit price and exchange rate puzzle.

After discussing briefly the empirical anomalies and their possible solution, we moved to the studies on Indian economy in this regard. Though, the monetary policy effects were not extensively explored for Indian economy, some studies deserved to be mentioned.

2.4 Studies on Monetary Policy in India

The existing literature on identification of monetary policy shocks and its impact on the Indian economy is limited[12]. However, there are some studies available which remotely dealt with the subject. Singh and Kalirajan (2006), for example, modelled the RBI policy reaction function to see how policy stance decisions[13] respond to the changes in goal variables; namely, output, inflation and the exchange rate. They found that the transmission effects of the RBI's policy stances on the goal variables are not very effective. They suggested that RBI should not be simultaneously working with instruments of quantity and price control. It should concentrate more on price variables for conducting monetary policy with effective interest rate as the main policy instrument.

Singh and Kalirajan (2007) argue that monetary policy in India is undergoing various transformations in the post reform period. The conventional instruments of price and quantity control of monetary transmission are losing their significance. There is a need for the RBI to

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[12] For literature on inflation targeting as a monetary policy option for India, refer to Mishra and Mishra (2009).
[13] For details on policy instruments and modelling of reaction functions, refer to Singh and Kalirajan (2006).

position itself for a more sophisticated root of monetary transmission. Authors tried to evaluate the effectiveness of interest rate channel of monetary transmission in the post liberalised Indian economy. They suggested the long run relationship and the short run dynamics support important role for the interest rate.

Mohan (2008), surveying the monetary policy transmission for India, suggested that monetary policy impulses impact prices and output through interest rate and exchange rate movements along with the monetary and credit aggregates. He further suggested that emerging market economies like India should allow greater flexibility for the exchange rate and, at the same time, maintain an adequate level of foreign exchange reserves in view of the volatility observed in international capital flows.

There are also a few descriptive studies available which deal with the issues of monetary policy formulation (for e.g., Rangarajan (2001), Vasudevan (2002) among others), limitations and constraints in pursuing monetary policy objectives (for e.g., Kanagasabapathy (2001) among others) and challenges faced by monetary policy due to increasing financial market reforms and growing linkages to the world economy (for e.g., Ramchandran (2000), Nachane (2005).

3. Methodology

The monetary policy shock is identified as the disturbance term in an equation of the form

$$S_t = f(\Omega_t) + \sigma_s \varepsilon_t^s \qquad (1)$$

Here S_t is the instrument of monetary policy and f is a linear function that relates S_t to the information set Ω_t. The random variable $\sigma_s \varepsilon_t^s$ is a monetary policy shock.

3.1 Vector Autoregression

A VAR is a convenient device for summarizing first and second order moment properties of the data. The basic problem with VAR is that a given set of second moments is consistent with many such dynamic response functions. Solving this problem amounts to making explicit assumptions that justify focusing on a particular dynamic response function. A VAR for a k-dimensional vector of variables Y_t, is given by

$$Y_t = A_1 Y_{(t-1)} + A_2 Y_{(t-2)} + \cdots \dots \dots \dots \dots \dots \dots \dots A_p Y_{(t-p)} + \mu_t, E\mu_t\mu_t' = \Sigma \ (2)$$

Here, p is a nonnegative integer and μ_t is uncorrelated with all variables dated (t-1) and earlier. Knowing A_i^s, the $\mu_t's$ and Σ are not sufficient to compute the dynamic response function of Y_t to the fundamental economic shock in the economy. The basic reason is that μ_t is the one step ahead forecast error in Y_t . Each element of μ_t reflects the effect of all the fundamental economic shocks. There is no reason to presume that any element of μ_t corresponds to a particular economic shock, for example, a monetary policy shock.

This shortcoming can be overcome by rewriting (2) in terms of mutually uncorrelated innovations. Suppose we had a matrix P such that $\Sigma = PP'$. If we had such a P, then $P^{-1}\Sigma P'^{-1} = I_k$. This implies that P can be used to orthogonalize μ_t. Choosing P is similar to placing identification restrictions on the system of dynamic simultaneous equations. Sims (1980) popularized the method of choosing P to be the Cholesky decomposition of Σ. The impulse response functions based on this choice of P are known as the orthogonalized impulse response functions. Choosing P to be the Cholesky decomposition of Σ is equivalent to imposing a recursive structure for the corresponding dynamic structural equation model.

3.3 Structural Vector Autoregression

An alternative to the recursive VAR or temporal ordering of variables is to allow for a more elaborate set of restrictions guided by economic theory. This is referred to as a structural VAR (SVAR). The SVAR approach integrates the need to identify the causal impulse response functions into the model specification and estimation process. Sufficient identification restrictions can be obtained by placing either short run or long run restrictions on the model. In this exercise we are going to make use of the structural autoregression with short run restrictions. The short run SVAR model (following from equation2) can be written as:

$$A(Y_t - A_1 Y_{(t-1)} \dots\dots\dots\dots\dots\dots\dots\dots - A_p Y_{(t-p)} = \mu_t = Be_t \qquad (3)$$

Here, A and B are KXK non-singular matrices of parameters to be estimated and e_t is a KX1 vector of disturbances for all s≠t. Sufficient constraints must be placed on A and B so that P is identified. The short run SVAR model chooses $P = A^{-1}B$ to identify causal impulse response functions.

4. Data and Variables

The model used in this paper assumes that it is sufficient to identify monetary policy shocks. Eight variables are chosen to explain all-possible interrelations between the policy and non-policy variables. The eight variables included in the model consist of two foreign variables and six domestic variables. These form two blocks in the model; one is the foreign block with two variables and next is the domestic block with six variables. The foreign variables are block exogenous to the system. It implies that domestic variables are not entering into the equations of foreign variables either contemporaneously or with a lag. This assumption is made due to the small size of the Indian economy relative to the world economy, which makes it unlikely that domestic variables can explain movements in foreign variables either contemporaneously or with a lag.

The data for the domestic variables has been collected from the, *'Handbook of Statistics on the Indian economy, 2005'* an annual publication of the RBI. For crude oil prices data has been sourced from the IMF (*http://www.imf.org/external/np/res/commod/datar.csv*) and the data for federal funds rate (a proxy for foreign interest rate) is taken from the Federal Reserve Bank of New-York (*http://www.newyorkfed.org/*). The period of analysis for this exercise covers from 1996 January to 2005 March[14].

4.1 Variables Included in the Model

The foreign variables included in the model are oil prices and the federal funds rate. The oil prices are crude oil prices and this is the simple average of three spot prices; Dated Brent, West Texas Intermediate and the Dubai Fateh. The federal funds rate is taken as a proxy for international interest rates. The domestic variables included in the model are three non-policy variables and three policy variables. Non-policy variables are inflation (measured by a rate of change in wholesale price index (WPI)), output (measured by index of industrial production (IIP)), exchange rate (as measured by nominal effective exchange rate (NEER)), monetary policy instrument, gross bank credit (GBC) and broad monetary aggregate (M3). The growth rate of reserve money (M0) and the call money rate (CMR) are used as monetary policy instruments (MPI). The yield of SGL transactions on treasury bills of 91 days (91 day Treasury bill rate) has also been tried as a monetary policy instrument.

4.2 Structure of the Model

The following identification structure has been used to isolate monetary policy shocks:

$$X_t = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 & 0 \\ a_{81} & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & 1 \end{pmatrix} \begin{pmatrix} oil \\ ffrate \\ inf \\ y \\ neer \\ mp \\ bc \\ m3 \end{pmatrix}$$

[14] This period is chosen because the macro-stabilization program undertaken after the balance-of-payment crisis in 1991 started to show its effect after 1995. And this period was a stable and normal period for formulating an economic model.

This characterizes the restrictions placed on the contemporaneous relationships among variables. Here, 'oil' is the world oil prices, 'ffrate' is the federal funds rate, 'inf' is WPI inflation, 'y' is output as measured by IIP, 'neer' is NEER, 'mp' is the monetary policy instrument, 'bc' is gross bank credit and 'm3'is broad monetary aggregate. The growth rate of reserve money (M0) and the call money rate (CMR) have been used as monetary policy instruments. Here, oil and ffrate form the foreign block and the remaining variables form the domestic block. In the domestic block inflation (inf), output (y) and the nominal effective exchange rate (neer) form the non-policy block and monetary policy instrument, gross bank credit (bc) and broad monetary aggregate (m3) form the policy block.

The non-zero coefficients a_{ij} in the above structure indicate that variable 'j' affects variable 'i' instantaneously. The coefficients on the diagonal are normalized to 1. The system is exactly identified. The international shocks can affect the domestic economy rapidly. Thus, the foreign block variables have an instant effect on all the variables in the domestic block. Output is made to respond to inflation contemporaneously[15]. The 'monetary policy instrument' equation reflects that it has been set after looking at current values of inflation, output and exchange rate. This assumption is valid for a developing economy like India, where central bank has multiple objectives. Unlike the structure followed for a developed economy (as in Sims and Zha (1995) or Kim and Roubini (2000)) where the exchange rate is considered to be a financial variable and assumed to be affected by all the variables instead of affecting them contemporaneously, in a developing economy central bankers are concerned about movements in exchange rate and take quick actions to smooth out fluctuations. Credit and M3 are placed in a policy block after the monetary policy instrument and are assumed to react to monetary policy instrument contemporaneously.

4.2 Pure Inflation Targeting Case

In the above-described model, the Reserve Bank's monetary policy reaction function is represented by the 'mp' equation. This has been made to react contemporaneously to shocks

[15] This assumption is motivated by the fact that nominal incomes are fixed in the short-run, meaning so is nominal spending.

in inflation, output and the exchange rate. This is more in line with the 'multiple indicator approach' currently followed by the RBI. To put the case of pure inflation targeting in the above structure, we allow only inflation to enter in the monetary policy reaction function as represented by the 'mp' equation. Thus the contemporaneous restriction matrix has been modified in the following way for the pure inflation targeting scenario:

$$X_t = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & 0 & 0 & 1 & 0 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & a_{76} & 1 & 0 \\ a_{81} & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & 1 \end{pmatrix} \begin{pmatrix} oil \\ ffrate \\ inf \\ y \\ neer \\ mp \\ bc \\ m3 \end{pmatrix}$$

In this scenario while setting up the 'monetary policy' instrument the RBI looks at only inflation. However these restrictions are only on the contemporaneous coefficients and this does not prevent the central bank responding to other variables with a lag.

5. Empirical Results and Discussion

All the series, other than interest rates, are taken at the 1993-94 base period and converted to their natural logarithms. In each equation of the VAR model, a full set of monthly dummies have been included to take care of deterministic seasonality. The VAR models are estimated via *Iterated Seemingly Unrelated Regression* (ISUR). The standard errors for impulse responses and forecast error variance decompositions are obtained via bootstrapping.

5.1. Stationarity Tests

We performed the Augmented Dicky Fuller (ADF) test and Phillips Perron (PP) for the presence of unit roots in the series.[16] The number of lagged difference terms included in testing for a unit root in each series has been decided on the basis of no autocorrelation in the error terms for the ADF tests. For the PP tests lags are selected on the basis of the Newey-West criterion. These tests suggest that all the variables other than the call money rate (and

[16] These results of these tests are given in Table A.1 and A.2 in Appendix section.

91 days treasury bill rate) contain a unit root. Thus, we used the first difference of the variables. Since all the variables other than the interest rate variables (ffrate, cmr and 91 Treasury bill rate) are converted to their natural logarithms, the resulting series after first difference are the growth rates. The variables entering into the estimation are: oil price inflation, change in ffrate, domestic (or WPI) inflation, growth of output, appreciation of neer, growth of reserve money (gm0) or the call money rate (CMR) as monetary policy instrument variables, growth of bank credit (gbc) and M3 growth (gm3). The appropriate lag length for the VAR model estimated has been decided on the basis of Akaike's Information criterion (AIC).[17] The number of lags included in the VAR model is two.

5.2 Results from Benchmark Identification

Figure 1 presents the impulse response functions of domestic variables to one standard deviation (s.d.) positive shock in M0 growth while figure 2 shows impulse response functions of domestic variables to one s.d. CMR shocks. Monetary policy shock, as identified by M0 growth shock, gives the price puzzle as given positive shock to M0 growth there is a fall in inflation. And for output, there is a small rise for two months it then starts falling. The exchange rate also gives a puzzling result as a positive innovation in M0 growth leads to an appreciating exchange rate. The credit and M3 growth rise following M0 growth shock for approx. four months before falling. After the fall, credit and M3 growth again rise for almost two months before the effect of positive shock in M0 growth on them dies down.

Insert Figure 1 here

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[17] It has to be noted that after fitting the VAR with lags as selected by the AIC criterion, the LM test for autocorrelation in the VAR residuals has been performed and if residuals are found to be autocorrelated at that number of lags, the number of lags has been increased to remove autocorrelation in the residuals.

The model with the CMR as monetary policy instrument gives theoretically consistent results for the major economic variables to one s.d. positive shock in monetary policy instrument (CMR). There is an immediate fall in inflation and output following a positive CMR shock. The price puzzle, which emerges when monetary policy shocks are identified by M0 growth shock, vanishes when monetary policy shocks are taken as shocks to the interest rate (CMR). The behaviour of exchange rate is also in line with the theory (unlike the model with M0 growth as monetary policy instrument) as a positive innovation to interest rate leads to a rise in (appreciation) of the exchange rate. This gives evidence in support of the fact that the rate variable is more appropriately signalling the stance of monetary policy than the quantity variable.

Insert Figure 2 here

Table 2 presents the Forecast Error Variance Decompositions (FEVDs) for the model in which CMR is used as monetary policy instrument[18]. The results of FEVD for inflation show that *neer* is playing an important secondary role in explaining movements in inflation. This indicates the sensitivity of domestic inflation to external fluctuations, outside fluctuations, as indicated by shocks to *neer*, are playing an important role in determining inflation. Inflation is affected less by output shocks and more by oil shocks as oil shocks explain almost 10% of volatility in inflation at a forecasting horizon of a year. This shows that cost-push factors (supply side factors) are more important driving inflation than demand-pull factors (demand side factors). Variations in *neer* are largely explained by its own shocks. The result for bank credit shows that it is becoming more responsive to shocks in the interest rate compared to the level of economic activity as proxies by output. This suggests the rising sensitivity of credit to interest rates than to incomes. Exchange rate shocks are playing an important role in explaining variations in credit and M3 growth. This result supports the rising importance of the exchange rate channel in the economy.

[18] Since, model with interest rate (CMR) gives theoretically consistent results for impulse responses; we have included FEVDs from this model due to space constraints.

Insert Table 2 here

We found that our benchmark identification with the interest rate as the monetary policy instrument gave meaningful results. It captured the changing monetary policy dynamics neatly. Estimated contemporaneous structural form coefficients from the VAR model (with the interest rate as the monetary policy instrument), as presented in Table 3, further justified the identification structure. The estimated contemporaneous structural coefficients supported the recursive identification, as the contemporaneous coefficients in their respective equations are significant. The coefficient on oil and the foreign interest rate enter positively and significantly in the inflation equation. This is indicative of quick pass through of outside factors to domestic inflation. These coefficients bring out some interesting facts about the institutional aspect of the Indian economy in the period after the mid 90s. First, the significant coefficients of oil and $ffrate$ in the 'inflation equation' support the fact that much of the WPI inflation is imported in nature. Second, since the oil coefficient is positive, it indicates the increase in international oil prices increases inflation immediately while the $ffrate$ coefficient is negative indicating that rise in the international interest rate is lowering inflation domestically. This result gives some important insights into the composition of the domestic money supply in India. Since, a higher interest rate abroad will result in capital outflow from the economy this will, in turn, reduce the domestic money supply and thus lower inflation. This provides evidence that capital inflows form a large part of domestic the money supply in India.

The significant negative coefficient of CMR in the 'gbc equation' implies credit is interest sensitive. This is in line with the theory that rise in the interest rate is leading to a fall in credit. Since the mid 1990s, the growth of M3 was mainly driven by bank credit to commercial sector and net foreign exchange assets of the banking sector; the significant and positive coefficient on gbc in $gm3$ equation captures this fact. Another interesting point is the positive coefficient on inflation in M3 growth equation. This again gives some indication about the nature of domestic inflation in India[19]. It suggests that inflation is governed mainly by supply side and external factors and this ‘cost push’ or supply side inflation may result in sluggishness in domestic activity and thus keeping in mind the growth objective of monetary policy, in response to a rise in inflation, there is an immediate increase in M3 to prevent aggregate demand from falling.

Insert Table 3 here

5.3 Comparison of the Benchmark Model with Pure Inflation Targeting Scenario

The results from benchmark model indicate that the identification strategy adopted here is able to capture the features of the Indian monetary policy well and produce theoretically consistent results. This allowed us to use this specification to analyze the hypothetical inflation targeting scenario and compare it with the current monetary policy procedure of the RBI. Figure 3 and Table 4 presents the impulse responses and FEVDs of model variables to monetary policy shocks in a hypothetical inflation targeting scenario as built in benchmark identification. The response of various variables to a positive interest rate shock in the ‘pure

[19] The fact that inflation in India was mainly supply side generated and imported in nature had been supported by the various arguments and analysis presented in various RBI publications from time to time. I have collected to few of them to support this argument. They are as following:

- The inflation rate came under pressure arising from a negative supply shock emanating from shortage of few food articles and food products………..” (Pg. No. VI –27, Report on currency and Finance 1998-99.)
- On an weighted average basis, the fuel group contributed the maximum to inflation during 2000-01(Pg.No. I-19, Report on currency and Finance1999-2000.)
- The inflation outcome was characterized by an absence of demand induced pressures.(Annual Report of RBI 2000-01)
- Reflecting the global situation, inflation in India firmed up in the last quarter of 2002-03, driven up by the hardening of international oil prices and supply side pressures on ion items like oil seeds, edible oils and oil cakes. (Annual Report of RBI 2002-03)
- With increasing globalization of the Indian economy, the pass through of international prices to domestic prices is becoming increasingly evident. (Annual Report of RBI 2003-04).

inflation targeting' case is not very different from the response in the 'multiple indicator approach'. This seems to imply that though not explicitly stated, but in the RBI's reaction function, inflation gets more weight compared to exchange rate and output. These results show operating procedure of monetary policy in India is towards inflation stabilization and informally along the lines of inflation targeting.

Insert Figure 3 here

Table 4 reveals the main changes in the interrelationship among variables in the pure inflation targeting scenario. There is a decrease in shocks to the exchange rate in explaining movements of inflation. Though the decrease is very marginal, it may be taken as slight evidence of insulation of inflation from external shocks in the pure inflation targeting case. Thus in the pure inflation targeting case the external shocks may lead to little less volatility of inflation compared to multiple indicator (MI) scenario.. Next, interesting point to note is that a little more variation in call money rate is explained by shocks to exchange rate and little less is explained by shocks to output in the pure inflation targeting case compared to MI scenario. Since, in this exercise monetary shocks are identified by call money rate shocks, this result may indicate that slightly more importance given to external fluctuations than to domestic activity in the pure inflation targeting case. And further, external shocks as proxied by exchange rate, are becoming a little more important in explaining variation in the growth of gross bank credit in the pure inflation targeting case.

Insert Table 4 here

These two scenarios are further compared using contemporaneous restriction matrices and resulting contemporaneous structural coefficients in both cases. These statistics present some interesting insights to the operation of monetary policy in the two alternate scenarios. The contemporaneous restriction matrices indicate that the 'CMR coefficient' is marginally higher in pure inflation targeting case than in the MI case. But this sharper response gets moderated since it depreciates the exchange rate with a lag as the impulse responses show and the resulting depreciation in exchange rate increases inflation with a lag. Further, in the pure inflation targeting case the value of the contemporaneous coefficient of $neer$ is higher in the equation of bc (bank credit) and $gm3$ (M3 growth) and this highlights the importance of the exchange rate channel in 'open economy inflation targeting'.

Insert Table 5, Table 6, Table 7 and Table 8 here

5.4 Monetary Policy Shocks as Estimated from the Benchmark Model

We found that monetary policy shocks as indicated by 'CMR fluctuations[20]' conformed to the historically observed fluctuations in it and thus, this model could be considered as a good approximation of reality. Figure 4 presents the estimated monetary policy shocks from the model. The figure showed that the period from late 1996 to late 1997 was characterized by loose monetary policy and we observed historically that the period of late 1996 to late 1997 was characterized by excess liquidity in the economy mainly due to the reduction in the Cash Reserve Ratio (CRR)[21], the Reserve Bank's intervention in the forex market in the form of dollar purchases, an upsurge in bank deposits and sluggish growth in non-food credit. However, due to the continuing volatility in the foreign exchange market in the wake of the South- East Asian Crisis, the Reserve Bank undertook a series of policy measures in early

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[20] CMR fluctuations highlight the overall financial sector' state in general and money market conditions in particular. The money market provides the institutional set-up for the transmission of monetary policy impulses. The central bank intervenes through this market to manage liquidity into the economy. Thus money market rates are the channel to transmit the impact of central bank's operations of liquidity management to the other rate variables associated with other segments of the financial markets. On the supply side, deposit mobilization, capital flows and Reserve Bank's operations affecting bank's reserve requirements influence these rates while on the demand side the main factors governing these rates are tax outflows, government borrowing programme, non food credit off take, seasonal fluctuations and large currency withdrawals. Against this background, we will analyze the 'estimated CMR shocks' from our model and its propensity to historical shocks.

[21] "Consistent with the medium term objectives and on a review of the monetary and credit situation, CRR to be maintained by Scheduled Commercial Banks (excluding Regional Rural Banks) was reduced by 2 percentage points from 12 % of their net demand and time liabilities to 10 % in 4 phases of 0.5% point each, effective from the fortnights beginning October 26, 1996, November 9, 1996, January 4, 1997 and January 18, 1997 respectively. Each percentage point reduction of CRR increased the lendable resources of banks by about Rs. 4,275 crore." *Report on Currency and Finance 1996-97, Chapter V 'Monetary and Banking Developments" page no V-21*

1998 to control liquidity and ease the pressure on the foreign exchange market. As a result, the fortnightly average CMR reached an historical high of 50% in the fortnight which ended January 30, 1998. This historical fact is supported by the estimated shocks from our model where we see a spike exactly in the same month. In the period from 1999 to 2000, the Indian economy faced challenges on several fronts. On the one side, there was acceleration in global output and trade due to the continuing strength of the U.S economy and sharp recovery of the Asian economy, but on the other side the gains from global economic recovery were eroded by a more than doubling in oil prices due to production curbs by OPEC. For oil importing country like India, this oil price surge translated into inflationary pressure and constriction of import purchasing power. During this period monetary policy remained mainly tight due to inflation considerations and also the sporadic volatility of the foreign exchange market. This is also indicated by the graph of CMR shocks. The 'repo rate' reduction in October 30, 2002 brought down the call money rate as also evident from the figure. The period of 2002-03 was characterized by ample liquidity in the economy due to sustained accretions of capital inflows, contraction in food credit and liquidity overhang. Monetary policy was mainly loose and this is also indicated in the figure. The period of 2003-2004 was a period of uncertainty for financial markets due rising oil prices and their impact on inflation and growth. There was an increase in interest rates from record lows as seen in 2003-04 due to the international trends and rise in inflation. This slight reversal in trend has also been observed in our estimated shocks.

Insert Figure 4 Here

The monetary policy shocks, as proxies by CMR shocks, estimated from the model correspond to the historical observed facts and thus support the identification structure imposed here. We also estimated the shock in the 'pure inflation targeting' scenario and discovered that if there would have been the 'pure inflation targeting' scenario the monetary policy shocks would be sharper.[22] This is in line with our earlier findings. Figure 5 presents

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[22] As indicated by the decomposition matrices and contemporaneous structural coefficients.

the shocks as estimated in both the scenarios. The figure 5[23] indicates higher or sharper monetary policy response in the 'pure inflation targeting case' to shocks. This is indicative of the greater autonomy and freedom of the Central bank to respond to shocks in an inflation targeting scenario to defend inflation target.

Insert Figure 5 Here

5.4 Robustness Analysis

In this section we will assess the robustness of our benchmark identification scheme to various perturbations. First we tried to impose various different identification schemes in our benchmark analysis. As a first experiment, we tried with changing the position of nominal effective exchange rate. We ordered it first in the domestic block and thus assuming that it is exogenous to the domestic economy and then also ordered it last assuming that it is a financial variable and being affected by all the other variables in the system. However, the change in the position of nominal effective exchange rate did not make any difference to our results. Thus our benchmark-identified model is robust to the position of nominal effective exchange rate. Then we experiment with the position of output and inflation in our benchmark model. We placed output before inflation to see how this will affect our results. Our identification turned out to be robust to the position of inflation and output also and this does not affect our results.

Lastly, we ordered credit before monetary policy variable making the monetary policy variable to react to credit instantly.[24] In this identification, we ordered credit first in the domestic block. In this identification structure, there was not much change in the response of inflation and the exchange rate to monetary policy shock but the response of output to a monetary policy shock becomes more volatile and an initial fall in output due to a positive

[23] It has to be noted that the difference between the two series was too small to show graphically. Thus one series is plotted with a different intercept from the other. Thus figures on the Y-axis are only indicative and don't correspond to actual estimated shocks. This is just to portray graphically the sharper response in 'PIT' case.

[24] These results are available upon request.

interest rate shock is much sharper compared to the benchmark identification. The response of credit and M3 growth is also different from the benchmark identification. In the benchmark identification credit and M3 growth take almost 4 months to fall given a positive interest rate shock but in this case credit tends to rise for 3-5 months and then falls for a while before it dies down. In this case the M3 growth falls immediately following a positive interest rate shock and then rises for a while. The results of forecast error variance decompositions do not show much variation compared to the benchmark identification. However it is worth noticing that in this identification credit is explaining much of the variation in the CMR while the CMR is explaining less of the variation in bank credit. This seems counter intuitive as in the Indian economy, the credit demand becomes quite sensitive to interest rate movements from the mid 1990s and theoretically also this result seems inconsistent as growth of credit is supposed to be influenced by interest rate movements.

We also used the yield on the 91-day treasury bill rate as a monetary policy instrument. The use of the 91-day treasury bill rate gave some puzzling results with respect to output and the exchange rate. This is indicative of the fact that in the period considered here, the monetary policy stance of the RBI was the provision of adequate liquidity to meet credit growth and support investment demand and also to keep vigil on the prices and exchange rate. Thus, the RBI mainly influences liquidity in the economy to achieve the mentioned objectives. To influence liquidity the RBI intervenes through the money market, thus money market rates are better indicator of the stance of the monetary policy.

6. Conclusions

This paper builds a short-run Vector Autoregression model of monetary policy for India. The RBI's reaction function or feedback rule to changes in the foreign shocks and non policy variables determines the setting of the policy instrument variable. In the base-case scenario, the monetary policy instrument is set after looking at current values of inflation, output and exchange rate. This is more in line with the 'multiple indicator' approach followed by the RBI. The model with interest rate as monetary policy instrument behaved consistently. Responses to monetary shock are in directions suggested by theory and thus, it can be considered as a good approximation of reality. Therefore in the above structure, we put in the case of 'pure inflation targeting' to see how hypothetical inflation targeting regime would work for India. For this, we made monetary policy instrument to react only to inflation contemporaneously or in other words, monetary policy instrument is set after looking at current values of inflation only. The hypothetical inflation targeting regime suggests sharper response of interest rate to shocks. Further, in this scenario exchange rate becomes more important in explaining fluctuations in gross bank credit and M3 growth and thus highlights more use of exchange rate channel of monetary transmission in this scenario. There is also some evidence that this scenario may bring little insulation of domestic inflation from external shocks, i.e., external shocks may contribute less to the volatility of domestic inflation.

The VAR model also highlighted the determinants of inflation volatility in India since mid 1990s. Inflation in India is mainly affected by global supply factors and external fluctuations. Moreover, the pass through of these international shocks to domestic inflation is quite rapid as the estimated structural contemporaneous coefficient from VAR model showed.

This model also provided some useful insights about the theoretical framework for evolution of monetary policy in India. It suggested 'New Keynesian' framework with incorporation some form stickiness in the prices giving rise to non-neutral effects of monetary policy is needed to prepare the framework suitable for the evolution of monetary policy. Second, call money rate shocks gave theoretically consistent results for the major macro economic variables (output, inflation and exchange rate). This suggests that rate variables are better in signalling the stance of monetary policy for India than quantity variables and justifies the use of nominal interest rate as an instrument. Third, there is a growing importance of exchange rate channel in the transmission of monetary policy in India. The exchange rate shocks are playing central role in explaining the volatility of inflation, interest rate, growth of credit and money supply growth in India. Thus, exchange rate shocks and shocks originating from the rest of the world (transmitted through exchange rate) are important in conducting monetary policy and the model for evaluation of monetary policy should incorporate this.

The next interesting area for future research would be to develop the theoretical model for monetary policy in India incorporating the stylized facts as suggested by the VAR model in this exercise and use this for evaluating the inflation targeting monetary policy framework for India.

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<u>**Figures**</u>

Figure 1: Positive M0 Shock (Positive Monetary Shock) in a Benchmark Case

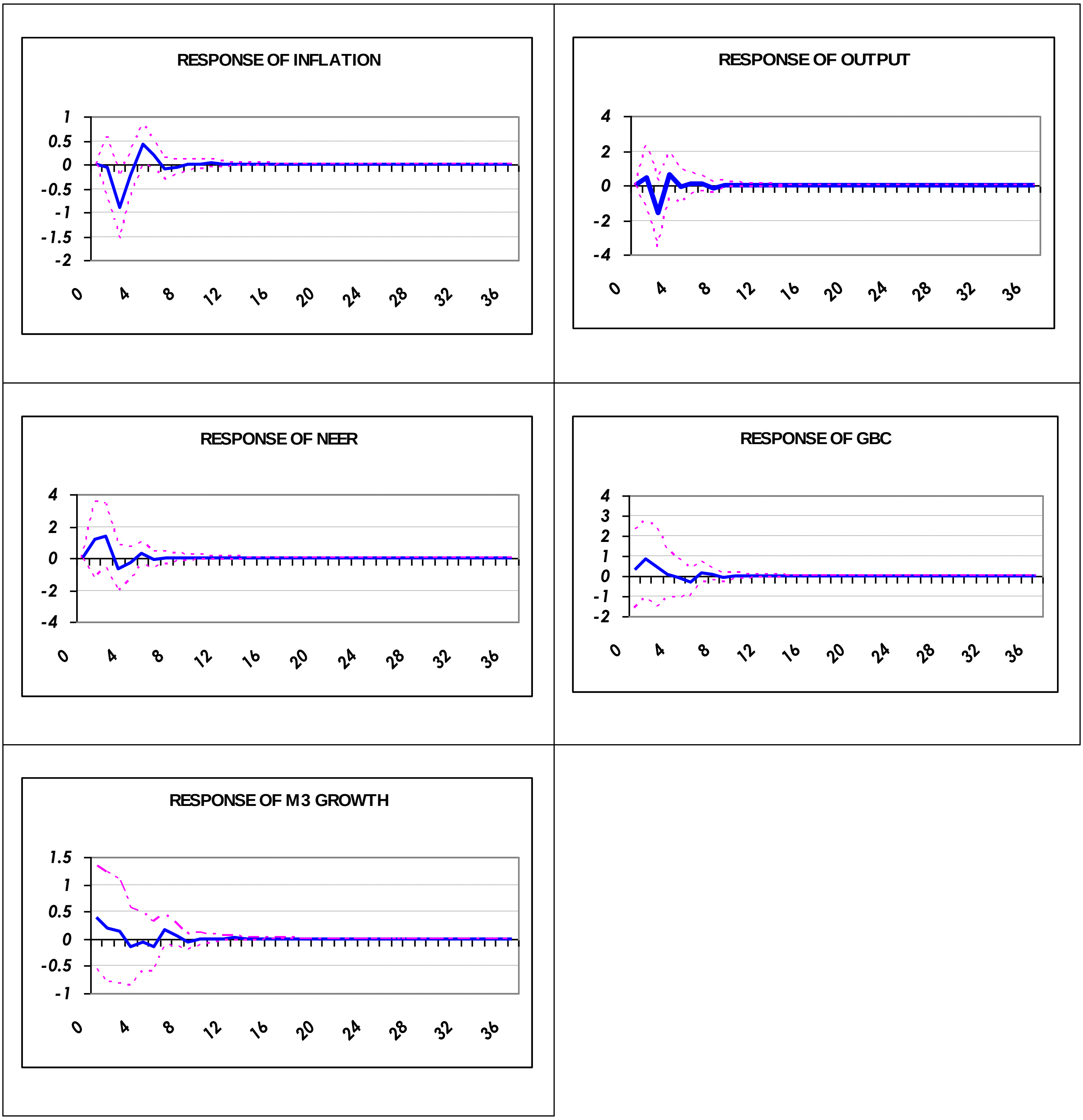


Figure 2: Positive CMR Shock (Negative Monetary Shock) in a Benchmark Case

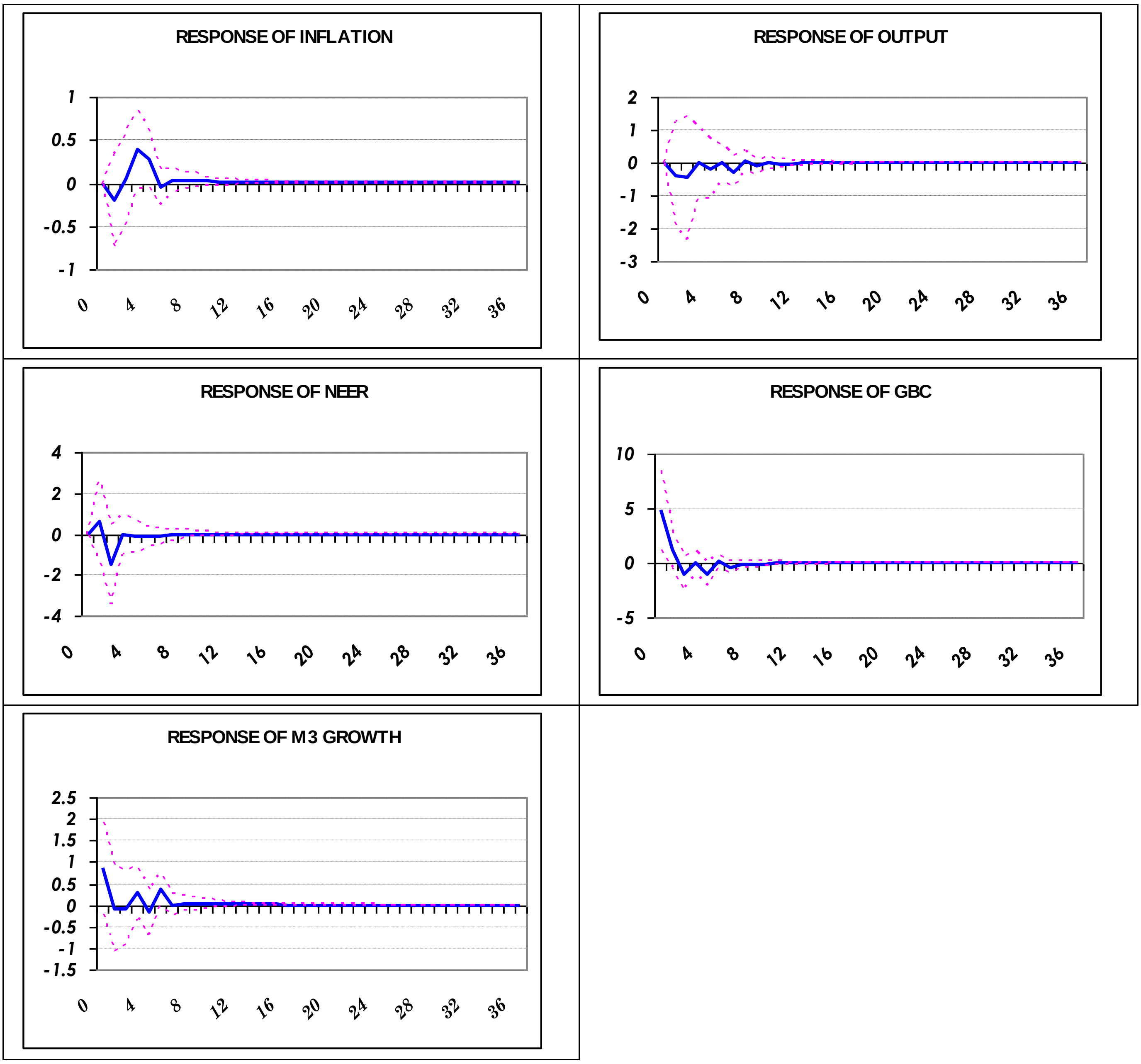


Figure 3: Positive CMR Shock (Negative Monetary Shock) in a Pure Inflation Targeting Case

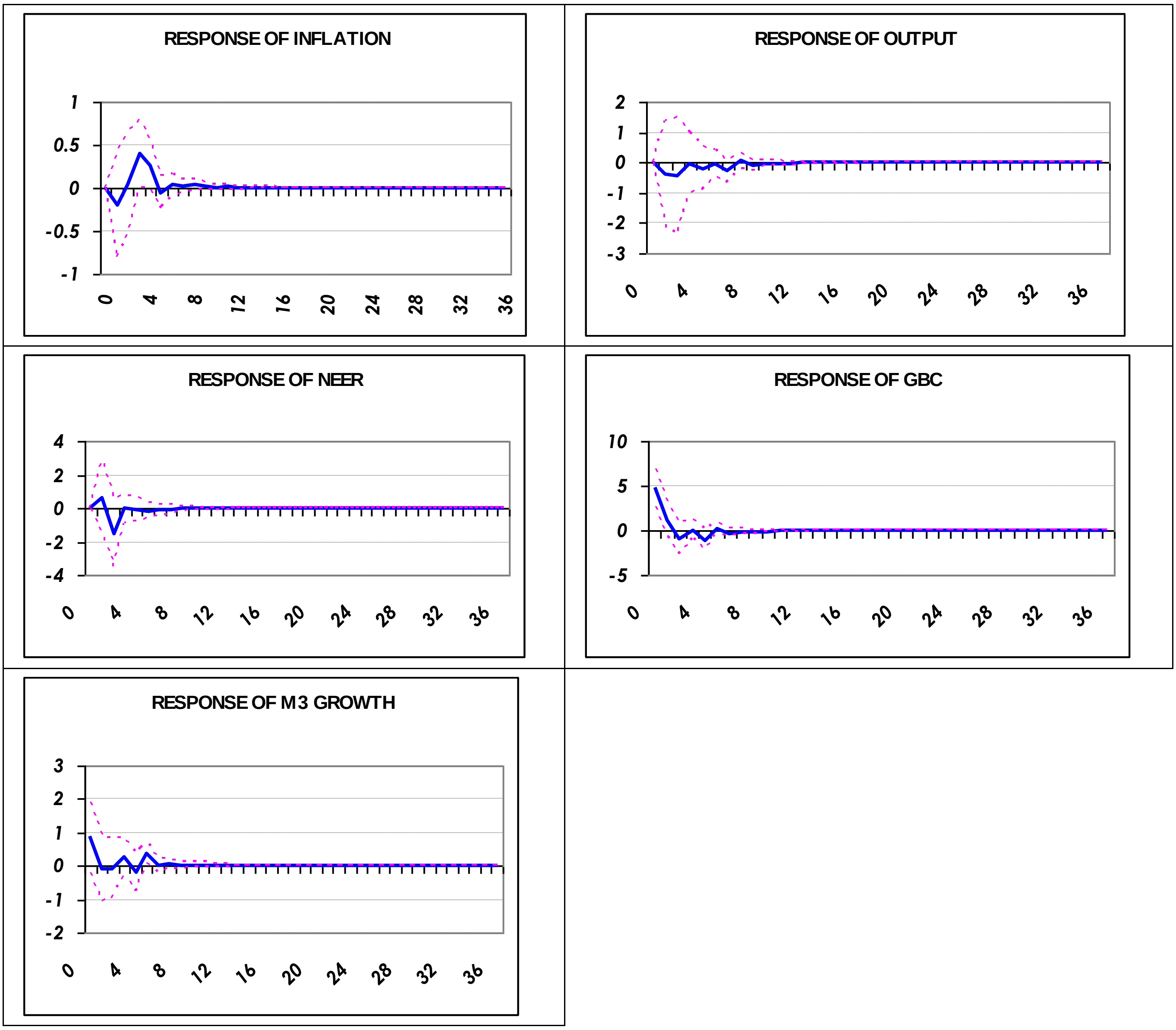


Figure 4: Estimated Monetary Policy Shocks in a Benchmark Case

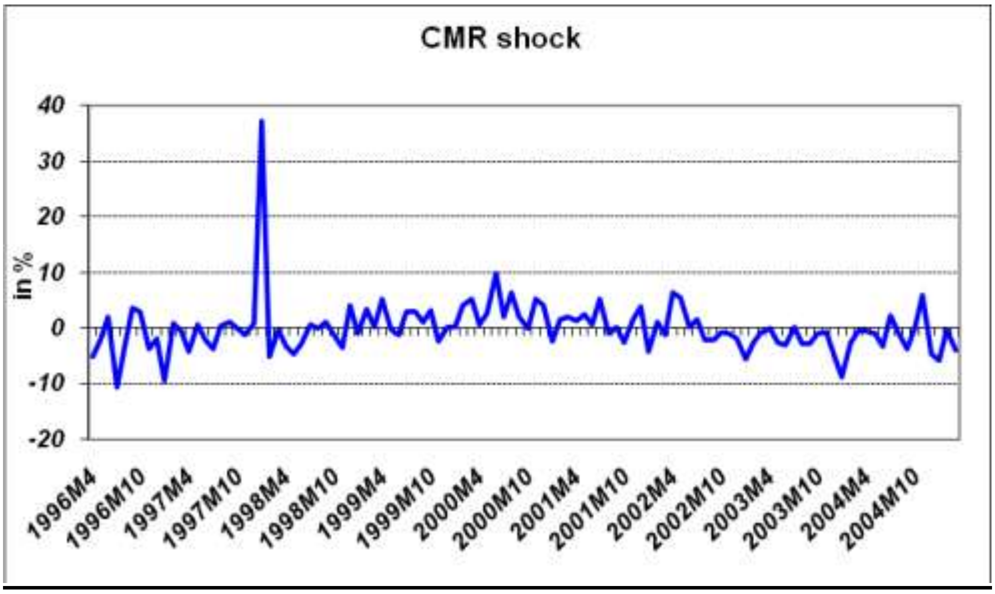
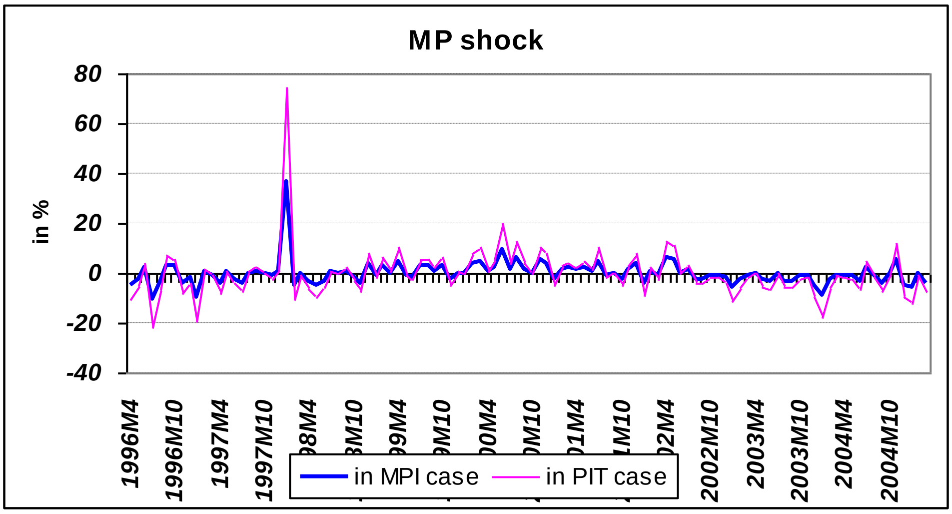


Figure 5: Estimated Monetary Policy Shocks in Pure Inflation Targeting Scenario



Tables

Table 2: Forecast Error Variance Decomposition in a Benchmark Case

(CMR as Monetary Policy Instrument)

Forecast Error Variance of Inflation as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	11.49(6.77)	5.05(4.83)	83.46(7.65)	0(0)	0(0)	0(0)	0(0)	0(0)
3	11.01(6.13)	8.01(5.32)	63.42(7.63)	0.56(1.51)	12.22(5.68)	0.2(0.88)	0.72(1.42)	3.88(2.54)
6	10.78(5.99)	8.11(5.08)	60.85(7.45)	0.94(1.62)	13.25(5.62)	1.16(1.38)	1.04(1.44)	3.87(2.41)
12	10.77(5.96)	8.38(5.24)	60.57(7.45)	0.95(1.62)	13.25(5.61)	1.17(1.39)	1.04(1.45)	3.87(2.42)

Forecast Error Variance of Output as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	1.87(3.83)	0.33(2.03)	0.32(1.93)	97.48(4.62)	0(0)	0(0)	0(0)	0(0)
3	2.52(4.29)	1.22(3.07)	2.98(3.84)	91.22(6.91)	0.79(2.52)	0.22(1.42)	0.97(2.01)	0.07(1.33)
6	2.58(4.15)	1.43(3.14)	2.98(3.63)	89.53(7.76)	1.48(2.93)	0.24(1.59)	1.61(2.86)	0.15(1.4)
12	2.58(4.12)	1.45(3.14)	2.98(3.61)	89.34(7.92)	1.56(3)	0.31(1.63)	1.63(2.88)	0.16(1.4)

Forecast Error Variance of NEER as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	1.73(4.23)	0.12(1.32)	2.35(4.23)	0.29(1.85)	95.51(5.63)	0(0)	0(0)	0(0)
3	2.64(4.07)	1.16(3.02)	2.67(3.54)	1.4(2.96)	87.21(7.32)	1.34(2.19)	1.75(2.33)	1.83(2.42)
6	2.69(3.99)	1.4(3.04)	2.74(3.45)	1.6(3.14)	86.39(7.7)	1.35(2.13)	1.99(2.34)	1.85(2.42)
12	2.69(3.97)	1.47(3.1)	2.74(3.43)	1.6(3.13)	86.29(7.73)	1.36(2.15)	1.99(2.33)	1.86(2.42)

Forecast Error Variance of CMR as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	1.33(3.81)	0.38(1.43)	0.28(1.94)	0.39(1.85)	0.52(1.85)	97.11(5.22)	0(0)	0(0)
3	1.56(3.97)	0.52(2.06)	2.51(4.05)	3.07(3.66)	6.13(5.97)	83.07(7.76)	2.85(3.01)	0.29(1.71)
6	1.64(3.83)	1.09(3.14)	2.78(4.18)	3.5(3.84)	6.25(5.92)	80.43(8.5)	3.35(3.27)	0.97(2.27)
12	1.62(3.83)	1.5(4.42)	2.81(4.14)	3.58(3.87)	6.29(5.95)	79.72(8.97)	3.44(3.39)	1.03(2.34)

Forecast Error Variance of GBC as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	0.02(2.25)	0.19(2.08)	0.01(1.54)	0.01(1.31)	0.04(1.81)	17.9(11.63)	81.7(11.59)	0(0)
3	0.07(2.9)	2.54(3.82)	1.62(2.27)	0.12(1.73)	7.98(5.17)	16.07(9.25)	71.26(8.91)	0.33(1.73)
6	0.83(2.95)	3.28(4.09)	1.55(2.09)	0.35(1.93)	9.78(5.3)	15.85(8.68)	67.82(8.54)	0.55(1.65)
12	0.88(2.96)	3.43(4.33)	1.56(2.08)	0.42(1.97)	9.78(5.32)	15.88(8.61)	67.48(8.45)	0.58(1.65)

Forecast Error Variance of GM3 as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	0.39(2.62)	0.29(2.05)	5.58(5.21)	0.66(2.07)	0.49(1.93)	2.24(3.45)	28.06(9.37)	62.29(9.01)
3	2.63(4.11)	0.67(2.47)	7.79(4.09)	1.7(2.8)	8.67(4.87)	1.76(2.73)	27.97(7.74)	48.82(6.35)
6	2.73(3.9)	0.69(2.39)	7.68(3.7)	1.77(2.81)	12.48(5.38)	2.16(2.66)	27.41(7.22)	45.08(5.98)
12	2.73(3.87)	0.72(2.44)	7.68(3.69)	1.82(2.83)	12.47(5.37)	2.16(2.66)	27.39(7.16)	45.03(5.95)

Note: Figures in brackets are standard errors calculated via boot strapping method.

Table 3: Estimated Structural Contemporaneous Coefficients in a Benchmark case

	oil	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
oil	13.268*** (0.9)	0	0	0	0	0	0	0
ffrate	-1.825 (1.28)	8.019*** (0.55)	0	0	0	0	0	0
inf	5.373*** (1.34)	-1.973** (0.78)	273.667*** (18.62)	0	0	0	0	0
y	-1.426 (1.39)	-0.581 (0.8)	15.637 (26.36)	91.823*** (6.25)	0	0	0	0
neer	-0.799 (1.4)	-0.566 (0.8)	42.084 (26.48)	-5.054 (8.84)	75.813*** (4.26)	0	0	0
CMR	1.924 (1.4)	-0.601 (0.8)	12.54 (26.7)	6.176 (8.86)	-5.527 (7.3)	0.453*** (0.03)	0	0
gbc	-1.266 (1.41)	0.683 (0.8)	-7.679 (26.72)	-4.017 (8.87)	4.212 (7.3)	-0.212*** (0.05)	97.759*** (6.65)	0
gm3	0.699 (1.42)	-0.498 (0.8)	90.019*** (27.42)	10.499 (8.91)	4.927 (7.33)	0.057 (0.05)	-65.618*** (10.41)	220.614*** (15.01)

Table 4: Forecast Error Variance Decomposition in a Pure Inflation Targeting Case

Forecast Error Variance of Output as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	1.87(2.58)	0.33(1.1)	0.32(1.07)	97.48(2.98)	0(0)	0(0)	0(0)	0(0)
3	2.52(3.52)	1.22(1.97)	2.98(3.3)	91.25(5.51)	0.76(1.69)	0.22(0.48)	0.97(1.37)	0.07(0.4)
6	2.58(3.49)	1.43(2.21)	2.97(3.23)	89.55(6.34)	1.47(2.05)	0.24(0.5)	1.6(2.24)	0.15(0.41)
12	2.58(3.49)	1.45(2.22)	2.97(3.22)	89.35(6.44)	1.55(2.11)	0.31(0.52)	1.63(2.26)	0.16(0.41)

Forecast Error Variance of Inflation as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	11.49(5.77)	5.05(3.86)	83.46(6.53)	0(0)	0(0)	0(0)	0(0)	0(0)
3	11.03(4.87)	8.02(4.7)	63.54(7.02)	0.56(1.18)	12.05(5.21)	0.2(0.59)	0.72(1.2)	3.88(2.61)
6	10.82(4.72)	8.13(4.65)	61.07(7.1)	0.9(1.13)	12.98(5.31)	1.17(1.13)	1.05(1.11)	3.88(2.66)
12	10.8(4.71)	8.41(4.82)	60.78(7.14)	0.91(1.13)	12.98(5.31)	1.18(1.13)	1.05(1.11)	3.88(2.66)

Forecast Error Variance of NEER as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	1.73(2.49)	0.12(0.67)	2.35(2.86)	0.29(1.01)	95.51(3.9)	0(0)	0(0)	0(0)
3	2.65(2.87)	1.16(1.93)	2.67(2.7)	1.27(1.8)	87.31(5.69)	1.36(1.82)	1.75(1.98)	1.83(2.19)
6	2.69(2.88)	1.4(2.09)	2.74(2.69)	1.47(2.12)	86.48(5.92)	1.36(1.8)	1.99(1.99)	1.86(2.2)
12	2.7(2.88)	1.48(2.18)	2.75(2.69)	1.47(2.12)	86.38(5.95)	1.37(1.81)	1.99(1.99)	1.86(2.2)

Forecast Error Variance of CMR as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	1.33(2.19)	0.38(1.17)	0.28(1)	0(0)	0(0)	98.01(2.66)	0(0)	0(0)
3	1.55(2)	0.51(1.45)	2.5(3.06)	2.24(2.59)	6.71(4.68)	83.37(6.66)	2.84(2.62)	0.29(0.82)
6	1.63(1.95)	1.08(2.5)	2.76(3.36)	2.56(2.73)	6.95(4.75)	80.72(7.66)	3.33(3.03)	0.96(1.62)
12	1.61(1.92)	1.5(3.45)	2.79(3.39)	2.63(2.77)	7.01(4.8)	80.01(8.21)	3.42(3.14)	1.03(1.7)

Forecast Error Variance of GBC as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	0.02(0.29)	0.19(0.84)	0.01(0.16)	0.13(0.64)	0.25(0.87)	18.03(6.68)	81.36(6.75)	0(0)
3	0.07(0.51)	2.53(2.49)	1.61(2.05)	0.25(0.78)	8.36(4.55)	16.1(5.53)	70.75(6.75)	0.33(0.94)
6	0.82(0.94)	3.25(3.11)	1.54(1.93)	0.46(0.92)	10.21(4.81)	15.87(5.33)	67.3(7.02)	0.55(0.86)
12	0.87(0.98)	3.4(3.33)	1.55(1.93)	0.53(0.94)	10.21(4.8)	15.91(5.31)	66.96(7.05)	0.58(0.88)

Forecast Error Variance of GM3 as Explained by Shocks to								
Horizon	*oil*	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
1	0.39(1.2)	0.29(1.03)	5.58(4.28)	0.51(1.31)	0.65(1.47)	2.26(2.72)	28.05(7.03)	62.26(7.36)
3	2.63(2.84)	0.67(1.27)	7.78(4.25)	1.59(2.37)	8.85(4.52)	1.77(2.11)	27.94(6.66)	48.77(6.53)
6	2.72(2.68)	0.69(1.29)	7.66(3.96)	1.68(2.5)	12.77(5.03)	2.17(1.99)	27.34(6.35)	44.96(6.61)
12	2.72(2.67)	0.72(1.35)	7.66(3.96)	1.72(2.52)	12.77(5.03)	2.18(1.99)	27.32(6.35)	44.91(6.62)

Note: Figures in brackets are standard errors calculated via boot strapping method.

Table 5: Estimated Contemporaneous Restriction Matrix

(Benchmark Case: CMR as Monetary Policy Instrument)

	oil	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
oil	0.075	0	0	0	0	0	0	0
ffrate	0.017	0.124	0	0	0	0	0	0
inf	-0.001	0.000	0.003	0	0	0	0	0
y	0.001	0.001	-0.001	0.011	0	0	0	0
neer	0.001	0.001	-0.002	0.001	0.013	0	0	0
CMR	-0.258	0.137	-0.117	-0.139	0.160	2.206	0	0
gbc	0.0001	-0.001	0.0001	0.0001	-0.0001	0.004	0.010	0
gm3	0.0001	-0.0001	-0.001	-0.001	-0.0001	0.0001	0.003	0.004

Table 6: Estimated Contemporaneous Restriction Matrix
(Pure Inflation Targeting Case: CMR as Monetary Policy Instrument)

	oil	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
oil	0.075	0	0	0	0	0	0	0
ffrate	0.017	0.125	0	0	0	0	0	0
inf	-0.001	0.001	0.004	0	0	0	0	0
y	0.001	0.001	-0.001	0.011	0	0	0	0
neer	0.001	0.001	-0.002	0.001	0.013	0	0	0
CMR	-0.258	0.138	-0.117	0	0	2.216	0	0
gbc	0.001	-0.001	0.001	0.001	-0.001	0.004	0.010	0
gm3	0.001	-0.001	-0.001	-0.001	-0.001	0.001	0.003	0.004

Table 7: Estimated Structural Contemporaneous Coefficients

(Benchmark Case)

	oil	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
oil	13.268*** (0.9)	0	0	0	0	0	0	0
ffrate	-1.825 (1.28)	8.019*** (.55)	0	0	0	0	0	0
inf	5.373*** (1.34)	-1.973** (0.78)	273.667*** (18.62)	0	0	0	0	0
y	-1.426 (1.39)	-0.581 (0.8)	15.637 (26.36)	91.823*** (6.25)	0	0	0	0
neer	-0.799 (1.4)	-0.566 (0.8)	42.084 (26.48)	-5.054 (8.84)	75.813*** (4.26)	0	0	0
CMR	1.924 (1.4)	-0.601 (0.8)	12.54 (26.7)	6.176 (8.86)	-5.527 (7.3)	0.453*** (0.03)	0	0
gbc	-1.266 (1.41)	0.683 (0.8)	-7.679 (26.72)	-4.017 (8.87)	4.212 (7.3)	-0.212*** (0.05)	97.759*** (6.65)	0
gm3	0.699 (1.42)	-0.498 (0.8)	90.019*** (27.42)	10.499 (8.91)	4.927 (7.33)	0.057 (0.05)	-65.618*** (10.41)	220.614*** (15.01)

Table 8: Estimated Structural Contemporaneous Coefficients

(Pure Inflation Targeting Case)

	oil	*ffrate*	*inf*	*y*	*neer*	*CMR*	*gbc*	*gm3*
oil	13.268*** (0.90)							
ffrate	-1.825 (1.28)	8.019*** (0.55)						
inf	5.373*** (1.34)	-1.973** (0.78)	273.667*** (18.61)					
y	-1.426 (1.39)	-0.581 (0.79)	15.637 (26.35)	91.82*** (6.25)				
neer	-0.798 (1.39)	-0.565 (0.797)	42.084 (26.53)	-5.05 (8.84)	75.81*** (5.16)			
CMR	1.946 (1.39)	-0.603 (0.79)	14.45 (26.35)	0	0	0.451*** (.03)		
gbc	-1.265 (1.41)	0.683 (0.80)	-7.679 (26.72)	-4.01 (8.85)	4.21 (7.30)	-0.21*** (0.04)	97.75*** (6.65)	
gm3	0.698 (1.41)	-0.497 (.80)	90.01*** (27.43)	10.50 (8.88)	4.925 (7.31)	0.056 (0.048)	-65.618*** (10.41)	220.61*** (15.01)

Appendix

Stationarity Tests

Table A.1. Stationarity Tests (Log-Level)

Variable	ADF	Lags	PPERRON	Lags	Remark
loil	-0.992(0.756)	0	-0.831(0.809)	4	I(1)
ffrate	-0.959(0.768)	1	-0.941(0.774)	4	I(1)
lwpi	-0.560(0.879)	1	-0.473(0.897)	4	I(1)
liip	-0.137(0.946)	1	-0.222(0.936)	4	I(1)
lneer	-2.670(0.079)	2	-2.359(0.153)	4	I(1)
lm0	-0.059(0.963)	0	0.320(0.978)	4	I(1)
cmr	-6.114(0.00)	2	-5.898(0.00)	4	I(0)
tbill	-2.650(0.083)	1	-2.843(0.052)	4	I(0)
lbc	1.919(0.999)	0	2.043(0.998)	4	I(1)
lm3	-1.541(0.513)	0	-1.694(0.434)	4	I(1)
lagprice	-2.362(0.153)	1	-2.327(0.164)	4	I(1)
lwpiag	0.451(0.983)	1	0.691(0.989)	4	I(1)

- In ADF regressions the number of lagged differenced terms included are selected on the basis of no autocorrelation left in the error terms at that number of lags
- For PPERRON test lags are selected on the basis of Newey-West criterion.
- The figure in the parenthesis is MacKinnon approximate p value.
- Suffix ‘l’ indicates that variables are taken in their natural logarithm form

Table A.2. Stationarity Tests (First Difference)

Variable	ADF	Lags	PPERRON	Lags	Remark
doil	-11.088(0.00)	0	-11.138(0.00)	4	I(0)
dffrate	-3.469(0.008)	1	-5.116(0.00)	4	I(0)
dwpi	-7.084(0.00)	1	-8.195(0.00)	4	I(0)
diip	-17.131(0.00)	1	-17.394(0.00)	4	I(0)
dneer	-7.819(0.00)	2	-8.016(0.00)	4	I(0)
dm0	-11.184(0.00)	0	-11.565(0.00)	4	I(0)
dbc	10.638(0.00)	0	-10.650(0.00)	4	I(0)
dm3	-9.481(0.00)	0	-9.438(0.00)	4	I(0)
dagprice	-6.819(0.00)	1	-8.517(0.00)	4	I(0)
dwpiag	.7.080(0.00)	1	-8.051(0.00)	4	I(0)