Vector Autoregression Model of Monetary Policy for India and the Case of Inflation Targeting

1. Introduction

The purpose of this paper is to build a short run vector autoregression monetary policy model for the Indian economy to assess the effects of change in monetary policy institutions or rules over the years and use this model to conduct policy experiments. We try to build the hypothetical pure inflation targeting case in the specified model of monetary policy and try to explore the effects of monetary policy shocks on other macroeconomic variables in a pure inflation targeting case, a scenario away from the multiple indicator approach currently followed by RBI. This experimentation will throw some light on the desirability and suitability of inflation targeting monetary policy regime for India.

Assessing the effects of change in monetary policy rules and institutions is always a burning issue among researchers and policy makers. How should the RBI respond to shock, which impact the economy? What are the consequences of shifting to some other policy regime or framework? These questions can be addressed within the confines of quantitative general equilibrium models. But we have variety of models, each with its own set of assumptions, limitations and policy implications. Which model among these can be used for policy experiments?

We followed Lucas Methodology to answer the above question. It consisted of three steps. In the first step, we use the model to isolate monetary policy shocks. This is important as a given monetary policy action and the events that followed it reflect the effect of all the shocks to the economy but our purpose here is to analyze what happens to the economy after a shock to a monetary policy. The reason for being focus on the monetary policy shocks is that different models respond differently to these shocks. These results will help us to determine the theoretical model, which fits the framework of Indian economy better among the variety of models available as a next step. As a last step, it will enable us to perform monetary experiments in this model economy and compare the outcome with actual economy’s response to corresponding experiments.

There exist some general strategies for isolating monetary policy shocks in the literature. We made use of vector autoregression for this exercise. It involves making enough identifying assumptions to allow estimating the parameters of Reserve Bank's feedback rule. Feedback rule implies the one, which relates policy makers' action to the state of the economy. The necessary identifying assumptions include the functional form assumptions, assumptions about which variables RBI look at when setting its operating instrument and an assumption about what the operating instrument is.

Along with this in the feedback rule must also be assumed. We assume that policy shock is *orthogonal* to these variables. This is referred as *recursiveness* assumption. The economic content of recursiveness assumption is that time t variables in the RBI's information set do not respond to time t realizations of monetary policy shocks.

However these recursiveness assumptions are controversial and alternative approaches exists. Though there are some advantages of abandoning recursiveness assumption but there is also a huge cost in terms of broad economic relationships which needs to be identified.

The rest of the paper is organized as follows: first we present some discussion on the changing monetary policy operating procedures in Indian economy; then we give the brief overview of methodology; next we present the set-up of the VAR model used in this exercise and finally we present the results followed by policy experiments, robustness check and conclusions.

2. Changing Monetary Policy Framework in India

The transition of economic policies from controlled to liberalized but regulated regime has been reflected in the changes in monetary management also in India. Though, the basic objectives of monetary policy of price stability and ensuring availability of credit to productive sectors have remained intact but the underlying operating procedures have gone under significant changes.

The monetary policy framework in India from the mid 1980s till 1997-98 can be characterized as a *monetary targeting framework*. This was in lines with the recommendations of the *Chakravarty Committee (1985)*. Since the money demand function was stable, the annual growth rate of broad money (M3) was used as an intermediate target of monetary policy to achieve monetary objectives. However, the monetary targeting was pursued in a flexible manner with a 'feedback'. This was necessary partly because of the high level of government borrowings and administered interest rates.

Deregulation and liberalization of the financial markets combined with the increasing openness of the economy in 1990s necessitated the re-look at the efficiency of broad money as an indicator of monetary policy. The ensuing financial innovations had indicated that in future money demand will not only be guided by real income changes but the interest rates will also influence the decision to hold money. In a similar vein, the *Working group on Money Supply: Analytics and Methodology of Compilation* (Chairman: Dr. Y.V. Reddy) observed that monetary policy based on demand function of money could lack precision. The Reserve Bank, therefore, formally adopted a 'multiple indicator approach' in April 1998. 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.

With the adoption of 'multiple indicator approach' the operating procedures of monetary policy have undergone change. There has been a shift away from direct to indirect channels of monetary transmission. In particular, short-term interest rates have appeared as an instrument to signal the stance of monetary policy. The reliance on reserve requirements, particularly the cash reserve ratio (CRR), has been reduced as an instrument of monetary policy. The liquidity management in the system is carried out through open market operations (OMO) in the form of outright purchases/sales of government securities and repo and reverse repo operations. Thus RBI has now become able to influence short-term interest rates by changing the liquidity in the system through repo operations under Liquidity Adjustment Facility (LAF).

3. Methodology

3.1 Monetary Policy Shock

We identify monetary policy shock with the disturbance term in an equation of the form

$$S_t = f(\Omega_t) + \sigma_s \varepsilon_t^s \tag{1}$$

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.

3.2 Vector Autoregressions

A VAR is a convenient device for summarizing first and second order moment properties of the data. The basic problem 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

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

Here, p is a nonnegative integer and μ_t is uncorrelated with all variables dated (t-1) and earlier. Knowing A_i's, the μ_t's and Σ is 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. in general, each element of μ_t reflect 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 very 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 Autoregressions

An alternative to the recursive VAR or temporal ordering of variables is to allow more elaborate set of restrictions guided by economic theory. This is referred to as 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 autoregressions with short run restrictions.

The short run SVAR model (following from equation2) can be written as:

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

Here, A and B are KXK nonsingular 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. Setting up of the VAR Model

The model used in this paper is assumed to be sufficient to identify the monetary policy shocks. This model reflects the fact that India is a small relatively open economy. Eight variables are chosen to explain the 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 are forming two blocks in the model; one is the foreign block with two variables and next is the domestic block with six domestic variables. The foreign variables are block exogenous to the system. It implies that domestic variables are not entering in the lag structure of the foreign variables. This assumption is made due to small size of Indian economy to the world economy, which makes unlikely for domestic variables to explain movements in foreign variables either contemporaneously or with a lag.

4.1 Variables included in the Model

The foreign variables included in the model are oil prices and 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. 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), output (measured by a index of industrial production), exchange rate (as measured by nominal effective exchange rate), monetary policy instrument, gross bank credit and broad monetary aggregate (M3). Growth rate of reserve money (M0) and call money rate (cmr) are used as monetary policy instruments. 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 for later sub period.

4.2 Structure of the Model

The following recursive structure has been used to identify monetary policy shocks:

$$BX_t = \begin{pmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 & 0 & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & 0 & 0 & 0 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} & 0 & 0 & 0 \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & b_{66} & 0 & 0 \\ b_{71} & b_{72} & b_{73} & b_{74} & b_{75} & b_{76} & b_{77} & 0 \\ b_{81} & b_{82} & b_{83} & b_{84} & b_{85} & b_{86} & b_{87} & b_{88} \end{pmatrix} \begin{pmatrix} oil \\ ffrate \\ inf \\ y \\ neer \\ mp \\ bc \\ m3 \end{pmatrix}$$

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 index of industrial production, ‘neer’ is nominal effective exchange rate, ‘mp’is monetary policy instrument, ‘bc’ is gross bank credit and ‘m3’is broad monetary aggregate. Growth rate of reserve money (M0) and call money rate (cmr) have been used as monetary policy instrument and 91 day treasury bill rate has also been tried for the later period.

Here, oil and ffrate are forming the foreign block and remaining variables are forming the domestic block. In the domestic block inflation, output and nominal effective exchange rate are forming the non-policy block and monetary policy instrument, gross bank credit and broad monetary aggregate are forming the policy block. This model implies that monetary policy instrument react contemporaneously to shocks in inflation, output and exchange rate.

4.2.1 Pure Inflation Targeting Case

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

$$BX_t = \begin{pmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 & 0 & 0 & 0 & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} & 0 & 0 & 0 & 0 \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} & 0 & 0 & 0 \\ b_{61} & b_{62} & b_{63} & 0 & 0 & b_{66} & 0 & 0 \\ b_{71} & b_{72} & b_{73} & b_{74} & b_{75} & b_{76} & b_{77} & 0 \\ b_{81} & b_{82} & b_{83} & b_{84} & b_{85} & b_{86} & b_{87} & b_{88} \end{pmatrix} \begin{pmatrix} oil \\ ffrate \\ inf \\ y \\ neer \\ mp \\ bc \\ m3 \end{pmatrix}$$

4.3 Period of Analysis

The period of analysis for this exercise is chosen from 1985 January to 2005 March. To successfully capture the changing monetary policy dynamics in Indian economy, this period is further divided into two sub periods: 1985 January to 1995 December and 1996 January to 2005 March.

5. Data Sources

The data for the domestic variables has been collected from the, *'Handbook of Statistics on Indian economy, 2005'* an annual publication of RBI. For crude oil prices data has been taken from the link: *http://www.imf.org/external/np/res/commod/datar.csv* and for federal funds rate from the link: *http://www.newyorkfed.org/*. All the series are converted to 1993-94 base for easy comparison across different periods.[1]

✓http://www.imf.org/external/np/res/commod/datar.csv

6. Estimation

The above-described VAR models have been estimated for different periods. In each equation 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 procedure. The following pre-estimation tests have been done before.

[1] The data for nominal effective exchange rate was not available monthly before 1990 January. Thus from annual data monthly data has been generated for 198m January to 1989 December by a cubic spline curve fitting method.

6.1 Stationarity Tests

We performed the augmented Dicky Fuller (ADF) test and Phillips Perron (PP) for the presence of unit roots in the series.[2] The number of lagged difference, terms included in testing for each series, has been decided on the basis of no autocorrelation in the error terms for the ADF tests. For PP tests lags has been selected on the basis of Newey-West criterion. These tests suggest that all the variables other than call money rate (and 91 days treasury bill rate for the later sub period) contains unit root.[3] 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, thus the resulting series after first difference are basically the growth rates. Thus the variables entering into estimation are: growth of oil prices, change in ffrate, inflation (monthly change in price level), growth of output, appreciation of neer, growth of reserve money (m0) or call money rate (cmr) as monetary policy variable, growth of bank credit and growth of m3

[2] These tests are not included due to the space constraint and are available with the author.
[3] The oil prices also turn out to be stationary for 1985 Jan to 1995 Dec.

6.2 Selection of Lag Lengths

The appropriate lag length for the VAR model estimated for each period has been decided on the basis of Akaike's Information criterion (AIC).[4] The following table presents the number of lags included in VAR model for each period.

Lags included in the VAR models

Period	Monetary policy Instrument (MPI)	Number of lags
1985M1 to 2005M3[5]	Growth of M0 as MPI	5
	Call money rate as MPI	5
1985M1 to 1995M12	Growth of M0 as MPI	2
	Call money rate as MPI	2
1996M1 to 2005M12	Growth of M0 as MPI	2
	Call money rate as MPI	2
	91 day Tbill rate as MPI	2
Pure inflation targeting case	Call money rate as MPI	2

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

[5] For this period the appropriate lag as selected by AIC criterion was 5, but due to the presence of autocorrelation at that lag length, the no. of lags has been increased to 5.

7. Theoretical Arguments

Theory implies that if output is at its full employment potential level then monetary tightening (positive interest rate) will effect inflation and not output and also it will appreciate exchange rate and in this scenario output will explain the substantial part of variation in inflation and inflation will also account for the much of the movement in output. However, if the output is not at potential the positive monetary shock or monetary tightening will decline output. It will have little effect on inflation and this will also depreciate exchange rate. In this scenario, inflation will be mainly explained by commodity and exchange rate shocks and less by output shocks.

8. Results

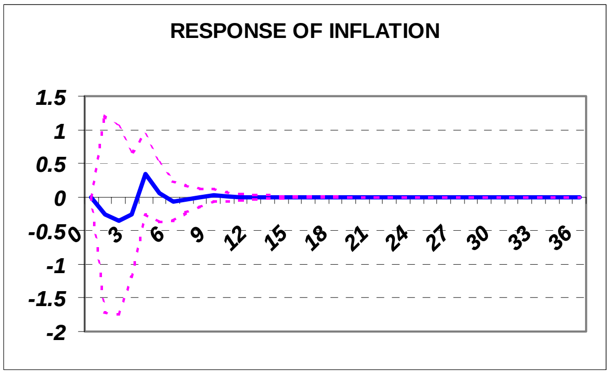
In this exercise we tried to see the effects of monetary policy shocks as measured by the growth rate of reserve money and call money rate on macroeconomic variables. Then the consistency of the response of macro variables to the monetary policy shock with broad results of theoretical models will enable us to use this model for our hypothetical inflation targeting exercise. However, we find that for the whole period (1985M1 to 2005M3) our identification scheme is giving completely contradictory results as expansionary monetary policy (as explained by increase in growth rate of reserve money) leading to fall in inflation and output and on the other hand contractionary monetary policy (as explained by increase in interest rate) lead to rise in inflation and output. This wayward result from the model can be explained due to major changes in monetary regime in the period. Thus model based on vector autoregression framework where there is a regime switch generally gives inconsistent results.[6] Then we split the sample into two sub periods. The results of the period from 1985 M1 to 1995 M12 with reserve money growth as monetary policy instrument and with call money rate as monetary policy instrument are presented in figures1 and 2 respectively.

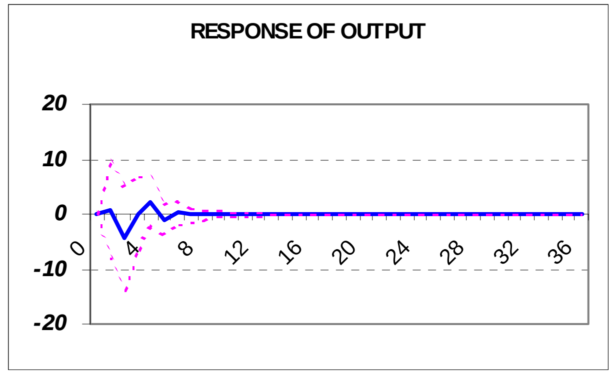
[6] The results for the full sample period have not been included here.

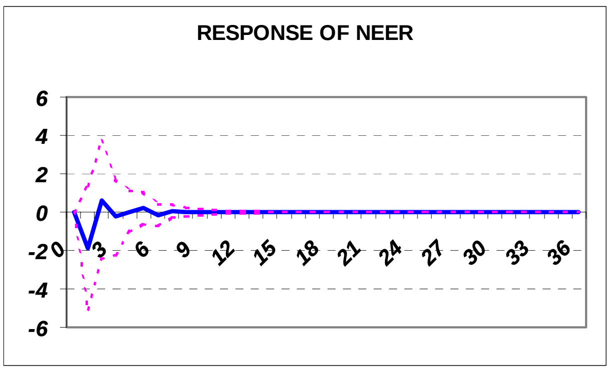
Figure1

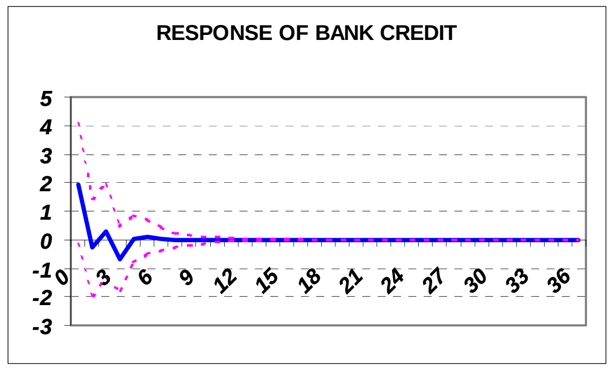
SAMPLE PERIOD: 1985M1 TO 1995 M3

POSITIVE M0 SHOCK (POSITIVE MONETARY SHOCK)









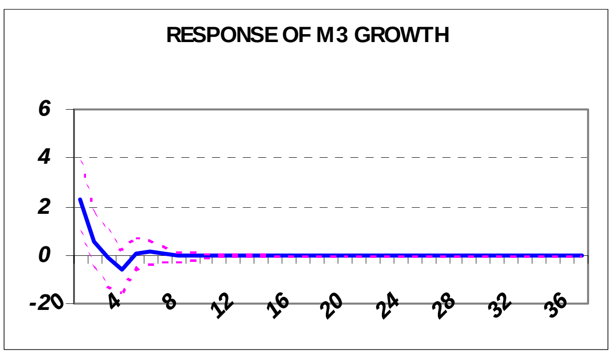
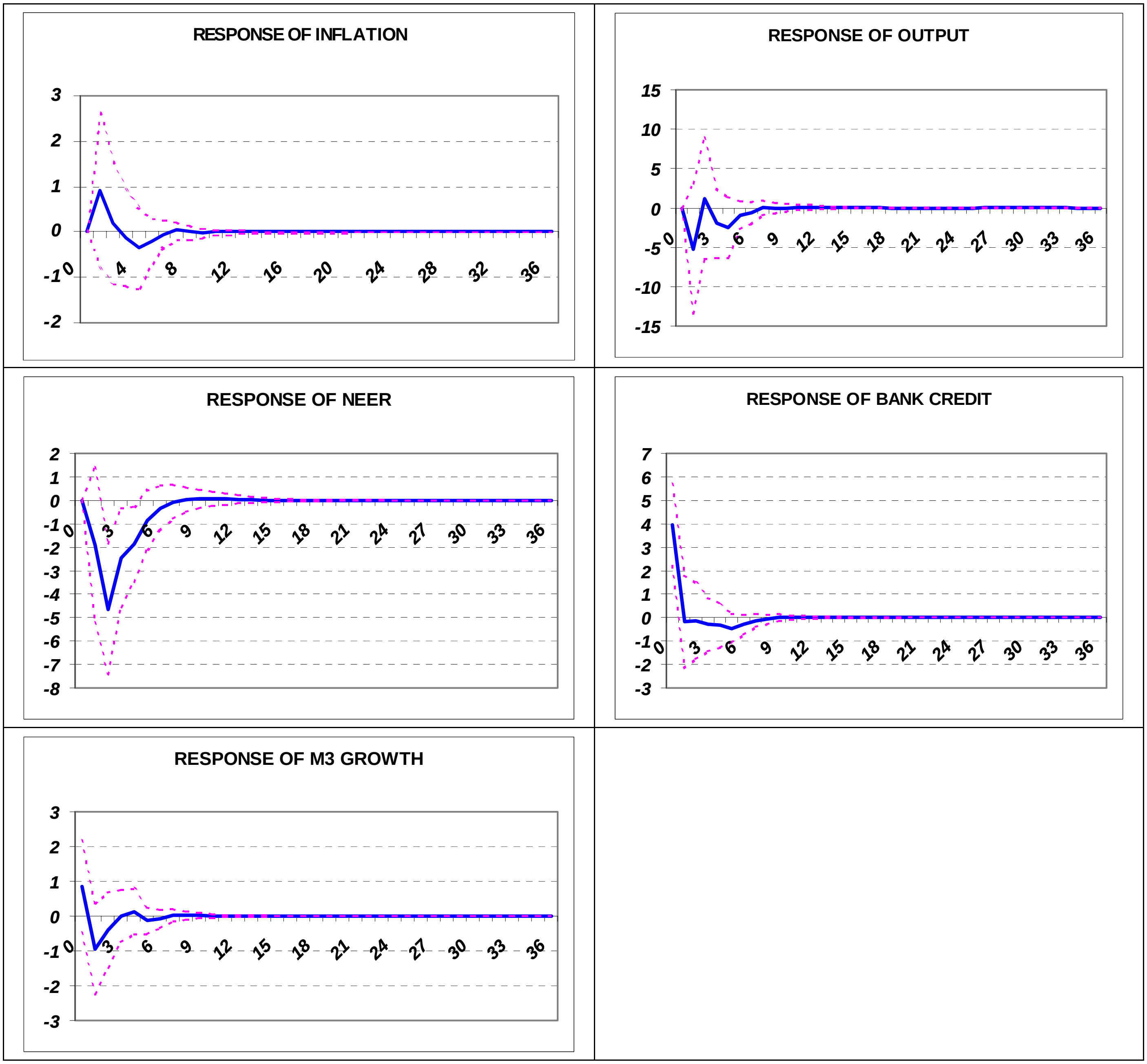


Figure 2

SAMPLE PERIOD: 1985M1 TO 1995 M3

POSITIVE CMR SHOCK (NEGATIVE MONETARY SHOCK)



These results indicate a famous ‘price puzzle’ discovered in the literature where positive innovations to growth of M0 leading to a fall in inflation while positive innovation to interest rate leading to its rise. However, the response of output to these innovations is quite consistent as a positive innovation M0 growth leads to a rise in output while positive innovation to interest rate leads to its fall. However, the effect of M0 shock on output is quite small and there is a very marginal increase in output for around 2 months and then it starts falling and then again rises after 4-5 months but it responds quite strongly to interest rate shocks and the fall in output is quite drastic.

The response of neer to positive innovation in M0 growth is quite in line with the theory as it leads to fall in appreciation or in other words to depreciation of neer. But the response of neer to interest rate shock is again contradictory to the theory as rise in interest rate is leading to fall in appreciation or in other words depreciation of neer.

Again, the responses of bank credit and M3 growth are quite in line with theory for positive shock to M0 growth. The positive shock to M0 growth is leading to initial rise in credit and M3 growth for about 4 months and then this rise dies out. The response of bank credit and M3 growth is quite similar with the exception that there is more variability in credit growth due to M0 shock than to M3 growth. However, the response of credit to positive innovation in interest rate is quite unlikely as it rises initially because of it while the response of M3 growth is also of initial rise for almost 2 months and then it starts falling.

Thus our results indicate that for the period of 1985 to 1995, the monetary shocks as identified by M0 growth gives more consistent results in line with theory. However, the monetary shocks, as identified by the interest rate variable, gives puzzling and contradictory results. This finding is again indicative of the fact that initially quantity variable seems to work better for the Indian economy than the rate variable to signal the stance of monetary policy.

Since we have found out that the M0 growth shocks are indicating the stance of monetary policy better. We now show the forecast error variance decompositions[7] for 1985M1 to 1995 M12 from the model with M0 growth as monetary policy instrument.

[7] Figure in the bracket of the following forecast error variance decomposition table and subsequent FEVDs table indicate the standard error calculated via bootstrapping method.

Table1

FORECAST ERROR VARIANCE DECOMPOSITION

M0GROWTH AS MONETARY POLICY INSTRUMENT

(1985M1 to 1995M12)

FORECAST ERROR VARIANCE OF INFLATION AS EXPLAINED BY SHOCKS TO								
HORIZON	OIL	FFRATE	INFLATION	OUTPUT	NEER	GM0	GBC	GM3
1	10.65(5.62)	0.37(1.19)	88.99(5.5)	0(0)	0(0)	0(0)	0(0)	0(0)
3	9.25(4.74)	4.17(3.89)	75.15(6.22)	3.38(2.89)	0.87(1.84)	0.14(1.17)	2.58(2.24)	4.46(3.07)
6	9.43(4.8)	4.73(4.08)	73.62(6.39)	3.59(2.83)	0.91(1.83)	0.27(1.26)	2.85(2.25)	4.59(3.05)
12	9.72(4.81)	4.73(4.05)	73.34(6.45)	3.58(2.81)	0.9(1.82)	0.28(1.27)	2.87(2.25)	4.58(3.04)

FORECAST ERROR VARIANCE OF OUTPUT AS EXPLAINED BY SHOCKS TO								
HORIZON	OIL	FFRATE	INFLATION	OUTPUT	NEER	GM0	GBC	GM3
1	1.13(2.47)	5.01(4.02)	20.28(7.79)	73.58(8.99)	0(0)	0(0)	0(0)	0(0)
3	2.34(2.57)	5.47(4.43)	15.15(5.98)	71.77(8.13)	0.48(1.61)	0.51(2.1)	2.26(2.69)	2.03(2.58)
6	2.48(2.61)	5.43(4.26)	15.64(5.82)	70.7(7.88)	0.76(1.7)	0.63(2.16)	2.31(2.73)	2.05(2.61)
12	2.58(2.62)	5.43(4.24)	15.63(5.8)	70.57(7.87)	0.76(1.71)	0.64(2.18)	2.34(2.73)	2.05(2.62)

FORECAST ERROR VARIANCE OF NEER AS EXPLAINED BY SHOCKS TO								
HORIZON	OIL	FFRATE	INFLATION	OUTPUT	NEER	GM0	GBC	GM3
1	2.25(2.32)	1.53(2.27)	0.14(1.05)	0.98(2.06)	95.09(3.62)	0(0)	0(0)	0(0)
3	2.83(3.1)	4.34(4.21)	1.07(2.37)	1.2(2.28)	88.23(7.08)	0.79(1.75)	0.7(1.89)	0.84(1.94)
6	2.84(2.97)	4.64(4.32)	1.09(2.31)	1.22(2.25)	87.39(7.36)	0.8(1.75)	1.05(1.89)	0.96(1.91)
12	2.85(3.02)	4.64(4.31)	1.09(2.3)	1.23(2.24)	87.37(7.38)	0.81(1.75)	1.05(1.88)	0.96(1.91)

FORECAST ERROR VARIANCE OF GM0 AS EXPLAINED BY SHOCKS TO								
HORIZON	OIL	FFRATE	INFLATION	OUTPUT	NEER	GM0	GBC	GM3
1	0.01(1.54)	5.66(5.14)	0(0)	0.4(1.61)	0.41(1.73)	91.89(6.12)	0(0)	0(0)
3	0.43(2.03)	6.3(5.15)	1.42(2.26)	11.11(5.72)	1.25(2.59)	71.97(7.4)	3.75(2.58)	3.78(3.33)
6	0.52(1.99)	6.22(4.88)	1.66(2.21)	11.85(5.8)	1.32(2.54)	69.85(7.33)	4.82(3.12)	3.76(3.36)
12	0.52(2)	6.22(4.85)	1.66(2.21)	11.89(5.81)	1.32(2.54)	69.77(7.34)	4.84(3.12)	3.77(3.37)

FORECAST ERROR VARIANCE OF GBC AS EXPLAINED BY SHOCKS TO								
HORIZON	OIL	FFRATE	INFLATION	OUTPUT	NEER	GM0	GBC	GM3
1	1.06(2.14)	1.15(2.84)	0.06(1.85)	1.89(2.04)	0.02(1.62)	2.8(3.23)	93.01(5.32)	0(0)
3	2.11(2.66)	2.28(2.98)	3.75(3.41)	6.17(3.95)	0.59(2.07)	2.44(2.68)	79.28(6.37)	3.38(2.52)
6	2.15(2.6)	2.6(2.83)	4.02(3.36)	8.17(4.57)	0.69(2.04)	2.61(2.72)	76.22(6.83)	3.54(2.38)
12	2.18(2.68)	2.61(2.83)	4.03(3.36)	8.17(4.56)	0.7(2.04)	2.61(2.71)	76.16(6.91)	3.54(2.37)

FORECAST ERROR VARIANCE OF GM3 AS EXPLAINED BY SHOCKS TO								
HORIZON	OIL	FFRATE	INFLATION	OUTPUT	NEER	GM0	GBC	GM3
1	0.52(1.57)	0.95(2.87)	0.18(1.78)	1.49(2.46)	0.02(1.38)	9.11(5.63)	33.66(6.91)	54.08(7.92)
3	1.37(2.19)	0.97(2.83)	5.75(3.76)	6.16(3.92)	0.63(2.11)	7.43(4.07)	33.16(6.57)	44.54(6.29)
6	1.37(2.11)	1.35(2.56)	6.37(3.85)	9.37(4.91)	0.67(2.09)	7.5(3.98)	31.34(6.21)	42.01(6.08)
12	1.4(2.09)	1.35(2.55)	6.41(3.87)	9.37(4.9)	0.68(2.08)	7.5(3.96)	31.32(6.18)	41.97(6.09)

The FEVDs as shown in table1 capture the interesting structural and institutional aspect of Indian economy prevailing from mid 80s to mid 90s. As the results indicate its own past movements basically explained that inflation but oil shocks played a significant secondary role in explaining volatility of inflation. And the small contribution also comes fro M3 growth in explaining movements of inflation. This implies that to certain extent supply side factors played greater role in explaining inflation. The pass through of neer to inflation was negligible and this again indicates the relatively closed nature of Indian economy and unimportance of external fluctuations in determining inflation.

The results for neer shows that it was exogenous to the system as none of the domestic variables explained much variation in neer. However foreign variables explain 2-4% variation in neer. This is again evidence in favor of relatively fixed exchange rate regime in the economy where exchange rate was not determined by fundamentals of the economy as reflected by the major macroeconomic variables.

The results for M0 growth again give some evidence in favor of growth objective of monetary policy as much of the variations in it is coming from output fluctuations along with minor role played by credit.

The results of growth of bank credit are quite in line with theory where inflation, output and money aggregate playing minor roles in explaining its movement.

The results for growth of M3 again capture the structural aspect of the economy. Since, much of the variation in it is coming from shocks to credit indicates the use of M3 as intermediate target and changes in credit as an operating procedure followed by the RBI. However, this result is also quite in line with theory. Further, the results give some evidence that money supply was relatively endogenous as all the domestic variables are playing minor roles in explaining its movements.

Now we present the results of the second sub sample, which starts from 1996 January and ends in 2005, March.

Figure3

SAMPLE PERIOD: 1996 M1 TO 2005M3

POSITIVE M0 SHOCK (POSITIVE MONETARY SHOCK)

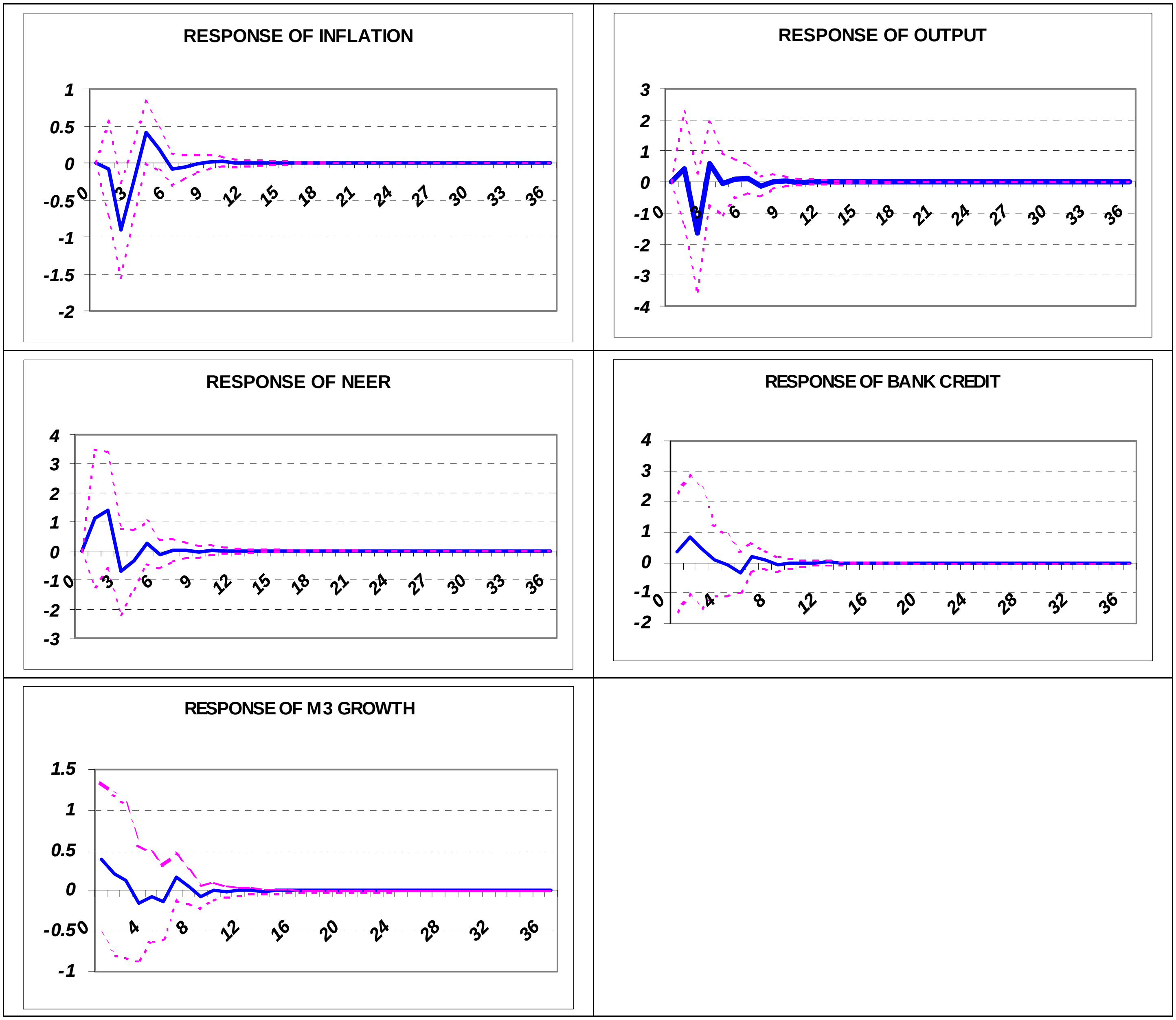
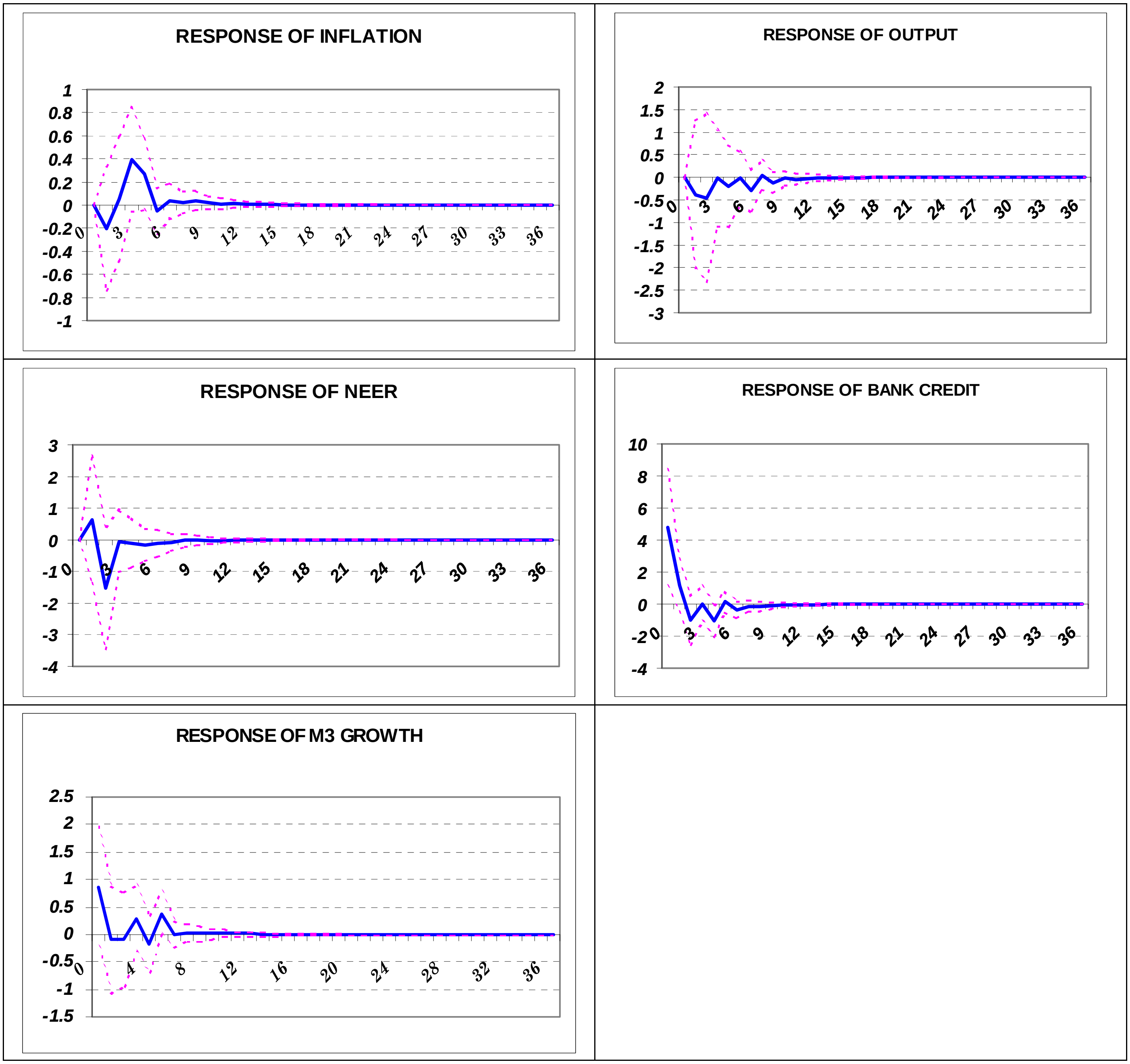


Figure 4

SAMPLE PERIOD: 1996 M1 TO 2005M3

POSITIVE CMR SHOCK (NEGATIVE MONETARY SHOCK)



In figure 3the response of macro variables to the shock in M0growth is presented while in figure4 the response of variables to CMR shock is given. Monetary policy shock, as identified by M0growth shock, again gave the price puzzle as positive innovation to it leads to fall in inflation. And for output though there is a small rise for two months but then it starts falling. However, exchange rate again give some puzzling result as positive innovation in M0 growth leads to a appreciating exchange rate. The response of credit and M3 growth shows a small rise following M0 growth shock and then they fell. And they again rise for almost 2 months and then the effect dies down.

However, call money rate shocks are giving more consistent results for the major economic variables as all the variables are behaving in line with the theory. 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 interest rate. The behaviour of exchange is also more in line with the theory as positive innovation to interest rate leads to a rise in appreciation of exchange rate. This gives evidence that in recent period rate variable are more appropriately signaling the stance of monetary policy than to quantity variable. This again gives the evidence of changing operating procedure of monetary policy[8] in India as we have shown for previous sub period quantity variables are more appropriately signaling the stance while in the later period rate variables are better.

Now we present the FEVDs for the model in which call money rate is used as monetary policy variable.

[8] We have used 91-day treasury bill rate also as measure of short run interest rate and as monetary plicy variable. The results are almost similar to call money rate.

Table 2

FORECAST ERROR VARIANCE DECOMPOSITION

CMR AS MONETARY POLICY INSTRUMENT

(1996M1 to 2005 M3)

FORECAST ERROR VARIANCE OF INFLATION AS EXPLAINED BY SHOCKS TO								
HORIZON	OIL	FFRATE	INFLATION	OUTPUT	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	INFLATION	OUTPUT	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	INFLATION	OUTPUT	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	INFLATION	OUTPUT	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	INFLATION	OUTPUT	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)	17.95(11.63)	81.78(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	INFLATION	OUTPUT	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)

The results of forecast error variance decomposition for inflation shows that neer is playing an important secondary role in explaining movements in inflation. This is in contrast to the initial sub period where neer played virtually no role in explaining movements of inflation. This fact indicates the relatively opening up of the Indian economy from the previous closed structure. Thus outside fluctuations as indicated by shocks to neer are playing important role in determining in inflation. This also gives some evidence of growing importance of exchange rate channel in a small open economy like India.

Further, since inflation is not affected that much by output shocks, it also shows that cost-push factors are more important to drive inflation than demand-pull factors. As the table also shows that oil shocks explain almost 10% of inflation after a year.

NEER is largely explained by its own shocks. The results of bank credit shows that they are becoming more responsive to shocks to interest rate as compared to the level of economic activity as proxies by output. This is in contrast to the previous period and again a justification of growing importance of interest rate channel in Indian economy,

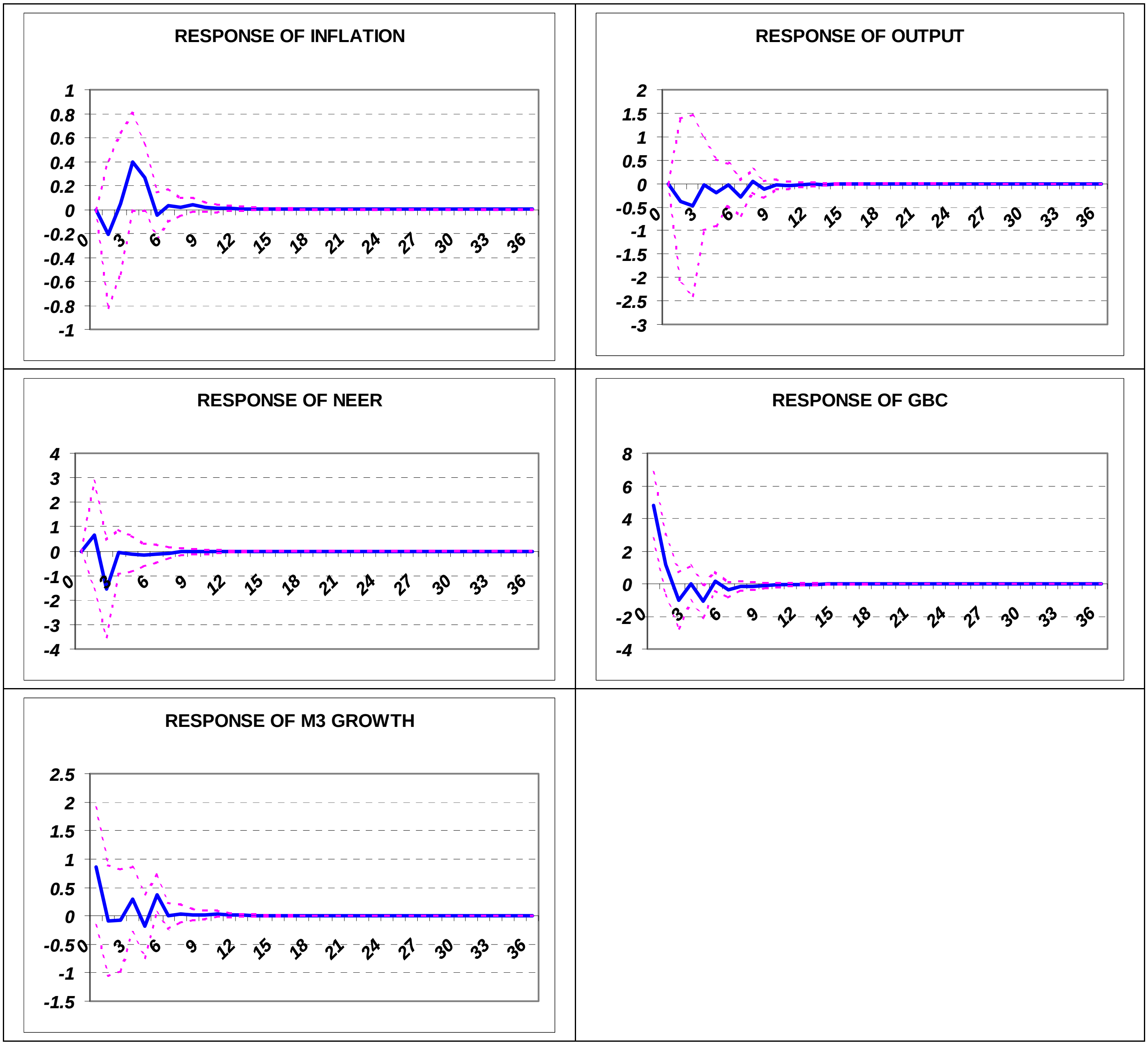
For M3 growth, the interesting development is the increasing role played by exchange rate shocks in explaining its movement. This gives justification of the exchange rate channel in the economy.

Thus we see our benchmark identification, though fails to give sensible results for the entire period, working well foe the sub period. It captured the changing monetary policy dynamics neatly. The model with call money rate as monetary policy instrument is working well for the later period (the period with which we are concerned). So we use this model for the same period for building up the pure inflation targeting case and see how the other variables response in this scenario. The figure5 shows the response of variables to positive call money rate shock in pure inflation targeting case.

Figure 5

PURE INFLATION TARGETING CASE

POSITIVE CMR SHOCK (NEGATIVE MONETARY SHOCK)



The figure 5 shows that response of variables to positive interest rate shock in ‘pure inflation targeting’ case is similar to the response in ‘multiple indicator approach’. This may point out the importance to price stability given by RBI. This implies that though not explicitly stated but RBI is giving priority to inflation over other variables. Thus these results shows that formal adoption of inflation target may not lead to any significant changes in the operating procedure of monetary policy in India. However, whether some variable will become more important for the movements in other macro variable and some will lose their importance in pure inflation targeting case, the forecast error variance decomposition results may throw some light on this issue.

Table 3

FORECAST ERROR VARIANCE DECOMPOSITION

CMR AS MONETARY POLICY INSTRUMENT

FORECAST ERROR VARIANCE OF INFLATION AS EXPLAINED BY SHOCKS TO								
HORIZON	DOIL	DFFRATE	INFLATION	OUTPUT	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 OUTPUT AS EXPLAINED BY SHOCKS TO								
HORIZON	DOIL	DFFRATE	INFLATION	OUTPUT	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 NEER AS EXPLAINED BY SHOCKS TO								
HORIZON	DOIL	DFFRATE	INFLATION	OUTPUT	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	DOIL	DFFRATE	INFLATION	OUTPUT	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	DOIL	DFFRATE	INFLATION	OUTPUT	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	DOIL	DFFRATE	INFLATION	OUTPUT	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)

Though there are not major changes in the interrelationship among variables. But some points are worth mentioning. There is a marginal decrease in shocks to exchange rate in explaining movements of inflation. Though the decrease is very marginal to draw some useful conclusion, but it may be taken as a slight evidence of insulation of inflation more from external shocks in pure inflation targeting case. Thus in pure inflation targeting case the external shocks may lead to little less volatility of inflation. Next, interesting point to note 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. 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 pure inflation targeting case. And further, external shocks as proxies by exchange rate are becoming a little more important in explaining variation of growth of gross bank credit. The pure inflation targeting case presents an interesting contrast with the 'multiple indicator approach' if we look at contemporaneous restriction matrices:

Estimated Contemporaneous Restriction Matrix

1996M1 to 2005M3

CMR as monetary Policy instrument

	doil	dffrate	wpiinf	diip	dneer	cmr	gbc	gm3
doil	0.07537	0	0	0	0	0	0	0
dffrate	0.01715	0.12471	0	0	0	0	0	0
wpiinf	-0.00136	0.00090	0.00365	0	0	0	0	0
diip	0.00151	0.00064	-0.00062	0.01089	0	0	0	0
dneer	0.00178	0.00047	-0.00207	0.00073	0.01319	0	0	0
cmr	-0.25855	0.13769	-0.11785	-0.13954	0.16083	**2.20603**	0	0
gbc	0.00017	-0.00050	0.00009	0.00011	-0.00022	0.00479	0.01023	0
gm3	0.00036	-0.00031	-0.00136	-0.00047	-0.00040	0.00086	0.00304	0.00453

Estimated Contemporaneous Restriction Matrix

Pure Inflation Targeting Case

CMR as monetary Policy instrument

	doil	dffrate	wpiinf	diip	dneer	cmr	gbc	gm3
doil	0.07537	0	0	0	0	0	0	0
dffrate	0.01715	0.12471	0	0	0	0	0	0
wpiinf	-0.00136	0.00090	0.00365	0	0	0	0	0
diip	0.00151	0.00064	-0.00062	0.01089	0	0	0	0
dneer	0.00178	0.00047	-0.00207	0.00073	0.01319	0	0	0
cmr	-0.25855	0.13769	-0.11785	0	0	**2.21628**	0	0
gbc	0.00017	-0.00050	0.00009	0.00042	-0.00057	0.00482	0.01023	0
gm3	0.00036	-0.00031	-0.00136	-0.00041	-0.00046	0.00086	0.00304	0.00453

These contemporaneous restriction matrices indicate that ‘cmr coefficient’is marginally higher in pure inflation targeting case than in ‘MPI case. But this sharper response gets moderated since it depreciates exchange rate with a lag as the impulse responses show and the resulting depreciation in exchange rate increases inflation with a lag.

Further, in pure inflation targeting case the value of contemporaneous coefficient of NEER is higher in the equation of bank credit and M3 growth and this shows the importance of exchange rate channel in ‘open economy inflation targeting’.

9. Robustness Check

We tried to make some changes in the ordering of the variables by placing output before inflation and then changing the position of the neer. We placed neer first in the domestic block and then last, but these changes did not affect the results.

10. Conclusion

The identification scheme adopted in this paper is able to capture somewhat the changing framework of monetary policy and some other interesting developments occurring in the economy. The impulse responses show the shift from quantity variable to rate variable in signaling the stance of monetary policy. The impulse responses and FEVDs suggest that in India the output is still away from its potential level. So as we mentioned in our theoretical arguments the two extreme cases where the economy can possible lie. In Indian context the latter situation seems to apply better where output has still not reached the full potential level and inflation is largely determined by commodity and exchange rate shocks and less by output shocks.

However, when we build the hypothetical inflation targeting case, we could find eventually no difference in the response of variables to monetary policy shock as compared to multiple indicator approach. However, FEVDs show that the pure inflation targeting brings little insulation of inflation from external factors but at the cost of slight vulnerability of interest rate and credit in the economy to these shocks. The 'contemporaneous restriction matrix' does indicate the that 'cmr coefficient' is higher in pure inflation targeting case which suggests sharper change in interest rates however this change gets moderated as it depreciates exchange rate with a lag and this increases inflation and also the higher value of neer coefficient in 'GBC' and 'GM3' equation indicates the importance of exchange rate channel in 'open economy inflation targeting'.

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