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EFFECTS OF MONETARY SHOCKS ON EXCHANGE RATE: EMPIRICAL EVIDENCE FROM INDIA

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Abstract:

This paper examines the effect of monetary policy shocks on exchange rate in a Multiple Indicator Approach (MIA) framework. This study has employed a monetary policy index of key monetary policy instruments in India (Bank rate, Cash Reserve Ratio, Repo and Reverse Repo rates). The study finds the empirical evidence for puzzling behavior of price level and exchange rate. Both price and exchange rate increase initially in response to a contractionary policy shock. Policy shocks affect output, inflation and exchange rate to an appreciable extent over a forecasting horizon of one year.

Key words: *Monetary Policy Transmission; Exchange rate; Impulse Response*

1. Introduction

The efficient implementation of a monetary policy strategy relies significantly on the channels of monetary transmission. These channels or vehicles of monetary transmission affect the financial market in a systematic way. In an emerging market setting, due to the underdeveloped financial system, policy signals achieve a weaker transmission effect (Bhattacharya, Patnaik and Shah, 2011). The key channels of monetary transmission, which have been identified for the Indian Economy, are interest rate, credit aggregates, asset prices and exchange rate (Mohan, 2006). Theoretically, the interest rate channel is the most significant and dominant one, since, it affects the financial market via all other three channels. However, due to the underdeveloped debt market and incompetent banking system in emerging economies, it has been empirically established that transmission mechanism through interest rate is weak (Moreno, 2008). Also the availability of loanable funds or the Credit Channel alone does not affect aggregate demand independently rather it only creates an amplification of interest rate effects (Bernanke and Gertler, 1995, Mohan, 2006). Nevertheless, exchange rate remains as one of the significant channels, transmitting monetary signals in emerging market economies (Adolfson, 2001, Bjornland, 2005).

The role of exchange rate in Monetary Transmission has received quite an ample attention in developed countries (Coibion, 2012, Bernanke and Blinder1992, Eichenbaum and Evans, 1995, Taylor, 1995, Sims and Jha, 2006), whereas very few studies have addressed this issue for developing and emerging economies like India. In the Indian context, the issue has attracted attention of the researchers since the adoption of Multiple Indicator Approach (MIA) Monetary Framework in April, 1998. In this framework, a range of indicators involving monetary aggregates, several rates of return in financial markets, movements in currency, data on fiscal position, trade, inflation, exchange rate, output and real sector activity are used for drawing policy perspectives.

The aim of the present study is to identify the effects of monetary policy shocks on exchange rate as well as other macroeconomic non-policy variables such as output and prices in the Indian context. In doing so, the present study introduces three main novelties from the empirical standpoint. First, while most of the previous studies have directly used a VAR framework, without including the cointegrating error. Since the macroeconomic variables are not stationary at levels and are likely to be cointegrated in Indian context, we have used a Vector Error Correction framework which includes the cointegration error. Second, most of the studies on the issue of Monetary Policy effects in India, have either used a narrative measure (Bhattacharya and Ray, 2007) or a single policy variable in a multivariate framework (Bhattacharya, Patnaik and Shah,2011) or they have used individual policy instruments separately to check the effect of policy shocks (Bhattacharya and Sensarma,2008). The combined effect of changes in all the policy instruments is difficult to capture since the issues of endogeneity in the model will appear. To account for this combined effect, we have constructed a Monetary Policy index using the method of Principal Component Analysis, which contains the effect of changes in all frequently used Policy instruments i.e. Bank Rate, Cash Reserve Ratio (CRR), Repo and Reverse Repo rates. Finally, the present study updates the subject with the inclusion of most recent data. The study focuses on the period after adoption of the MIA framework of monetary policy. Since the repo auctions have started in 2000, monthly data from April, 2001 to March, 2014 has been used for the analysis.

The paper is organized as follows. The second section reviews the related literature and points out the research gap, while the section 3 discusses the empirical models. The detailed description of Data and the sources is presented in Section 4. Results of empirical modeling are presented in Section 5. The final section covers conclusion and policy suggestions.

2. The Empirical Model

The empirical studies on monetary policy are predominantly based on a multivariate VAR framework, where the time path of each variable is affected by the current and past realizations of all other variables. This primitive form of VAR is known as the structural VAR .The generalized vector representation of a Structural VAR is as follows:

$$Bx_t = \Gamma_0 + \Gamma_1 x_{t-1} + \varepsilon_t \tag{1}$$

Where B is a (n x n) coefficient matrix, x_t is a (n x 1) matrix of n variables, Γ_0 is a (n x1) matrix of intercept terms, Γ_1 is a (n x n) coefficient matrix of lagged vector (x_{t-1}) and ϵ_{t-1} is a vector of pure innovations or shocks in all n variables. The structure of such a system includes feedback, since each variable is allowed to contemporaneously affect the other variable. In such kind of a framework, the error terms in each of the equations is correlated with the other regressors, so the primitive VAR form cannot be estimated directly. Multiplying both left hand side and right hand side of equation (1) with B^{-1}, will generate a reduced form of VAR, also known as Standard VAR. Hence the generalized Standard VAR equation is as follows:

$$\begin{aligned} x_t &= A_0 + A_1 x_{t-1} + e_t \\ where: A &= B^{-1}\Gamma_0 \\ A_1 &= B^{-1}\Gamma_1 \\ e_t &= B^{-1}\varepsilon_t \end{aligned} \tag{2}$$

However, the primitive form of VAR is not completely identifiable, until the parameters are appropriately restricted (Sims, 1980). If the minimal restrictions (i.e. $(n^2-n)/2$) for n variables) are put in the order in which variables are ordered in a VAR model, it is known to be a recursive structural model, else it is non-recursive in nature. The specific ordering of the variables puts the systematic restrictions in a VAR framework. The variable which comes first in order is not affected by shocks to the other variables, but shocks to the first variable affect the subsequent ones.

The VAR framework is based on the pre-requisite of stationarity of time series variables. If the variables are not stationary in levels, then a differenced form needs to be utilized for the same. This approach, however does not take into account a prevailing long run relationship, if the series are cointegrated, which in effect is considered to be a loss of information(Bhattacharya, Patnaik, Shah, 2010). Although most of the studies employ VAR model due to its higher robustness, VECM generated impulse responses are more precise, when the variables involved have stochastic trends and are cointegrated (Jang, Ogaki, 2003).

We employ the VECM framework to determine the effect of monetary policy shocks on Indian Rupee/US dollar exchange rate. For an open economy like India, the domestic variables are treated to be endogenous and the foreign variables as exogenous (Bhattacharya, Patnaik, Shah, 2010, Mishra and Mishra, 2010) since, shocks to foreign variables affect domestic variables, but same is not true in case of vice versa. The VECM model employed in this study is:

$$\Delta x_t = \pi_0 + \alpha\beta x_{t-p} + \pi_1 \Delta x_{t-1} + \pi_2 \Delta x_{t-2} + \ldots\ldots + \pi_p \Delta x_{t-p} + \delta X_t + u_t \quad (3)$$

Where $x_t = \begin{bmatrix} y_t \\ p_t \\ e_t \\ r_t \\ m_t \end{bmatrix}$ and $X_t = \begin{bmatrix} p_t^* \\ i_t^* \end{bmatrix}$

where

$x_t =$ Vector of endogenous variables including exchange rate e_t, policy rate r_t, output y_t, price level p_t and money supply m_t,

$X_t =$ Vector of exogenous variables: US price level p_t^* and US interest rate i_t^*.

$\pi_0 =$ Vector of intercept terms

$\pi_i =$ Coefficient matrix with elements $\pi_{jk}(i)$

$\beta =$ Cointegrating Vector

$\alpha =$ Vector of adjustment parameters

$u_t =$ Vector of error terms

Identification of Shock Structure

The effect of domestic monetary policy shocks on exchange rate can be identified by using Cholesky decomposition which involves a specific ordering of variables contained in the VECM framework. Our model for identification scheme includes exchange rate, output, price level, policy rate and money supply. Therefore, we have the following the identification scheme:

$$\begin{bmatrix} u_t^y \\ u_t^p \\ u_t^e \\ u_t^r \\ u_t^m \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_y^p & 1 & 0 & 0 & 0 \\ a_y^e & a_p^e & 1 & 0 & 0 \\ a_y^r & a_p^r & a_e^r & 1 & 0 \\ a_y^m & a_p^m & a_e^m & a_r^m & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_t^y \\ \varepsilon_t^p \\ \varepsilon_t^e \\ \varepsilon_t^r \\ \varepsilon_t^m \end{bmatrix} \quad (4)$$

The matrix on the left side of the equation represents the composite errors of the reduced form equation and the (5x1) matrix on the right indicates the pure innovations or shocks.

The ordering is done here assuming that RBI announces monetary policy statements, after considering current values of exchange rate, output and prices. Consequently, all of these factors have contemporaneous effect on Policy announcements. However, policy innovations have no have no immediate effect on these macroeconomic variables, but only on Money Supply. That is exactly in line with the MIA framework and hence, the policy rate has been ordered after exchange rate, output and price level in the sequence. The restrictions arising out of this ordering result in a specific composition of each of the residuals in error vector u_t. Decomposing the residuals of different compositions in this framework to see the contemporaneous effect of variables on each other is basically known as the Cholesky Decomposition. Accumulating these contemporaneous affects over a series of time periods constitutes an Impulse Response Function(IRF), which can be plotted on a two dimensional graph.

3. Data Description and Monetary Policy Index

3.1. Data Description

We estimate the VECM model employing monthly data from April, 2001 to March, 2014. This sample period has been selected based on two pre-conditions i.e. (1) MIA framework was adopted in April, 1998 and (2) Repo auctions have started in April, 2001. The endogeneous variables[1] include rupee-dollar nominal exchange rate (e), real income or output (Index of Industrial Production), general price level (Wholesale Price Index), Broad money (M3) and a monetary policy index (constructed using a Prinicipal Component Analysis (PCA) of Bank rate, CRR, Repo and Reverse Repo rates). The 3-months Treasury bill rates of U.S and the U.S. Producer Price Index (P.P.I.) form the set of exogeneous world variables[2]. The data is taken in the form of seasonally adjusted[3] values (except exchange rate) in their natural logarithms (except interest rates, which are in their linear form).

3.2. Monetary Policy Index

In order to capture the monetary policy stance in an efficient way, we construct a monetary policy index for India using the method of Principal Component Analysis (PCA). Data on CRR, Repo rates and Bank rate is utilized to construct this index via PCA method. Before applying PCA for Bank rate, CRR, Repo and Reverse Repo rates, the degree of correlation among them, needs to be determined. Table 1 shows the correlation matrix for these four policy rates, which is obviously show high inter-correlation relationship. Therefore, use of the index is justified as using these variables

[1] The data on all the endogeneous variables for India has been collected from RBI's Handbook of Statistics on the Indian Economy.
[2] Data on 3-months Treasury bill rates of U.S. and PPI have been collected from the Federal Reserve website.
[3] Data has been seasonally adjusted using ARIMA X12 procedures

together in the model may lead to a serious multicollinearity problem. Finally, we have employed the PCA weights for constructing a composite index of monetary policy.

Table1. Correlations among policy rates

Correlations	BR	CRR	REPO	REV
BR	1.000000			
CRR	0.301324	1.000000		
REPO	0.560655	0.609671	1.000000	
REV	0.478440	0.564320	0.916622	1.000000

The number of Principal Components generated is equal to the number of variables used to construct the index, which means 4 PC's will be generated in this case. The first component accounts for the maximum variance and the succeeding components will account for smaller proportions. The variance that is accounted for a given component is expressed in terms of Eigen Values. Sum of all the Eigen values is equal to the number of variables or the number of PC's generated. Table 2 shows the PC's and their respective eigen values. In accordance with the Eigen Value-one criterion (also known as the Kaiser Criterion), only PC's with Eigen Value more than one have to be retained and interpreted. Table 2 shows that out of the four PC's, only PC1 needs to be retained which explains about 69% of the total variance. Each of the PC's generated have been assigned a specific weighted composition for all the 4 variables. The Eigen Vector or the weights of different variables in PC1 as shown in Table 3 are multiplied with the time series of the respective variables. These individual weights are then added to make a new time series. This variable is converted into an index by taking the first value of the series as the base value. The index thus formed will be used in the analysis in its logarithmic form.

Table2. Principal Component Analysis

Principal Component	Eigen Value	Difference	Proportion	Cumulative Eigen Value	Cumulative Proportion
PC1	2.759430	2.054087	0.6899	2.759430	0.6899
PC2	0.705343	0.245924	0.1763	3.464773	0.8662
PC3	0.459419	0.383610	0.1149	3.924192	0.9810
PC4	0.075808	---	0.0190	4.000000	1.0000

Table3. Eigen Vectors (Loadings)

	PC1
BR	0.409224
CRR	0.445885
REPO	0.572878
REV	0.552750

4. Empirical Results

4.1 Stationarity and Cointegration among variables

To check the stationarity of the variables in a robust manner, two alternative unit root tests are used. The Augmented Dickey-Fuller (ADF) test and Phillips–Perron (PP) test share the same null hypothesis of a unit root. Appropriate lag length for ADF test has been selected using Schwarz Information Criterion (SIC) for a maximum lag of 12 periods in each case. Appropriate bandwidth for Phillips-Perron test has been selected using Newey-West Criterion. Variables have been tested for stationarity at level as well as at first difference using the appropriate specification for “with or without a drift”. The unit root equation for all other variables except ln (e) includes a constant term as an exogenous component (whereas ln (e) equation includes no such component). The natural logarithm of IIP, M3 and WPI has been found to be stationary at levels when a trend term is introduced (the results for the same have not been reported). Both ADF and PP test results show that all the macroeconomic variables are stationary at first difference i.e. they are integrated of order 1. These results are reported in Table 4.

Table 4: Results of ADF and PP Unit root tests

Variables	ADF		PP	
	Test statistic	Lag Length (SIC)	Test statistic	Bandwidth (Newey-West Criterion)
$\ln e$	-0.207540 (0.6093)	1	-0.154202 (0.6282)	5
$\Delta \ln e$	-7.159579*** (0.0000)	0	-7.196619*** (0.0000)	1
$\ln r$	-2.394641 (0.1458)	4	-1.906668 (0.3282)	6
$\Delta \ln r$	-3.893410*** (0.0030)	3	-6.453061*** (0.0000)	3
$\ln y$	0.540943 (0.9874)	1	0.538049 (0.9873)	6
$\Delta \ln y$	-17.45077*** (0.0000)	0	-17.58407*** (0.0000)	1
$\ln p$	0.284229 (0.9765)	1	0.376444 (0.9811)	4
$\Delta \ln p$	-5.967924*** (0.0000)	0	-5.860036*** (0.0000)	1
$\ln p^*$	-1.348535 (0.6047)	0	-1.240433 (0.6548)	2
$\Delta \ln p^*$	-12.37381*** (0.0000)	0	-12.33765*** (0.0000)	2
i^*	-1.029901 (0.7405)	1	-1.158185 (0.6903)	7

$\Delta i*$	-5.994594*** (0.0000)	0	-6.057703*** (0.0000)	4
$\ln m$	0.834942 (0.9942)	0	3.332928 (1.000)	106
$\Delta \ln m$	-11.58362*** (0.0000)	0	-11.77155*** (0.0000)	27

*** represents statistically significant values at 1% significance level

Johansen's Cointegration test has been used to examine the possibility of long run co-movement among variables. Johansen's test results are sensitive to the lag length and to determine optimal lag length, a traditional VAR is estimated using data series at level for endogenous variables. Table 5 shows different lag length criteria for a VAR specification of the endogeneous variables, with 12 maximum lags in each case. Lag order selection is based on AIC (Akaike Information Criterion). It indicates an optimal lag length of 2 periods. Using this lag length, we have conducted the Johansen test and results are presented in Table 6. Both Trace test and Max tests show that there are two long run cointegrating vectors.

Table 5: Lag order selection criteria

Lags	LR	FPE	AIC	SIC	HQ
0	NA	9.22E-13	-13.52239	-13.38883	-13.46841
1	1421.303	2.15E-19	-28.79382	-27.99246*	-28.4699
2	91.73996*	1.24e-19*	-29.35228*	-27.88312	-28.75842*
3	36.24559	1.34E-19	-29.28452	-27.14756	-28.42072
4	36.00933	1.42E-19	-29.24381	-26.43905	-28.11008
5	35.91025	1.48E-19	-29.23598	-25.76342	-27.83231
6	13.37452	2.14E-19	-28.92091	-24.78055	-27.24731
7	29.89972	2.35E-19	-28.8984	-24.09025	-26.95487
8	22.13125	2.92E-19	-28.77996	-23.304	-26.56649
9	24.91177	3.42E-19	-28.75736	-22.61361	-26.27395
10	29.30066	3.59E-19	-28.88765	-22.0761	-26.13431
11	26.7346	3.92E-19	-29.03518	-21.55583	-26.01191
12	27.43775	4.10E-19	-29.29828	-21.15114	-26.00507

Notes: 1. * indicates lag order selected by the criterion (at 5% level). 2. LR: sequential modified LR test statistic, 3. FPE: Final prediction error, 4. AIC: Akaike Information criterion 5. SIC: Schwarz Information criterion, 6. HQ: Hannan-Quinn information criterion

Table 6: Results of The Johansen's Cointegration test

Rank Order(r)	Eigen value	λ_{trace}	0.05 Critical value	$\lambda_{\max}$	0.05 Critical value
$r = 0$	0.391290	104.9579* (0.0000)	69.81889	52.12341* (0.0001)	33.87687

$r \leq 1$	0.275017	52.83454* (0.0158)	47.85613	33.76874* (0.0071)	27.58434
$r \leq 2$	0.110973	19.06580 (0.4882)	29.79707	12.35085 (0.5134)	21.13162
$r \leq 3$	0.039141	6.714949 (0.6110)	15.49471	4.192351 (0.8385)	14.26460
$r \leq 4$	0.023738	2.522598 (0.1122)	3.841466	2.522598 (0.1122)	3.841466

p-values are in parenthesis
* represents statistically significant values at 5% level

4.2 Impulse Response Functions

Lag order selection tests indicate an optimal lag of 2 periods for VAR setup. Hence the VECM representation of the model should include 1 lag. Therefore using one period lag, VECM is estimated. Using the Cholesky ordering as specified above in section 4, Impulse Response Functions are generated over a period of 24 months. Figure 1 shows the response of all endogeneous variables to a contractionary monetary policy shock. The results obtained are theoretically consistent. As shown in Figure 1(a), whenever Reserve Bank of India, takes contractionary steps by increasing the policy rates, there is always a decline in output, which is followed by decline in prices (Figure 1 (b)). However, initially, the prices have shown an increasing trend towards monetary tightening. This is in confirmation to the empirical "price puzzle"[1] . The decline in prices is observed to be maximum after a lag of one year. Clearly the graph 1(b) shows that inflation adjusts slowly in response to the policy rates. It stabilizes after some time. So, RBI's control over inflation is working in lags. Also, in an emerging economy setup like India, central bank's focus is on inflation and the economic growth comes secondary in the short run. In order to control inflation very often output gets adversely affected, which is clearly visible from graphs 1(a) and 1(b). Exchange rate response (Figure 1(c)) is also supporting a puzzling behavior (see also Kim and Roubini, 2000). A positive shock to policy rates leads to an immediate rise in exchange rate and then it comes down slightly to attain a stable level. The impulse response functions generated have shown theoretically and empirically consistent results, which gives robustness to the identification structure of the model.

[1] Kim and Roubini (2000) have summarized various empirical puzzles.

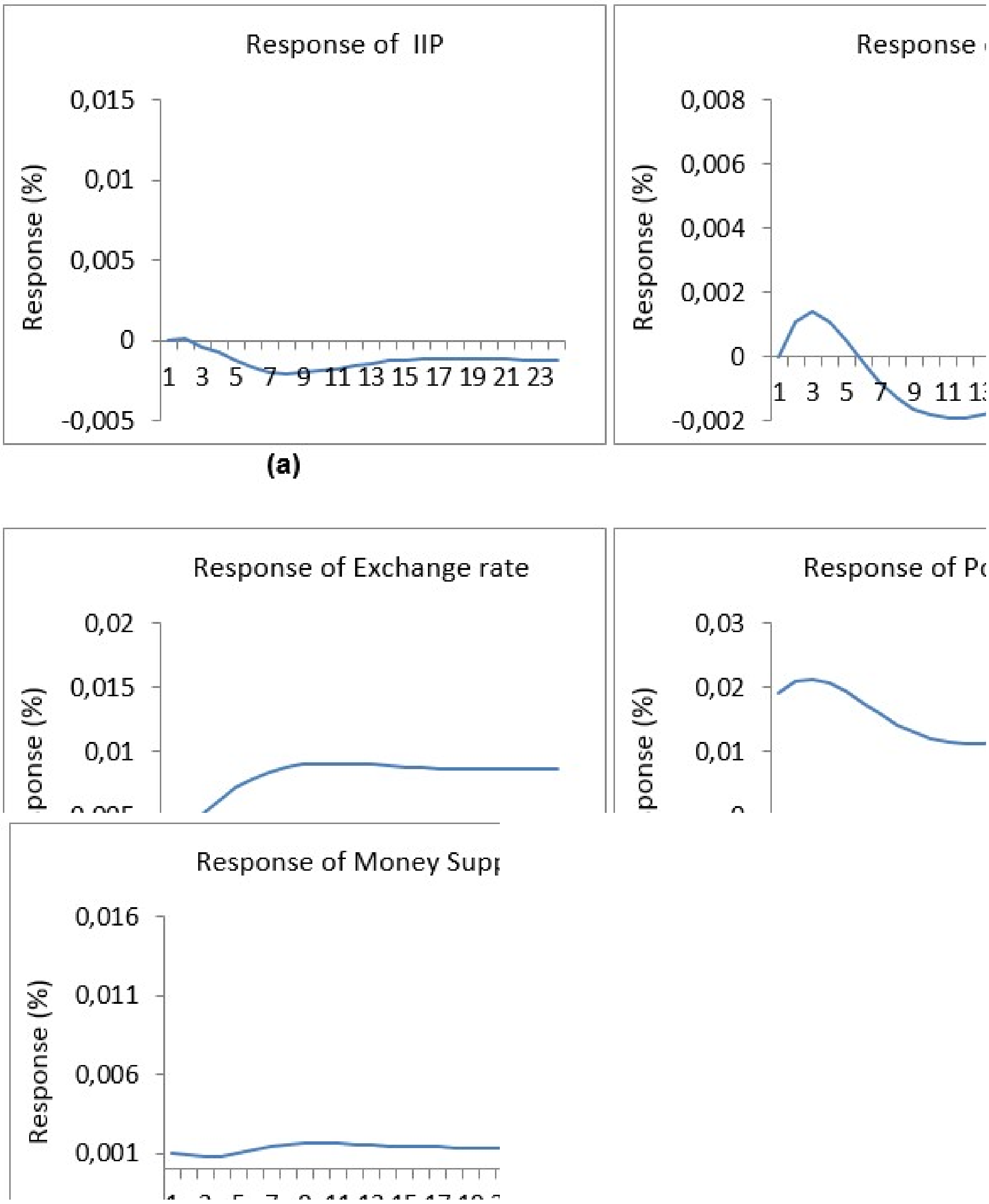

Figure 1. Impulse Response Functions:
(a) Response of IIP; (b) Response of WPI; (c) Response of Exchange Rate; (d) Response of Policy Rate; (e) Response of Money Supply

4.3. Forecast Error Variance Decomposition (FEVD) Analysis

Table 5 shows the Forecast Error Variance Decomposition (FEVD) results for the same Cholesky ordering as employed above. For a one year forecast horizon, shocks to monetary policy rate accounts for about 4% of the fluctuations in the output. It also accounts for about 8% inflation movements over the same forecasting horizon. Policy shocks affect a year ahead exchange rate forecast to an appreciable extent of 11%. Money Supply is playing an important role in managing inflation, since it accounts for about 18% variation in a 12 month forecast. Output and Inflation together account for a huge (32%) proportion of one year policy rate forecasts. Exchange rate do explain monetary stance to a proportion of 10%. Again, this adds to the robustness of our model, since it captures the intention of MIA framework.

Table 7: Results of Forecast Error Variance Decompositions

Variance Decomposition of Output					
Period	Output	Inflation	Exchange rate	Policy rate	Money Supply
1	100.0000	0.000000	0.000000	0.000000	0.000000
3	86.47338	2.186316	8.017971	0.061550	3.260779
6	65.44188	5.675844	13.83924	1.498011	13.54502
9	46.68250	11.52634	16.75660	3.499717	21.53484
12	37.71093	13.03476	18.56735	4.232038	26.45493
Variance Decomposition of Inflation					
Period	Output	Inflation	Exchange rate	Policy rate	Money Supply
1	0.000199	99.99980	0.000000	0.000000	0.000000
3	0.602780	94.36146	2.307136	2.585835	0.142789
6	1.722609	90.53853	2.592254	2.512043	2.634560
9	1.913552	81.46697	2.344743	4.523759	9.750972
12	1.666168	70.80004	2.155193	8.191847	17.18675
Variance Decomposition of Exchange rate					
Period	Output	Inflation	Exchange rate	Policy rate	Money Supply
1	0.065844	1.417660	98.51650	0.000000	0.000000
3	1.355556	5.821644	88.21556	4.355841	0.251396
6	2.813769	14.90669	73.53785	8.305279	0.436419
9	2.908177	20.36739	66.03230	10.33075	0.361382
12	2.793367	22.90802	62.67459	11.31071	0.313321
Variance Decomposition of Policy rate					
Period	Output	Inflation	Exchange rate	Policy rate	Money Supply
1	3.449398	1.386157	1.372362	93.79208	0.000000
3	6.420966	10.45100	4.075209	78.19636	0.856466

6	14.50936	7.452208	5.149671	71.64034	1.248425
9	19.04399	8.007140	7.931177	64.06631	0.951380
12	20.11734	12.39746	10.52529	56.20451	0.755410
Variance Decomposition of Money Supply					
Period	Output	Inflation	Exchange rate	Policy rate	Money Supply
1	0.198352	0.001617	0.283501	0.660498	98.85603
3	1.272117	1.295786	0.186666	0.707483	96.53795
6	2.307583	0.939446	0.157758	0.920865	95.67435
9	3.269248	0.778306	0.114488	1.449659	94.38830
12	4.052382	0.728227	0.089111	1.823935	93.30634

5. Conclusion

The present study analyzed the effects of monetary policy shocks using a recursive-VAR framework based on the Multiple Indicator Approach (MIA) adopted by RBI in formulating monetary changes. While examining these effects in an open economy like India, world variables need to be considered in the form of exogenous variables. We have employed U.S. interest rate and U.S. Producer Price Index as exogenous variables apart from the endogenous domestic monetary variables. We have examined the responses of the macro entities for the monetary policy shocks. The results of this examination are qualitatively robust and consistent with theory as well as empirical literature. The persistent decline in prices after an initial appreciation for a quarter, in response to a contractionary shock is a clear evidence of the "price puzzle". Exchange rate do portray a puzzling behavior, as in response to a contractionary policy, it increases (depreciates) for about one year and then comes to stability. RBI, through Monetary Policy announcements is controlling inflation, output and exchange rate to an extent of 8%, 4% and 11%, respectively. Therefore, the transmission of monetary signals is quite appreciable in Indian context. However, it comes into play after a lag of one year. The prevalent output, inflation and exchange rate contribute significantly in forecasting monetary policy rate.

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