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# The Effect of Exchange Rate on Inflation in India: A Structural Vector Autoregression Estimation

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**Abstract:** This paper estimates the effect of the changes in the exchange rate on domestic inflation under the managed floating exchange rate regime in India. The potential channels of causality between exchange rate, inflation rate, output and interest rate, and the sources of contemporaneous shocks are identified following the Kamin and Rogers framework. Using monthly data for the period from April 1994 to April 2017, this paper estimates the structural relationship among the variables applying the VAR and SVAR estimation methods. The SVAR estimates show that variations in the exchange rate are explained more by the output gap than the inflation rate. The estimated effect of changes in the exchange rate on inflation is just 0.1 percent while the effect of changes in inflation on the exchange rate is more than 4 percent. The low effect of exchange rate on inflation in India is largely due to the RBI's managed floating exchange rate regimes that goes hand to hand with the market determination of the exchange rate. The effective intervention of the Reserve Bank of India evens out exchange rate volatility by increase/decrease in net foreign exchange assets and sterilises the expansionary monetary effect by increase/decrease in net domestic credit. The effective RBI intervention on the foreign exchange rate almost neutralises the effect of exchange rate on inflation rate in India.

***Keywords:*** Managed floating exchange rate, volatility, domestic inflation, structural vector autoregression estimation

## Introduction

The relationship between exchange rate and inflation is of vital importance for any economy, especially so in developing and emerging market economies. In many of these economies, exchange rate fluctuations significantly affect the general level of prices (Dornbusch, 1976). The volatility in the exchange rate affects the price level in many ways. A depreciation in the exchange rateleads to a rise in the price of imported goods forcing the importing country to pay more in home currency in exchange for other currency which in turn adds to production costs that leads to domestic inflation.A stable exchange rate is considered less inflationary than a more flexible regime as it has a restrictive impact on the determinants of inflation such as money supply and money demand (Crockett and Goldstein, 1976). For example, in the United States, a 10 percent deprecation of dollar leads to 1.6 percent increase in one year and 4.6 percent increase after four yearsin the price level (Koch et al. 1988). Therefore, the stability of the exchange rate is crucial for domestic economic management as a stable exchange rate is expected to reduce domestic inflation pressures of an economy. In fact, the main objective of any central bank's monetary policy is to maintain stability in both foreign exchange rate and domestic price level.

India has gone through several exchange rate regimes likepar-value system(1947-1971), pegged regime (1971-1992) and managed floating exchange rate or market determined exchange rate system (1993 onwards) (Kapur *et al.* 2003). The market determined exchange rate system in India also coincides with the adoption of structural reformsand opening up the domestic markets for globalisation. The current Indian exchange rate policy focuses on 'manage volatility' with no fixed targets underlying demand and supply conditions to determine exchange rate movement in an orderly way (RBI, 1993). The Figure 1presents the trend in the exchange rate of Indian rupee with the UD dollar in India between 1994-2017 on yearly average basis. In can be noted that between 1994 and 2002, the exchange rate trend has been increasing at an increasing rate, due to globalisation and huge import dependency. The exchange rate has been increasing at a slow rate between 2002 to 2011 because the country has started producing many products by itself which lead to low imports and reduced the need of foreign currency for exchange. From 2012 onwards, the trend of exchange rateper US dollar has been increasing at the rate of 3.69 percent, as the import of more technical tools from the US made per dollar more expensive in relation to the Indian rupee.

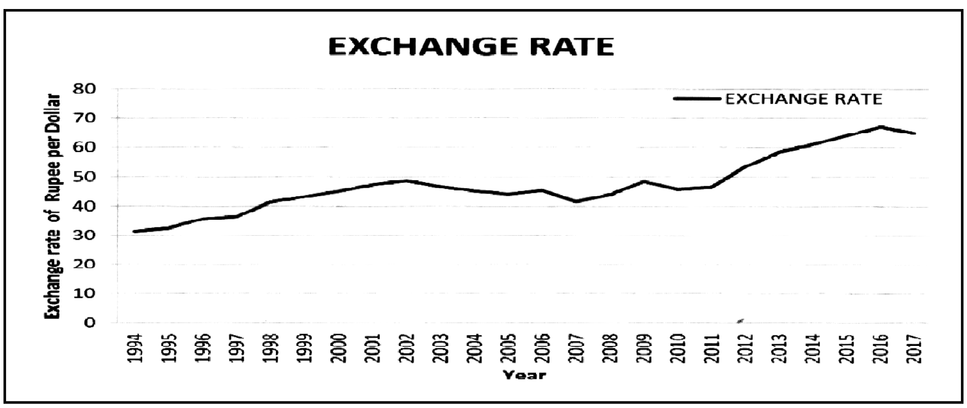


**Figure 1:** Trend in Exchange Rate in India, 1994-2017

On the inflation side, India has been experiencing a rising trend of inflation, on average 5.11 percent per year or 0.70 percent on monthly basis, which is considered much higher compared to other growing economies. The Figure 2 presents the trend of inflation in India during the period from 1994 to 2017 which shows that there has been an increasing trend in inflation at an average rate of 9.97 percent. From 1998 to 2008 the trend has been on average 4.93 percent and it has been increasing at a decreasing rate as there was high agricultural production. From 2009 to 2017, the inflation trend has been on average 7.90 percent. The inflation peaked to 13.17 percent in 1998 at the backdrop of an exceptionally turbulent and unfavourable international economic environment. The year also saw a significant decline in the GDPs of several East Asian countries, continuing recession in Japan, the severe financial crisis in Russia, and unusual volatility in capital and forex markets of industrial countries.

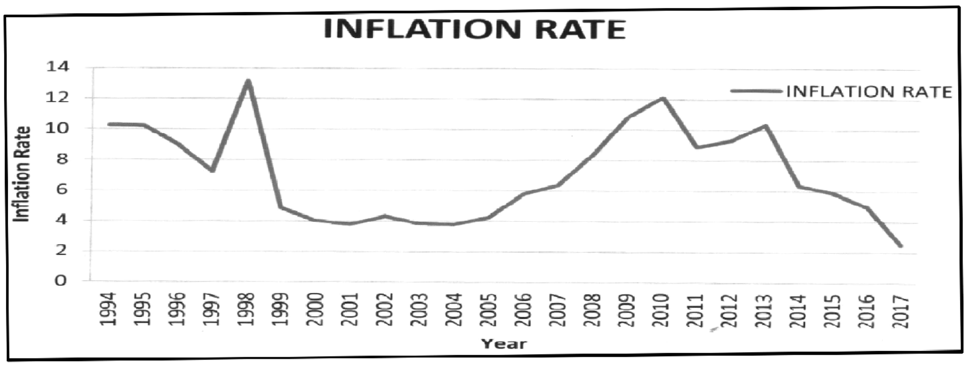


**Figure 2:** Trend in Inflation Rate in India, 1994-2017

The depreciation of Indian rupee has made domestic inflation more acute, and the trendsin inflation rate and exchange rate India are highly unstable in India. There are many different factorsthat contribute to the volatility in the exchange rate as well as the price level. The main objective of this study is to understand the effect of instability exchange rate on domestic inflation in India. The study follows the theoretical approach of Kamin and Rogers (2000)and empirically the structural vector autoregression (SVAR) model onmonthly data for the period 1994 to 2017to examine the relationship between exchange rate and inflation in India. Studies on the relationship between exchange rate and inflation further note that theeffect of exchange rate on domestic price level depends on the exchange rate regime also. Different exchange rate regimes impact inflation differently. Therefore,this study focuses on the managed floating exchange rate regime in India, where the market determination of the exchange rate with RBI's intervention is simultaneously carried.

## A Brief Review of Recent Studies

The theoretical relationship between the exchange rate and domestic price level has been variously modelled in economic studies using various approaches. The trade or elasticity approach states that at any point of time if import exceeds exportscausing trade deficit, then the exchange rate falls andthe domestic currency depreciates. In such a situation,the export will be cheaper and import will be costlier. The speed of adjustment to restore the balance will depend on the degree of responsiveness of the trade towards the price change. The purchasing power parity (PPP) or the "law of one price" approach suggests that the price of similar products of two different countries should be equal if they are measured in the common currency. The PPP equilibrium value of exchange rate e is determined as $e = p_d/p_f$, where $P_d$ is the domestic price level and $P_f$ is the foreign price level of a commodity. If there exists any difference, then the demand should shift from one country to another in such a way that the price will have to converge. The monetary exchange rate approach focuses on the monetary policies of two countries in order to determine their currency exchange rate, using price dynamics and interest rate dynamics. A change in domestic money supply leads to a change in the level of prices and a change in the level of prices leads to a change in the exchange rate. The exchange rate determination model may also incorporate unanticipated shocks to the trade balance and change in the long-run exchange rate along with inflation. A domestic (foreign) trade balance surplus (deficit) indicates an appreciation of the exchange rate.

Empirically, Deravi *et al.* (1995) examines the effect of exchange rate depreciation on price level using a vector autoregressive model of the exchange rate, price level and money supply forthe period from January 1975 to February 1990 in Iran. The estimated results show that exchange rate depreciation leads to changes in price level and the explanatory power of money supply is less than the exchange rate in explaining and predicting the price level. Monfared and Akin (2017) also analyse the relationship between exchange rate and inflation in Iran for the period 1976-2012 estimating VAR model. based in Iran on time series data, using Hendry General to Specific Modeling method and Vector Autoregression (VAR) model. The estimated results show that money supply and exchange rate affect inflation positively and the impact of money supply on inflation is greater than that of the exchange rate.

Ebiringa and Nnneka (2014) show that an exchange rate movement positively affects price level changes and negatively affects interest rate in Nigeria in the short-run. In the long-run exchange rate pass through (ERPT) effect has been higher in import than in consumer prices, implying that the pass-through effects decline along the pricing chain.In euro currency countries, Comunale and Kunovac (2017) observe that exchange rate changes of euro against its trading partners are reflected more quickly and more sizably in movements in import price inflation and less in producer and consumer price inflation. The nominal effective exchange rate of the euro against its main trading partners has depreciated by 4 percent that put substantial upward pressure on import prices for consumer goods increasing the price of these goods by 3.5 percent.

In India, Mohanty and Bhanumurthy (2014) evaluates different exchange rate regimes in India and investigates the relationship between various exchange rate regime and inflation using the autoregressive distributed lag model. The empirical estimates suggest that the relation between the two variables is very insignificant.

## Data and Methodology

For analysing the impact of exchange rate on inflation in India, this study uses monthly data for the period April 1994 to April 2017, consisting of 277 observations, collected from the Reserve Bank of India's Handbook of Statistics on Indian Economy. Besides the exchange rate and price level, this study also uses two other variables, output and interest rate. The income variable is measured by the output gap, the index of industrial production (IIP) less Hodrick-Prescott filtered smooth series, a proxy for the output produced in the country.The IIP, measuring the amount of output which has been produced in the country, includes basic goods, capital goods, intermediate goods and consumer goods, with weights to each category of goods. Theoutput level is directly related to the price level in any economy. As the country produces more output the domestic price will be less and there will be less import, whereas if the country produces less output the price paid will be more as importsgo up. The exchange rate is measured as a percentage change in rupees per US dollar, $[(RER_t - RER_{t-1})/RERt\text{-}1]*100$, measuring the value of the domestic currency in term of foreign currency. Inflation is measured as percentage change in wholesale price index (WPI), $[(WPI_t - WPI_{t-1})/WPI_{t-1}]*100$, indicating domestic price level. The WPI consists of five commodity categories - primary articles, food articles, non-food articles, fuel and power and manufacturing products. The interest rate is measured by a weighted average call money rate, an indicator of response to monetary policy.

## Theoretical Model

Kamin and Rogers (2000) provide a framework that incorporates nearly all of the potential channels of causality linking exchange rate, inflation rate, output and interest rate, and that identify the sources of contemporaneous shocks. The total income (*Y*) i.e. GDP is divided into domestic demand (DD) and net exports (*NX*):

$$Y = DD + NX \tag{1}$$

Net export is positively related to the real exchange rate (RER), the real rupee value of the foreign currency:

$$NX = a_{21}\, RER - a_{22}\, Y \tag{2}$$

The domestic demand is determined by the real interest rate (*r*), fiscal deficit (*FD*), bank credit (*BC*), nominal interest rate (*IR*), rate of domestic inflation (*INF*), the real exchange rate (*RER*) and real wage rate (*RW*):

$$DD = a_{31}\, r + a_{32}\, FD + a_{33}\, BC - a_{34}\, IR - a_{35}\, INF - a_{36}\, RER + a_{37}\, RW \tag{3}$$

The bank credit is determined by the real domestic money holding (DM) and net capital inflows, a proxy for borrowing from abroad (CI):

$$BC = a_{41}\, DM + a_{42}\, CI \tag{4}$$

Domestic money demand is expressed in terms of income and interest rate:

$$DM = a_{51}\, Y - a_{52}\, IR \tag{5}$$

The nominal interest rate is determined by a central bank reaction function based on inflation, output, and level of capital inflows:

$$IR = a_{61}\, INF + a_{62}\, Y - a_{63}\, CI \tag{6}$$

The central bank raises interest rate with an increase in inflation and economic activity and reduces interest rate with an increase in net capital inflows.

The inflation rate is determined by real exchange rates, output level, and exchange rate depreciation. Increases in the level of real exchange rate shift demand toward non-traded goods, thereby raising overall prices for a given level of the nominal exchange rate. Increases in output raise inflation through traditional demand effects, while depreciation in the nominal exchange rate (NERD) raises inflation by increasing the cost of imported goods:

$$INF = a_{71}\, RER + a_{72}\, Y + a_{73}\, NERD \tag{7}$$

The net capital inflows is determined by interest parity - domestic and foreign interest rates, and nominal exchange rate depreciation (NERD):

$$CI = a_{81}\, IR^{d} - a_{82}\, IR^{f} - a_{81}\, NERD \tag{8}$$

When the government targets the real exchange rate, the government sets a real exchange rate target first and then adjusts the nominal exchange rate in response to domestic and foreign inflation in order to meet that target. Hence, nominal depreciation of the exchange rate is determined by domestic inflation ($INF^{d}$), foreign inflation ($INF^{f}$), and real exchange rate:

$$NERD = a_{91}\, INF - a_{92}\, INF^{f} + a_{93}\, RER \tag{9}$$

The government sets the target real exchange rate in response to balance-of-payments pressures. Hence, improvements in net exports cause the real exchange rate to appreciate, as do increases in net capital inflows. The real net exports are not affected by changes in the terms of trade, but increases in oil prices (OP) improve the dollar valuation of the balance of payments and hence encourage real exchange rate appreciation:

$$RER = a_{101}\, NX - a_{102}\, CI + a_{103}\, OP \tag{10}$$

The fiscal deficit declineswith increases in output which improves tax revenue. But, increases in net capital inflows raise the fiscal deficit, both because improved access to foreign credit allows the government to borrow more abroad and because improved investor attitudes allow the government to pursue less constrained policies. Conversely, the increase in inflation prompt the government to tighten fiscal policies by primary (non-interest) fiscal deficit through budget balance, but the increase in inflation that the feedthrough interest rates tend to raise overall budget deficit. Increase in oil prices, a major source of revenue for the government, tend to lower fiscal deficits:

$$FD = -a_{111}\, Y + a_{112}\, CI - a_{113}\, INF - a_{114}\, OP \tag{11}$$

The last key variable, level of real wage rate (RW) depends positively on output and negatively on inflation:

$$RW = a_{121}\, Y - a_{122}\, INF \tag{12}$$

These 12 specifications constitute the potential channels of causality between endogenous variables exchange rate, inflation rate, output and interest rate, with contemporaneous and external shocks. Therefore, the structural model can be specified as:

$$V_t = \Sigma_{i=1}^{k} a_1 Y_{t-i} + \Sigma_{i=1}^{k} a_2\, INF_{t-i} + \Sigma_{i=1}^{k} a_3 IR_{t-i} + \Sigma_{i=1}^{k} a_4 RER_{t-i} \tag{13}$$

This can be written in matrix form as:

$$\begin{bmatrix} Y_t \\ INF_t \\ IR_t \\ RER_t \end{bmatrix} = \begin{bmatrix} a_{11}a_{12}a_{13}a_{14} \\ a_{21}a_{22}a_{23}a_{24} \\ a_{31}a_{32}a_{33}a_{34} \\ a_{41}a_{42}a_{43}a_{44} \end{bmatrix} \begin{bmatrix} Y_{t-i} \\ INF_{t-i} \\ IR_{t-i} \\ RER_{t-i} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \tag{14}$$

The SVAR is applied in the estimation.

By progressive substitution of variables, the full twelve equation system can be reduced to a three equation system, with three endogenous variables - output, inflation and real exchange rate, and one exogenous variable - foreign interest rate:

$$Y = -a'_{11} INF + a'_{12} RER - a'_{13} INF^{f} \tag{15}$$

$$INF = a'_{12} RER + a'_{22} Y \tag{16}$$

$$RER = a'_{31} INF^{f} + a'_{32} INF + a'_{33} Y \tag{17}$$

where the parameters $a'$ are combinations of the parameters of the full model, and VAR is applied in the estimation.

## Structural Vector Autoregression (SVAR) Model

In order to estimate the relationship between the dynamics of the exchange rate and domestic price level through output and interest rate, a structural vector autoregressive (SVAR) model is used. Let there be two variables, $y_t$ and $z_t$ where the sequence and time path of each is effected by the current and past realisation of the other variable:

$$y_t = \beta_{10} + \beta_{12}\, z_t + \gamma_{11}\, y_{t-1} + \gamma_{12}\, z_{t-1} + \varepsilon_{yt} \tag{18}$$

$$z_t = \beta_{20} + \beta_{21}\, y_t + \gamma_{21}\, y_{t-1} + \gamma_{22}\, z_{t-1} + \varepsilon_{zt} \tag{19}$$

where both $y_t$ and $z_t$ are stationary, $\varepsilon_{yt}$ and $\varepsilon_{zt}$ are white noise (zero mean and constant variance) disturbances with a standard deviation of $\sigma_y^2$ and $\sigma_z^2$ respectively, and $\varepsilon_{yt}$ and $\varepsilon_{zt}$ are uncorrelated. The two equations constitute a first-order structural vector autoregression (SVAR) with lag length equal to one. As the structural equations have large numbers of parameters to be estimated, a reduced form from:

$$\begin{bmatrix} 1 & \beta_{12} \\ \beta_{21} & 1 \end{bmatrix} \begin{bmatrix} y_t \\ z_t \end{bmatrix} = \begin{bmatrix} \beta_{10} \\ \beta_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{zt} \end{bmatrix} \quad (20)$$

Or
$$Bx_t = \tau_0 + \tau_1 x_t + \varepsilon_t \quad (21)$$

Pre-multiplying the equation by $B^{-1}$:

$$x_t = \pi_o + \pi_1 x_{t-1} + e_t \quad (22)$$

where $\pi_o = B^{-1} \ \tau_0$, $\pi_1 = B^{-1} \ \tau_1$ and $e_t = B^{-1} e_t$.

The VAR in reduced form is now specified as:

$$y_t = \pi_{1o} - \pi_{11} y_{t-1} + \pi_{12} z_{t-1} + e_{1t} \quad (23)$$

$$z_t = \pi_{2o} - \pi_{21} y_{t-1} + \pi_{22} z_{t-1} + e_{2t} \quad (24)$$

whereas 3.5 and 3.6 are called VAR in Reduced form. The error terms are composites of two shocks $\varepsilon_{yt}$ and $\varepsilon_{zt}$, so $e_{1t}$ and $e_{zt}$ can be written as:

$$e_{1t} = (\varepsilon_{yt} - \beta_{12} \varepsilon_{zt}) / (1 - \beta_{12} \beta_{21}) \quad (25)$$

$$e_{2t} = (\varepsilon_{zt} - \beta_{21} \varepsilon_{yt}) / (1 - \beta_{12} \beta_{21}) \quad (26)$$

where $e_{1t}$ and $e_{2t}$ follow white noise. The reduced form of VAR can be estimated for a multivariate case by using more endogenous variable.

## Empirical Analysis

The Table 1 presents the summary statistics of the variables used for the study.The mean of IIP is 100.01, the exchange rate is Rs. 47.50 per dollar, the inflation rate is 100.10, and interestrate is 7.50 percent. Before applying econometric estimations, first, the data has to be checked if it is stationary and satisfies other times series properties like causality, cointegration, etc. Then only VAR estimation, stability test and at last SVAR analysis can be carried with impulse response function and variance decomposition.

**Table 1:** Descriptive Statistics of Variables in the SVAR Analysis

| *Variable* | *Description* | *Mean* | *Standard deviation* |
|---|---|---|---|
| IIP | Index of industrial production (IIP) | 100.008 | 28.97 |
| RER | Rupees per US$, | 100.105 | 24.45 |
| WPI | Wholesale price index | 47.50 | 9.37 |
| IR | Weighted call money rate | 7.50 | 3.50 |
| N | Observations | 277 | |

Stationary Test: A crucial for time series analysis is to check if the statistical properties like mean, variance and covariance are constant over time. If the series is non-stationary, it is not possible to generalise the results of the data. The stochastic behaviour of variables is analysedthrough the Augmented Dickey-Fuller (ADF) test. The null hypothesis for the ADF test is that the series has a unit root and the alternative hypothesis is that the series doesn't have a unit root. In the presence of unit root, the series is considered to be non-stationary and autocorrelated, and hence it has to be differenced to make it stationary. The variables have to be stationary at levels or at differences. The ADF results presented in Table 2 shows that probability values are less than 5percent and hence the null hypothesis that the series have unit root is rejected. Therefore, all the variables are stationary at the first difference and integrated of order zero, I(1).

**Table 2:** Augmented Dickey-Fuller Test of Stationarity

| *Variable* | *Coefficient* | *p-value at levels* |
|---|---|---|
| IIP | -2.59 | 0.000 |
| RER | -0.708 | 0.000 |
| WPI | -1.11 | 0.000 |
| IR | -0.569 | 0.005 |

Cointegration Test:The Johansen cointegration test checks if the series has any long term or equilibrium relationship. Since the variables are I(1) process and if the variables are cointegrated, a vector error correction mechanism (VECM) should be used to check for short-run disequilibrium and if the variables are not cointegrated, vector autoregression (VAR) model is used in order to estimate the contemporaneous effect of variables. The Johansen cointegration test results presented in Table 3 that all p-values both for trace and maximum eigen value are greater than 0.05. Therefore, the null hypothesis that the series have cointegration is accepted and the variables do not have long term relationship. If the equations are cointegrated, then by checking the probability values of hypothesis at most 1 or at most 2 the number of cointegrated variables can be estimated.

**Table 3:** Johansen Test of Cointegration

| *Hypothesisedno.of CE(s)* | *Eigen value* | *Trace value* | *p-value* | *Maximum eigen values* | *p-value* |
|---|---|---|---|---|---|
| None* | 0.235 | 93.997 | 0.060 | 39.860 | 0.087 |
| At most 1* | 0.157 | 54.137 | 0.087 | 25.409 | 0.072 |
| At most 2* | 0.151 | 28.729 | 0.099 | 24.395 | 0.065 |
| At most 3* | 0.029 | 4.334 | 0.077 | 4.334 | 0.097 |

*Note:* * Number of co-integrating equations at 5 percent significance level of p-values.

Causality Test: The causality test is a way to investigate causation between two variables in a time series.The Granger causality test results presented in Table 4 show that there is bidirectional causality between exchange rate and call money rate, output gap and inflation rate, and output gap and call money rate and inflation rate.

**Table 4:** Granger Test of Causality

| *Null hypothesis* | *p-value* |
|---|---|
| Output gap does not cause inflation rate | 0.755 |
| Inflation rate does not cause output gap | 0.886 |
| Call money rate does not cause exchange rate | 0.017 |
| Exchange rate does not cause call money rate | 0.004 |
| Call money rate does not cause output gap | 0.644 |
| Output gap does not cause call money rate | 0.197 |
| Exchange rate does not cause output gap | 0.037 |
| Output Gap does not cause exchange rate | 0.039 |
| Inflation rate does not cause exchange rate | 0.001 |
| Exchange rate does not cause inflation rate | 0.009 |
| Call money rates does not cause inflation rate | 0.973 |
| Inflation rate does not cause call money rates | 0.934 |

*Note:* 5 percent significance level of p-values.

Lag Length Selection: As the variables are autoregressive, how many autoregressive terms should be included in the model so that model is fit for the estimation has to be identified. Inclusion of too many lags decreases the degrees of freedom, while too few lags give rise to specification bias. The appropriate lag length is identified by various criteria like FPE, AIC, SIC and HQ criteria. The estimation results of lag lengths presented in Table 5 shows all the lag length criteria suggestlag length is 4, except SC and HQ criteria. Therefore,the estimatingmodels are fitted with 4 lags.

**Table 5:** Lag Length Selection Criteria

| *Lag* | *Final predictor error (FPE)* | *Akaike information criterion(AIC)* | *Schwarz information criterion(SIC)* | *Hannan-Quinn information criterion (HQ)* | *LR test statistic at 5 percent level* |
|---|---|---|---|---|---|
| 0 | 18241.250 | 21.163 | 21.219 | 21.184 | NA |
| 1 | 9863.118 | 20.548 | 20.812* | 20.654 | 196.207 |
| 2 | 9297.301 | 20.489 | 20.965 | 20.680 | 46.563 |
| 3 | 9961.192 | 20.558 | 21.245 | 20.834 | 12.593 |
| 4 | 9157.922* | 20.473* | 21.372 | 20.834 | 51.623* |

*Note:* * indicates lag order selected by the criterion.

## Vector Autoregression Estimates

In the VAR equations, a variable is a function of its own lagged values as well as the lagged values of other endogenous variables. The lag length identified by the criteria a 4 and therefore all the variables are lagged by 4 periods. The estimation ofeach of the set of four equations is by the OLS method as the lagged values of the variables are exogenous and the error terms are serially uncorrelated. The estimated VAR results are presented in Table 6. The VAR results show that the first and second lags of the output gap and fourth lag of call money rate significantly positively affect the current output gap, whereas the fourth lags of output gap influence current output gap negatively. The current inflation rate is influenced negatively by the first lag of interest rate and positively by the second lag of the call money rate and third lag of the exchange rate. The present call money rate is influenced negatively by the fourth lag of output gap, third lag of inflation rate and first lag of call money rate, and positively by the first and second lags of call money rate, and first lag of exchange rate. The current exchange rate is effectedpositively by the first lag of output gap, and negatively by the second lag of inflation rate, second lag of call money rate, and first and fourth lag of exchange rate.

**Table 6:** VAR Estimates of Output Gap, Inflation, Call Money Rate and Exchange Rate

| *Variable* | *Output gap* | *Inflation* | *Call money rate* | *Exchange rate* |
|---|---|---|---|---|
| Yt-1 | 0.136* (0.002) | 0.0140 (0.766) | -0.025 (0.379) | 0.048* (0.005) |
| Yt-2 | 0.151** (0.014) | 0.008 (0.860) | 0.039 (0.185) | -0.008 (0.623) |
| Yt-3 | -0.016 (0.792) | 0.017 (0.724) | 0.010 (0.700) | -0.005 (0.790) |
| Yt-4 | -0.324* (0.00) | 0.050*** (0.09) | -0.072* (0.013) | 0.013 (0.437) |
| INFt-1 | 0.007 (0.926) | -0.136** (0.03) | 0.010 (0.791) | 0.007 (0.758) |
| INFt-2 | -0.039 (0.625) | -0.011 (0.861) | 0.018 (0.635) | -0.081* (0.00) |
| INFt-3 | 0.0156 (0.850) | -0.021 (0.745) | -0.011* (0.00) | 0.036 (0.121) |
| INFt-4 | -0.054 (0.470) | -0.023 (0.691) | 0.014 (0.684) | -0.019 (0.370) |
| IRt-1 | -0.036* (0.008) | 0.026 (0.793) | 0.404* (0.00) | 0.036 (0.333) |
| IRt-2 | 0.195 (0.158) | 0.013* (0.002) | 0.137** (0.03) | -0.088** (0.03) |
| IRt-3 | -0.186 (0.180) | 0.011 (0.917) | 0.046 (0.484) | -0.069*** (0.08) |
| IRt-4 | 0.097** (0.039) | -0.0007 (0.994) | 0.167* (0.005) | 0.059*** (0.09) |
| RERt-1 | -0.305 (0.159) | -0.007 (0.966) | -0.431* (0.00) | 0.339* (0.00) |
| RERt-2 | 0.059 (0.803) | -0.005 (0.979) | -0.160 (0.154) | -0.113*** (0.09) |
| RERt-3 | 0.341 (0.138) | 0.066** (0.017) | 0.115 (0.293) | 0.043 (0.511) |
| RERt-4 | -0.263 (0.221) | -0.073 (0.665) | -0.096 (0.351) | -0.142** (0.02) |
| Constant | -0.614* (0.003) | -0.236* (0.005) | 1.674* (0.00) | 0.245 (0.348) |
| R2 | 0.612 | 0.572 | 0.512 | 0.412 |
| Adjusted R2 | 0.499 | 0.399 | 0.489 | 0.350 |

*Note:* p-values in parentheses. *, **, *** significant at 1, 5 and 10 percent levels.

## Stability Test of VAR Model

The stability and stationarity of the VAR model areassessed by the characteristic roots graph. The stability condition requires characteristic roots of a sequence to lie outside the unit root circle. If this holds, then approaches infinity after n iterations and the sequence has finite and time-invariant mean-variance. For the inverse of characteristic roots of AR polynomial, the roots are expected to lie within the unit root circle. In Figure 3, all the characteristic roots of each polynomial equations lie within the unit root circle. Therefore, the VAR model achieves stability and hence, each sequence has finite and time-invariant mean and variance. The values of the characteristic roots are presented in Table 7.

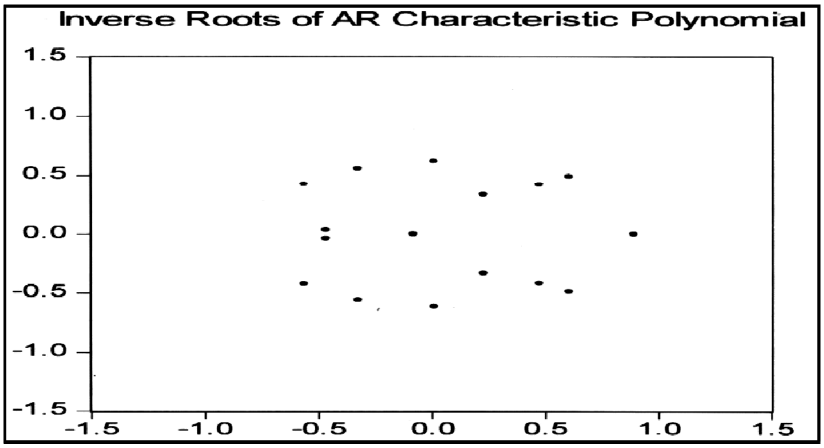


**Figure 3:** Stability of VAR Model

**Table 7:** Inverse Roots of AR Characteristic Polynomial

| *Root* | *Modulus* |
|---|---|
| 0.893 | 0.893 |
| 0.607 - 0.489 | 0.779 |
| 0.606 + 0.489 | 0.779 |
| -0.562 - 0.423 | 0.703 |
| -0.562 + 0.423 | 0.703 |
| -0.325 - 0.555 | 0.642 |
| -0.325 + 0.554 | 0.642 |
| 0.476 - 0.420 | 0.635 |
| 0.476 + 0.420 | 0.635 |
| 0.009 - 0.616 | 0.616 |
| 0.009 + 0.616 | 0.616 |
| -0.466 - 0.034 | 0.468 |
| -0.466 + 0.034 | 0.468 |
| 0.228 - 0.336 | 0.406 |
| 0.228 + 0.336 | 0.406 |
| 0.081 | -0.081 |

*Note:* No root lies outside the unit circle. VAR satisfies the stability condition.

## Structural Vector Autoregression Estimates

As the causality test shows all variables do not bidirectionalcause each other. That means in the structural model of each variable the restrictions should be put. In the case of the SVAR model, the variables carry a contemporaneous effect and residuals also carry indirect contemporaneous effects. The VAR model estimation yields 74 parameters, 68 coefficients, 4 variances, and 2 covariances. The SVAR system estimation yields 80 parameters. Therefore, 74 parameters in a structural equation cannot be estimated using 68 parameters in reduced form equations. If only six parameters are restricted, it is possible to identify the SVAR system, otherwise, it is an under-identified system. Hence, six restrictions should be imposed on structural equations in order to make the system exactly identified and estimate the system. The six restrictions are:

Output gap does not cause inflation rate and call money rate, so $a_{12}$ and $a_{13}$ are equal to zero.

Inflation rate is not caused by output gap and call money rate, so $a_{21}$ and $a_{23}$ are equal to zero.

Call money rate is not caused by output gap and inflation rate, so $a_{31}$ and $a_{32}$ are equal to zero.

The Table 8 presents the SVAR estimates of the contemporaneouseffects of each variable on other variables in the structural system. The coefficients, a12, a21, a23, and a31 are statistically significant and positive, while a13, and a32 coefficients are insignificant. Therefore, the output gap has a contemporaneous effect on the inflation rate, the inflation rate has a contemporaneous effect on the output gap, call money rate has a contemporaneous effect on the output gap, and the inflation rate hasa contemporaneous effect on call money rate.

**Table 8:** SVAR Estimates of Output Gap, Inflation, Call Money Rate and Exchange Rate

| *Parameter* | *Coefficient* | *Std.error* | *z-statistics* | *Probability* |
|---|---|---|---|---|
| $a_{12}$ | 5.284* | 0.226 | 23.367 | 0.000 |
| $a_{13}$ | 0.518 | 0.319 | 1.621 | 0.105 |
| $a_{21}$ | 5.620* | 0.240 | 23.367 | 0.000 |
| $a_{23}$ | 2.330* | 0.248 | 9.379 | 0.000 |
| $a_{31}$ | 0.937* | 0.073 | 12.901 | 0.000 |
| $a_{32}$ | 0.579 | 0.060 | 0.956 | 0.339 |

*Note:* * significant at 1 percent level.

## Impulse Response Function

Dynamic causality is analysed through Impulse Response Functions (IRFs) and is shown in Figure 4. The IRFs trace the time path of various shocks on the variables contained in the system. The IRFs are shown for 10 months. The responses show that when one standard deviation shock is given to a variable how other variables in the system react. When one SD shock inthe exchange rate, the output gap is negative till 3rdperiod, from 4th period it increases and it again tends back to zero. So, fluctuations in the exchange rate negatively influence the exchange rate as the decrease in value of home currency leads to high payment for imported materials in production which in turn increases the output gap. With one SD shock inthe exchange rate, inflation rate tends to zero change till 3rdperiod, from 4th period it increases and slowly it tends to zero and negative till 6thperiod. This shows that the effect of exchange rate on inflation is very less. The negative impact is due to the higher import price caused by exchange rate depreciation. For one SD inthe exchange rate, the call money rate becomes negative for every period i.e. if there is exchange rate depreciation, call money rate decreases as fall in currency value does not attract investment which leads to a fall in the call money rate.

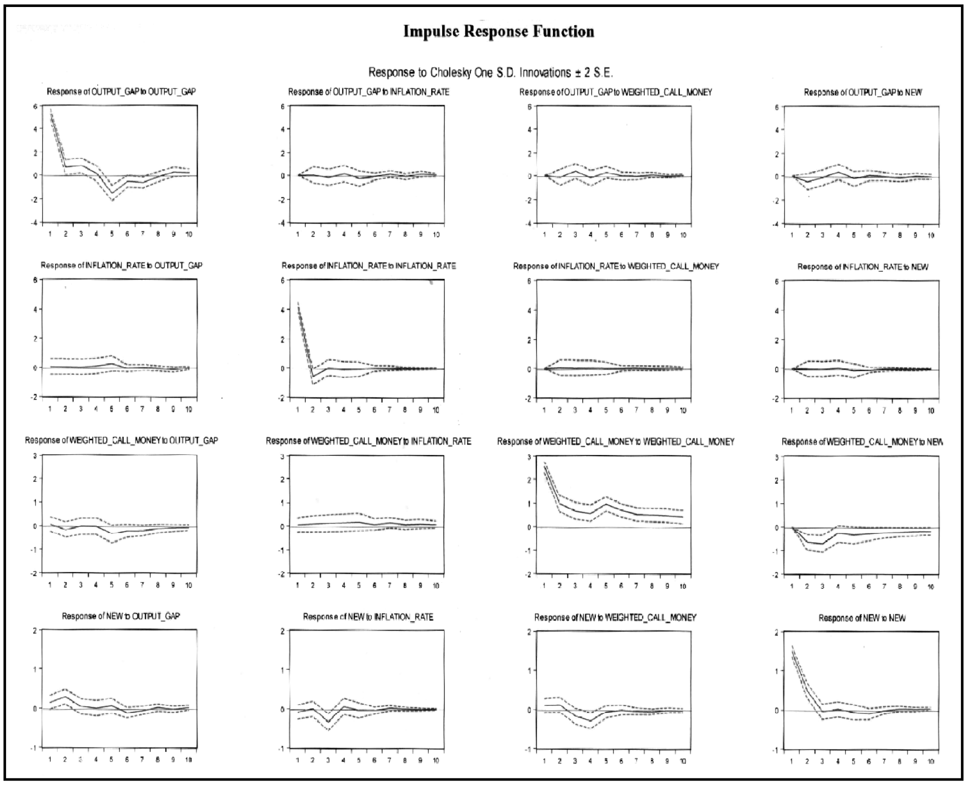


**Figure 4:** Impulse Response Function

## Variance Decomposition

The variance decomposition indicates the amount of contribution of each variable to the other variables in the model. It determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to other variables.The variance decomposition of the exchange rate with each variable for a period of 24 months ispresented in Table 9. The variations in the exchange rate over the period are about 1.7 percent, and more than 85 percent of the variation is due to its own shocks. Changes in the output gap and inflation rate are the other two main contributors to exchange rate variations relative to the call money rate. A unit shock in output gap contributes 4.46percentand 5.01percentchange in the exchange rate in 3rd and 24th month respectively. The shock in inflation rate contributes 4.13percent change in the exchange rate in 3rd and the same effect of inflation shock persists till the 24th month. The effect of call money shocks on the exchange rate is 1.88percent in 3rd month and in 6th month the effect increases to 4.67percentand tends to be the same throughout to 24th month.

**Table 9:** Variance Decomposition of Exchange Rate

| *Periods* | *Standard error* | *Output gap* | *Inflation rate* | *Call money rate* | *Exchange rate* |
|---|---|---|---|---|---|
| 3 | 1.681 | 4.463 | 4.132 | 1.880 | 89.524 |
| 6 | 1.718 | 4.862 | 4.197 | 4.671 | 86.270 |
| 9 | 1.721 | 4.964 | 4.203 | 4.833 | 85.999 |
| 12 | 1.723 | 5.010 | 4.199 | 4.912 | 85.878 |
| 15 | 1.723 | 5.013 | 4.198 | 4.956 | 85.831 |
| 18 | 1.723 | 5.012 | 4.198 | 4.978 | 85.812 |
| 21 | 1.723 | 5.012 | 4.198 | 4.989 | 85.801 |
| 24 | 1.723 | 5.012 | 4.198 | 4.995 | 85.795 |

The variance decomposition of inflation rate presented in Table 10 reveals that, compared to variations in the exchange rate, the variations in inflation rate is large, 4.2 percent, but the major source of such variation,about 99 percent, is its own shocks. The shock in output gap contributes little more than half a percent change in the inflation rate, and the shock in exchange rate contributes about 0.13 percent change in inflation rate while the contribution of call money rate on change in inflation rate is negligible.

**Table 10:** Variance Decomposition of Inflation Rate

| *Periods* | *Standard error* | *Output gap* | *Inflation rate* | *Call money rate* | *Exchange rate* |
|---|---|---|---|---|---|
| 3 | 4.227 | 0.544 | 99.898 | 0.037 | 0.007 |
| 6 | 4.242 | 0.546 | 99.257 | 0.065 | 0.131 |
| 9 | 4.244 | 0.626 | 99.145 | 0.095 | 0.134 |
| 12 | 4.244 | 0.630 | 99.131 | 0.102 | 0.136 |
| 15 | 4.245 | 0.634 | 99.122 | 0.106 | 0.137 |
| 18 | 4.245 | 0.635 | 99.119 | 0.109 | 0.137 |
| 21 | 4.245 | 0.635 | 99.117 | 0.110 | 0.137 |
| 24 | 4.245 | 0.635 | 99.116 | 0.111 | 0.137 |

## Conclusion

This study estimates the effect of changes in the exchange rate on domestic inflation under the managed floating exchange rate regimein India. Four variables are considered in the study, exchange rate, price, output and interest rate, as endogenous variables. The exchange rate is measured as rupee per dollar value, inflation rate by the wholesale price index, output by the index of industrial production and interest rate by weighted average call money rate. This study uses monthly data for the period April 1994 to April 2017 collected from the RBI Handbook of Statistics on the Indian Economy. This study follows the framework of Kamin and Rogers (2000) that incorporates nearly all of the potential channels of causality linking exchange rate, inflation rate, output and interest rate, and that identify the sources of contemporaneous shocks. In the empirical analysis, VAR and SVAR models are used. The SVAR estimates show that variations in the exchange rate are explained more by the output gap than the inflation rate. The estimated effect of changes in the exchange rate on inflation is just 0.1 percentwhile the effect of changes in inflation on the exchange rate is more than 4 percent in India.

The rather low effect of exchange rate on inflation in India compared to other countries is due to the effective intervention effect of the central bank, the Reserve Bank of India. The RBI intervenes to even out exchange rate volatility by increase/decrease in net foreign exchange assets, and also the RBI sterilises the expansionary monetary effect by increase/decrease in net domestic credit. The less effect of exchange rate on inflation rate is also due to the regime of managed floating exchange rate where the intervention of RBI is hand to hand with the market determination of exchange rate. Thus, the RBI intervention on the foreign exchange rate makes a huge difference, and almost neutralises the effect of exchange rate on inflation rate in India.

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