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The Relative Strengths of Policy Propagation Channels on the Real Economy in India: SVAR Estimation of Monetary Transmission Mechanism Effects

T. Lakshmanasamy
Formerly ICSSR Senior Fellow and
Professor, Department of Econometrics, University of Madras
Chennai, India. E-mail: tlsamy@yahoo.co.in

Abstract

Economic policy changes affect the economy through multiple channels and the channel effects vary. The central bank monetary policy aims to control the output and prices through money and capital markets. The monetary transmission channels are the interest rate, credit, exchange rate and asset price channels through which monetary shock propagates to the real economy.
This paper examines the relative strengths of the monetary transmission channels in India from 2000Q1 to 2023Q4 using quarterly data applying the structural vector autoregression estimation method. The estimated results the significance of interest rate and asset price channels in transmitting monetary shocks to the real economy in India, while credit and exchange rate channels are weak. A disaggregated analysis of the components of aggregate demand shows that the maximum impact is borne by investment demand and imports. Variance decomposition analysis indicates that interest rate accounts for a significant percentage of the fluctuations in the components of aggregate demand, except private consumption. Robustness checks show that all the channels of monetary policy are robust and all the components of aggregate demand except for private consumption are robust around the period where the impacts are felt the most.

Keywords: Monetary policy, transmission channels, interest rate, credit, asset price, exchange rate, aggregate demand, SVAR estimation

Introduction

Despite the generalised use of monetary instruments to effectively control the money market, importantly the interest rates, the interaction of the central bank policy with the real economy is intricate and multifaceted. The monetary policy does not act through a single transmission channel. The transmission channels are many and their links with the real economy are extremely complex. Structural and economic reforms and subsequent transitions to new policy regimes in many emerging economies have brought the analysis of monetary transmission mechanisms into sharp focus. Monetary policy decisions affect the general economic performance by influencing the aggregate demand functioning through the money and capital markets. There is a general consensus that monetary policy affects the real economy at least in the short run and monetary policy decisions are generally transmitted to the real sector through four main channels - interest rate, credit, exchange rate and asset price channels. The traditional monetary transmission mechanism is the interest rate channels that affect the costs of borrowing, levels of physical investment, and aggregate demand. Further, the frictions in the credit markets caused by the monetary transmission through interest rates

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also affect the aggregate demand. Other channels that transmit monetary policy changes into the economy are the credit, asset price and exchange rate mechanisms. In essence, the between monetary policy and aggregate demand is through some transmission mechanism through which monetary shock propagates to the real economy. The transmission mechanisms differ from one country to another depending upon their legal and financial structures.

The interest rate channel is the key monetary transmission mechanism in the basic Keynesian model through which monetary tightening is transmitted to the real economy. A contractionary monetary policy leading to a rise in real interest rate raises the cost of capital thereby causing a decline in investment spending and hence a decline in aggregate demand and a fall in output. Under the credit channel, the amount of credit issued to businesses and consumers is influenced by the policy changes which in turn affects the output. The credit channel of monetary policy transmission is an indirect amplification mechanism that works along with the interest rate channel. The credit channel affects the economy by altering the amount of credit that firms and/or households can access. The credit channel operates in two ways: the bank lending channel and the balance sheet channel. The bank lending channel relates to the supply of loans by banking institutions. Certain types of borrowers such as small firms unlike large firms cannot directly access the credit markets through stocks and bonds markets without going through banks. The balance sheet channel refers to the variations in the net financial income and the net wealth of economic agents due to the changes in the monetary policy.

The asset price channel operates through the effects of monetary policy decisions made by the central bank on asset prices and the stock market which in turn affects the economy. It involves two channels: Tobin's q theory of investment and wealth effects on consumption. Tobin (1969) defines q as the market value of firms relative to the replacement cost of capital. The q theory provides a transmission mechanism by linking Tobin q and investment spending through the valuation of equities. A contractionary monetary policy causes the money supply to fall with less money for the public to spend on equities thus decreasing the demand for equities and consequently lowering stock prices. The alternative asset price channel, the wealth effects on consumption, relates to the effects of monetary tightening on the holding of common stocks by the public as financial wealth which determines the consumption spending of people. When stock prices fall so also the value of financial wealth and hence the lifetime resources of consumers, thus decreasing consumption.

The exchange rate channel of the monetary transmission mechanism involves exchange rate effects on net exports. This channel also involves interest effects, because when domestic real interest rate rise, domestic currency deposits become more attractive relative to deposits dominated in foreign currencies, leading to a rise in the value of domestic currency deposits relative to other currency deposits i.e. an appreciation of the domestic currency and thereby causing a fall in net exports. The importance of the exchange rate channel in the transmission of monetary shocks depends on several factors such as the exchange rate policy which determines the responsiveness of the exchange rate to monetary policy, the degree of openness of the economy, the elasticity of net imports to exchange rate fluctuations, degree of exchange rate pass-through to domestic prices, etc. All these transmission channels of the central bank's monetary policy affect the aggregate demand and aggregate spending thereby influencing the real economy.

While the impact of the central bank's monetary policy on the real economy and prices is shaped by the monetary transmission mechanism as a whole and by their respective importance, the regulatory framework of banking, banking practices, degree of liquidity constraints, and the structure of assets and liabilities of nonfinancial institutions influence the extent to which household and business expenditures are affected by monetary policy and interest rate changes. It is a widely accepted view that monetary tightening leads to lower output and lower prices in the short run. But, it is also important to understand which sectors of the economy the impact is felt the most as there are different macroeconomic implications. Higher interest rates can push households to postpone consumption and save while making investments more costly causing a slowdown in the investment. While both will reduce aggregate demand, the one emanating from the slowdown in investment could have longer-term growth implications in contrast to the one originating from the decline in consumption demand. Further, net imports/exports can increase or decrease due to the combined effect of exchange rate changes as a consequence of monetary tightening and from the secondary impact of change in consumption and investment.

A systematic analysis of the monetary transmission mechanism first aims to obtain a good quantitative assessment of the dynamic consequences of a change in the policy-controlled interest rate on the main macroeconomic variables. Armed with these estimates, then an estimate of the overall impact of policy and the channels through which it takes place is to be ascertained. In India, the Reserve Bank of India is the central bank that is responsible for monetary policy decisions. This paper tries to understand the monetary transmission mechanism of central bank policy and the relative importance of the monetary transmission mechanism channels in India. The specific objectives of the study are to identify the channel through which the monetary policy influences output and prices and to ascertain the components of aggregate demand of the economy in which the effect of the monetary policy transmission has the maximum impact in India.

Literature Review

Barran et al. (1997) study the effect of monetary policy on economic activity in nine European Union economies using quarterly data for the period 1976Q1 to 1994Q4 applying the SVAR model based on Cholesky decomposition. It is assumed that monetary authorities react to contemporaneous variables that enter into the model. The study argues that financial institutions, regulations and operational procedures of monetary policy are responsible for differences across countries in the channels, timing and amplitude with which monetary policy actions influence economic activity. The study finds that the monetary policy shock leads to a decline in output ranging from 0.2 to 0.7% in the countries studied. The output begins to fall immediately after the interest rate shock, or after just one quarter. Adding the main components of final demand i.e. private consumption, private investment and residential investment to the base model, the decline in investment is greater than that of aggregate output.

As regards the channels through which monetary policy affects the economy, a base VAR model including different transmission variables, such as the exchange rate, credit to the private domestic sector and the long-term interest rate is estimated. It is observed that a rise in the interest rate results in an appreciation of the currency i.e. decrease in the exchange rate in most countries while the response of GDP is either positive or insignificant. In the case of the long-term interest rate channel, a shock in the long-term rate makes output decline in most countries, but the fall in GDP is not always significant. Therefore, both the exchange rate and long-term interest channels are of less significance. In the case of the credit channel, credit rapidly decreases after a monetary shock in most countries enhancing the decrease in output implying the existence of the credit channel in European countries. However, a sectoral analysis for Germany and France does not provide evidence for a credit channel.

Clements et al. (2001) analyse the effects of monetary policy shocks on GDP and CPI across countries in the euro area and try to identify the relative strength of credit, exchange rate and interest rate channels of monetary policy transmission mechanism using quarterly data over the period 1983Q1 to 1998Q4 applying the SVAR model based on Cholesky decomposition. Monetary shocks have a strong effect on output in Austria, Germany and the Netherlands, an extremely weak effect on output in Finland and Spain, and moderate effects in Belgium, France, Italy and Portugal. As regards the channels, the credit channel is present in all countries but Finland, Ireland and Italy and is strong in the Netherlands, Belgium, France and Spain. The exchange rate channel is relatively small in the Euro area. A large share of the differences in the strength of monetary policy across countries relates to the interest rate channel.

Peersman and Smets (2003) study the macroeconomic effects of an unexpected change in monetary policy in the Euro area using quarterly data from 1980 to 1998 applying the VAR model using Cholesky decomposition. They describe benchmark VAR models with a vector of exogenous variables viz. world commodity price index, US real GDP, and the US short-term nominal interest rate, to control for changes in world demand and inflation. A typical monetary policy shock is somewhat greater in the US than in the Euro area, which is reflected in a stronger impact on output and prices. The impact of the monetary shock on prices is much faster in the US. The response of output to the monetary policy shock is mainly due to a decrease in investment which responds with a magnitude of three times as large as GDP, and to a lesser extent in private consumption. There is an immediate liquidity effect on M1, but a more gradual decrease of M3 and other credit aggregates.

Disyatat and Vongsinsinsirikul (2003) identify the channels through which monetary policy shocks are propagated and the components of real GDP that are most affected by monetary policy in Thailand using quarterly data from 1991Q1 to 2001Q4 applying the VAR model based on recursive Cholesky decomposition. For the base model, a monetary shock results in a U-shaped output response which bottoms out after 4-5 quarters and dissipates after 12 quarters. The variance decomposition results indicate that interest shocks are quite persistent even after 2 years accounting for around 35% of the fluctuation in output. With regard to the components of real GDP, monetary policy operates on the real economy largely through its impact on investment followed by consumption and import, while the impact on export is the least. As regards the channels of the transmission mechanism, the bank lending, asset price and exchange rate channels are not very strong in impacting the output but are expected to operate in the future. The traditional interest rate channel accounts for roughly half of the output effect after four quarters and the variations in the other three variables play a role in hastening the dissipation of monetary policy shocks. The study finds that monetary shocks lead to a substantial decline in investment and the price, bank loan and consumption responses are small in Thailand. Exogenising bank loans have more impact on the response of investment than consumption suggesting that the bank lending channel works mainly by constraining investment rather than consumption.

Al-Mashat and Billmeier (2008) examine the channels of monetary transmission in Egypt by estimating a structural vector error correction model using quarterly data from 1981Q1 to 2002Q4. To assess the potential changes in the transmission channels that could have occurred due to the structural reforms initiated in the economy during the 1990s, the empirical analysis is re-applied to two distinct sub-samples 1981Q1 to 1990Q3 and 1992Q1 to 2002Q4. In the case of the interest rate channel, an unexpected tightening in monetary policy i.e. an increase in the real interest rate leads to a temporary decrease in output and inflation. A positive supply shock that causes output to rise above its potential level leads to a lower long-run inflation level. A positive demand shock causes output to rise above its potential level translating into higher inflation. The variance decomposition of the interest rate channel shows that aggregate demand shocks are the main causes of output variability in the short to medium terms (80% and 57% respectively), while in the long term aggregate supply shocks are the main determinants (52%) of output variability. In the short term, aggregate supply shocks account for 25%, while aggregate demand shocks account for about

10% of the inflation variability. In the case of the exchange rate channel, an unexpected tightening in monetary policy causes the real effective exchange rate to appreciate by 0.5% and a positive aggregate supply shock causes the real exchange rate to depreciate by 1%. In the case of the credit channel, there is a weak transmission from policy changes to bank lending and output does not react to bank-lending shocks. The response of the nominal interest rate to monetary policy in the pre-reform period is smaller than that in the post-reform period. Overall, the study finds no evidence that bank lending plays a very important role in transmitting monetary policy changes.

Aleem (2010) examine the effects of an unanticipated monetary tightening on GDP, prices and overnight call money rate and the role of bank lending, asset price and exchange rate channels of monetary transmission in India using quarterly data from 1996Q4 to 2007Q4 employing the SVAR approach. In the benchmark VAR model, a positive call money rate shock leads to a U-shaped response in GDP. Prices also decline in response to a positive monetary policy shock. An unanticipated monetary policy shock has temporary effects on the overnight call money rate which falls initially to 0.22% below the baseline but then it converges toward the baseline. Regarding the monetary transmission channels in India, the study reestimates the model exogenising bank loans (bank lending channel), Sensex-30 (asset price channel), and real effective exchange rate (exchange rate channel). The estimated results show that there is a significant reduction in the responses of GDP to positive overnight call money rate innovations suggesting the importance of the bank lending channel in India. The results further reveal the absence of the exchange rate channel and the insignificance of the asset price channel in the transmission of monetary shocks to the real sector in India.

Khundrakpam (2012) analyses the impact of monetary policy on aggregate demand in India using the SVAR model on quarterly data from 2000Q1 to 2011Q1. The overall impact of aggregate demand is then decomposed to understand the differential impact among the components viz. private consumption, investment, government consumption, imports and exports. The estimated results show that an interest rate hike impacts the growth of aggregate demand significantly negatively. The disaggregated analysis shows that the maximum impact is borne by investment demand and imports. Impact on private consumption growth and export growth are relatively far more subdued, while there is hardly any cumulative impact on government consumption growth. The variance decomposition analysis indicates that interest rate accounts for a significant%age of the fluctuation in the growth of all the components of aggregate demand, except government consumption. The interest rate channel completely dominates the exchange rate channel in monetary transmission, though the latter channel has a non-negligible impact on investment and imports.

Khundrakpam and Jain (2012) examine the relative importance of interest rate, asset price, exchange rate and credit channels of monetary policy to GDP growth and inflation in India using quarterly data from 1996-97Q1 to 2011-12Q1 applying the SVAR models. The baseline SVAR model shows that external exogenous factors prolong the impact of monetary policy transmission on GDP growth and inflation in India. The variance decomposition indicates the importance of interest rates in an increased fluctuation of economic activity and that monetary policy has been sensitive to inflation in India. In the case of the credit channel, the impulse response of GDP growth to shock in policy rate up to the third quarter is quite similar to endogeneity and exogeneity of credit but the impact thereafter dissipates much faster when credit is exogenous showing the significant operation of credit channel on GDP growth in India. In the case of the asset price channel, the impulse response of GDP growth to shock in policy rate dissipates much faster when the channel is blocked indicating that the asset price channel is an important channel of monetary policy transmission in India.

In the case of the exchange rate channel, endogeneity or exogeneity of the exchange rate makes very little difference to the impulse response of GDP growth indicating that the exchange rate channel of monetary transmission to GDP is either weak or absent in India. In the case of the direct interest channel, almost half of the monetary transmission is explained directly by the interest rate indicating that it is the most important channel of monetary policy transmission in India. Overall, credit, asset price, interest rate and exchange rate are the main channels of the monetary policy transmission mechanism in India.

Sengupta (2014) studies the effect of the introduction of the liquidity adjustment facility (LAF) in India in 2000 as an operating procedure for monetary policy and assesses the changing importance of transmission channels of monetary policy in the pre-LAF and post-LAF periods using monthly data from April 1993 to March 2012 applying the VAR technique. The paper finds a structural break in the post-reform period and the bank lending channel remains an important means of transmission of monetary policy in India. However, in the post-LAF period, the importance of the bank lending channel has been weakened and the interest rate and asset price channels have become stronger while the exchange rate channel shows a weak mild improvement

Data and Methodology

This paper uses quarterly data collected from the Reserve Bank of India Handbook of Statistics on the Indian Economy from 2000Q1 to 2023Q1. The variables considered are gross domestic product, aggregate demand and its components, price level and policy rate as endogenous variables and the world commodity price index, federal funds rate, and GDP of the US as the exogenous variables. Bank credit to the commercial sector, BSE Sensex and real effective exchange rate are used as both endogenous and exogenous variables. The aggregate demand is measured by the gross domestic product (GDP), the price level is represented by the wholesale price index (WPI), the policy rate is represented by the weighted average call rate, and the components of real GDP are private consumption (C), investment (I), government consumption (G), exports (E) and imports (M). Each component of aggregate demand is subtracted from GDP to arrive at the other residual components of aggregate demand viz. non-investment (NIGDP), non-private consumption (NCGDP), non-export (NXGDP), non-import (NMGDP) and non-government (NGGDP) components of aggregate demand. The monetary transmission channel variables viz. bank credit to commercial sectors (loans), stock exchange index (S&P BSE Sensex) and real effective exchange rate (REER) are treated as both endogenous and exogenous variables. The data on the world commodity price index is collected from the website Alfred.stlouisfed.org and the data on the stock exchange index is collected from the BSE website. All the variables are seasonally adjusted and logarithmically transformed except the weighted average call rate. Empirically, the monetary transmission mechanism is analysed by the Structural Vector Auto Regressions (SVAR) estimation method. These are dynamic systems of equations that examine the interrelationships between economic variables, imposing minimal assumptions about the underlying structure of the economy.

Structural Vector Autoregression (SVAR) Method

Before estimation, as the data are time series, the series are to be tested for certain properties.

Stationarity Test: The time series is stationary if its first three moments viz. mean, variance and autocovariance (at lags) are all constant over time i.e. no unit root present. A series with unit root present is non-stationary i.e. mean, variance and autocovariance are not constant over time. When the series is stationary, fluctuations around the mean will have broadly constant amplitude and any deviation from the mean will tend to revert back to its mean i.e. mean reversion. Non-stationary data can be made stationary by differencing it. Estimation with non-stationary time series data leads to a spurious regression i.e. misleading statistical evidence and meaningless conclusion. Therefore, it is important to test the presence of unit root i.e. stationarity of time series data.

Dicky-Fuller Test: The Dickey-Fuller test checks whether the unit root is present in a time series. The DF is carried out by estimating a simple autoregressive AR (1) $\delta x_t + \varepsilon_t$ process:

$$y_t = \rho y_{t-1} + \delta x_t \, \varepsilon_t \qquad (1)$$

where x_t are optional exogenous regressors which may consist of a constant or a constant and trend, ρ and δ are parameters to be estimated and ε_t are assumed to be white noise. Subtracting y_{t-1} from both sides, the estimating equation is:

$$\Delta y_t = \alpha y_{t-1} + \delta x_t + u_t \qquad (2)$$

where α = (ρ-1) and is evaluated using the conventional t-test.

Augmented Dickey-Fuller Test: The simple Dickey-Fuller unit root test is valid only Δthe series is an AR (1) process. If the series is correlated at higher order lags, the assumption of white noise disturbances ε_t is violated. The ADF test constructs a parametric correction for higher-order correlation by assuming that the y series follows an AR (p) process. Adding p-lagged difference terms of y to the test regression:

Δyt = αyt-1 + δxt + β1Δyt-1 + β2Δyt-2 +… + βpΔyt-p + vt

$$\Delta y_t = \alpha y_{t-1} + \delta x_t + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \cdots + \beta_p \Delta y_{t-p} + v_t \qquad (3)$$

The hypotheses for the stationarity test are: H0: α = 0, a unit root is present and H1: α < 0, a unit root is absent.

Lag Length Selection: To find the order of the lags i.e. optimal lag, various lag-length selection procedures are used. An optimal lag is chosen by minimising the values of lag length based on certain information criteria. The lag selection criteria are LR, AIC, SIC, FPE HQC, etc.

Likelihood Ratio (LR) Test: The LR test assesses the goodness of fit of two competing statistical models based on the ratio of their likelihoods, specifically one found by the maximisation over the entire parameter space and another found after imposing some constant. Starting from the maximum lag, the hypothesis is to test the coefficients on lag l are jointly zero using the χ^2 statistics:

$$LR = (T-m)\{\log|\Sigma_{\varepsilon,l-1}| - \log|\Sigma_{\varepsilon,l}|\} \sim \chi^2(k^2) \qquad (4)$$

where m is the number of parameters per equation (m=0,1,…,M).

Final Prediction Error (FPE): The FPE criterion provides a measure of model quality by simulating the situation where the model is tested on a different data set. The most accurate model has the smallest FPE. The FPE is defined by:

$$FPE(m) = \left[\frac{T+Km+1}{T-Km-1}\right]^K \det \tilde{\Sigma}_u(m) \qquad (5)$$

Based on the FPE criterion, the estimate $\hat{p}\ (FPE)$ of p is chosen such that:

$$FPE[\hat{p}(FPE)] = \min\{FPE(m) | m = 0,1,\ldots,M\} \qquad (6)$$

The order minimising the FPE values is then chosen as an estimate of p.

Akaike Information Criterion (AIC): The AIC compares the best, neither under-fits nor over-fits, of a set of statistical models to each other. The AIC is defined by:

$$AIC(m) = \ln|\tilde{\Sigma}_u(m)| + \frac{2}{T}(\text{Number of freely estimated parameters})$$

$$= \ln|\tilde{\Sigma}_u(m)| + \frac{2mK^2}{T} \qquad (7)$$

The estimate $\hat{p}$(AIC) for p is chosen so that this criterion is minimised.

Schwarz (or Bayesian) Information Criterion (SIC/BIC): The SIC chooses the least complex probability model among multiple options using a likelihood function. The SIC is defined by:

$$SIC(m) = \ln\left|\tilde{\sum}_u(m)\right| + \frac{\ln T}{T} \text{(Number of freely estimated parameters)}$$
$$= \ln\left|\tilde{\sum}_u(m)\right| + \frac{\ln T}{T} mK^2 \quad (8)$$

The order estimate $\hat{p}$ (SIC) is chosen so as to minimise the value of the criterion.

Hannan–Quinn Criterion (HQC): The HQC is a measure of the goodness of fit, not based on the log-likelihood function but related to Akaike's information criterion. The HQC is defined by:

$$HQC(m) = \ln\left|\tilde{\sum}_u(m)\right| + \frac{2\ln\ln T}{T} \text{(Number of freely estimated parameters)}$$
$$= \ln\left|\tilde{\sum}_u(m)\right| + \frac{2\ln\ln T}{T} mK^2 \quad (9)$$

The estimate $\hat{p}$ (HQ) is the order that minimises HQC(m) for m = 0,1…. M.

Cointegration: When all the variables are stationary at levels i.e. integrated of order 0 [I(0)], then there is no correlation between several time series in the system over the long term i.e. no cointegration of the equations. But if the two series are not stationary at levels, the series has to be made stationary and tested for cointegration for those variables which are stationary of the same order (Engle and Granger, 1987). When the variables are cointegrated i.e. they have a long-run relationship, the Vector Error Correction Model (VECM), and if the variables are not cointegrated, the Vector Autoregression Model (VAR) are applied in the estimation.

Johansen Cointegration Test: The Johansen test is used to test cointegrating relationships between several non-stationary time series data. Consider y_t a VAR of order p given by:

$$y_t = a_1 y_{t-1} + \cdots + a_p y_{t-p} + \delta x_t + \varepsilon_t \quad (10)$$

where y_t is an nx1 k-vector of variables that are integrated of order one i.e. I(1), x_t is a d-vector of deterministic variables and ε_t is an nx1 vector of errors. Rewrite the VAR as:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + \delta x_t + \varepsilon_t \quad (11)$$

where $\Pi = \sum_{i=1}^{p} a_i - I$ and $\Gamma_i = \sum_{j=i+1}^{p} a_j$ (12)

If the coefficient matrix Π is reduced to rank r<n, there exist nxr matrices α and β each with rank r such that $\Pi = \alpha\beta'$ and $\beta' y_t$ is stationary i.e. I(0). The r is the number of cointegrating relationships, the elements of α are known as the adjustment parameters in the vector error correction model and each column of β is a cointegrating vector. The Johansen method is to estimate the Π matrix from an unrestricted VAR and to test whether for rejection of the restrictions implied by the reduced rank of Π. Johansen proposes two different likelihood ratio tests for testing the number of cointegrating relations: the trace test and the maximum eigenvalue test.

Trace Test: The trace test tests the null hypothesis of r cointegrating relations against the alternative of k cointegrating relations, where k is the number of endogenous variables, for r = 0,1,…,k-1. The alternative of k cointegrating relations corresponds to the case where none of the series has a unit root and a stationary VAR may be specified in terms of the levels of all the series. The trace statistic for the null hypothesis of r cointegrating relations is computed as:

$$LR_{tr}(r|k) = -T\sum_{i=r+1}^{k} log(1-\lambda_i) \quad (13)$$

where T is the sample size and λ_i is the ith largest eigen value of the Π.

Maximum Eigen Value Test: The maximum eigen value test tests the null hypothesis of r cointegrating relations against the alternative of r+1 cointegrating relations. The test statistic is computed as:

$$LR_{max}(r|r+1) = -T\, log(1-\lambda_{r+1}) = LR_{tr}(r|k) - LR_{tr}(r+1|k) \quad (14)$$

for r = 0, 1, …, k– 1.

Structural Vector Autoregression (SVAR): The VAR modelling makes few assumptions about the underlying structure of the economy and instead focuses entirely on obtaining a good statistical representation of the past interactions between economic variables, letting the data determine the model. The SVAR model attempts to characterise the economy by making a minimum number of a priori assumptions. Let the system be described by a linear stochastic dynamic system as:

$$y_t = b_0 y_t + b_1 y_{t-1} + \cdots + b_p y_{t-p} + \delta x_t + \varepsilon_t \quad (15)$$

y_t where y_t is an nx1 vector of variables in the system at time t, b_i for i = 0,….., p, are nxn matrix of coefficients, z_t is an nx1 vector of intercepts, deterministic trends or other exogenous variables and ε_t an nx1 vector of structural shocks with a variance-covariance matrix of E(εt, ε't) = I. $E(\varepsilon_t \varepsilon_t') = I$. The reduced form VAR equation is given by:

$$y_t = a_1 y_{t-1} + \cdots + a_p y_{t-p} + \delta x_t + u_t \quad (16)$$

where u_t is the nx1 vector of residuals with variance-covariance Ωmatrix $E(u_t u_t') = \Omega$.

Impulse Response Function: Defining $a_0 = (I - b_0)^{-1}$ implying ai = a0bi that $a_i = a_0 b_i$, for i=1,…,p, the structural shocks and the reduced-form residuals are related by:

$$u_t = a_0 \varepsilon_t \text{ so that } \Omega = a_0 a_0' \quad (17)$$

The equations (15) and (16) can be expressed in MA form as:

$$y_t = [I - b(L)]^{-1} \varepsilon_t \quad (18)$$

$$y_t = [I - a(L)]^{-1} \varepsilon_t \quad (19)$$

The impulse response to structural shocks can then be obtained from equations (18) and (19) using the relation:

$$[I - b(L)]^{-1} = [I - a(L)]^{-1} a_0 \quad (20)$$

Imposition of further identification assumptions are to be imposed to recover the structural shocks ε_t from the reduced-form residuals u_t. The standard and widely used recursive identification scheme is to assume that a_0 is lower triangular and is implemented through the Cholesky decomposition of the matrix Ω.

Just as an autoregression has a moving average representation, a vector autoregression can be written as a vector moving average (VMA). The VMA representation allows tracing the time path of the various shocks on the variables in the VAR system (Sims, 1980; 1992). The VMA corresponding to the VAR with the recursive (Cholesky) ordering is given by:

$$y_t = \mu + \theta_0 \varepsilon_t + \theta_1 \varepsilon_{t-1} + \cdots + \theta_p \varepsilon_{t-p} \quad (21)$$

where μ contains nx1 vector of mean values of endogenous variables, $\theta_0 = a_0$ is the lower triangular matrix. The impulse responses to the orthogonal shocks ε_{jt} are given by:

$$\frac{\partial y_{it+s}}{\partial \varepsilon_{jt}} = \frac{\partial y_{it}}{\partial \varepsilon_{jt-s}} = \theta_{ij}^{s} \quad i,j = 1,\ldots,n \quad S > 0 \quad (22)$$

where θ_{ij}^{s} is the (i,j)th element of θ_s. The plot of θ_{ij}^{s} against s is called the impulse response function (IRF) of y_i with respect to ε_j.

Variance Decomposition: Forecast error variance decomposition further uncovers the interrelationships among the variables in the system, which decomposes the proportion of the movements in a sequence due to its own shocks versus shocks to the other variable. As n increases, the variance decompositions should converge. Using the orthogonal shocks ε_t the h-step ahead forecast error vector, with known VAR coefficients, can be expressed as:

$$y_{T+h} - y_{T+h|T} = \sum_{s=0}^{h-1} \theta_s \varepsilon_{T+h-s} \quad (23)$$

For a specific variable y_{iT+h}, the forecast error has the form:

$$y_{iT+h} - y_{iT+h|T} = \sum_{s=0}^{h-1} \theta_{i1}^{s} \varepsilon_{1T+h-s} + \cdots + \sum_{s=0}^{h-1} \theta_{in}^{s} \varepsilon_{nT+h-s} \quad (24)$$

Since the structural errors are orthogonal, the variance of the h-step forecast error is given by:

$$var(y_{iT+h} - y_{iT+h|T}) = \sigma_{\varepsilon_1}^2 \sum_{s=0}^{h-1} (\theta_{i1}^{s})^2 + \cdots + \sigma_{\varepsilon_n}^2 \sum_{s=0}^{h-1} (\theta_{in}^{s})^2 \quad (25)$$

where $\sigma_{\varepsilon_j}^2 = var(\varepsilon_{jt})$. The portion of $var(y_{iT+h} - y_{iT+h|T})$ due to shock ε_j is given by:

$$FEVD_{ij}(h) = \frac{\sigma_{\varepsilon j}^2 \sum_{s=0}^{h-1} (\theta_{ij}^{s})^2}{\sigma_{\varepsilon_1}^2 \sum_{s=0}^{h-1} (\theta_{i1}^{s})^2 + \cdots + \sigma_{\varepsilon_n}^2 \sum_{s=0}^{h-1} (\theta_{in}^{s})^2} \qquad i,j = 1, \ldots, n \quad (26)$$

Benchmark SVAR Model: Since the Cholesky decomposition method is used for the identification of monetary policy shock, the benchmark SVAR model in three variables viz. output (GDP), prices (WPI) and interest rate (CR) can be written as:

$$\begin{bmatrix} \varepsilon_t^{gdp} \\ \varepsilon_t^{wpi} \\ \varepsilon_t^{cr} \end{bmatrix} = \begin{bmatrix} c(1) & 0 & 0 \\ c(2) & c(3) & 0 \\ c(4) & c(5) & c(6) \end{bmatrix} \begin{bmatrix} e_t^{gdp} \\ e_t^{wpi} \\ e_t^{cr} \end{bmatrix} \quad (27)$$

where e_t denotes VAR residuals and ε_t denotes structural shocks. The first equation represents a slow response of real GDP to shocks in prices and interest rates. The second equation shows that prices respond slowly to shocks in interest rates but react immediately to changes in real GDP. The last equation implies call rate responds contemporaneously to shocks in real GDP and prices.

To examine the various transmission channels, each of the corresponding variables representing a specific channel is added to the benchmark model, alternatively as an exogenous variable and then as the fourth endogenous variable. When treated as an exogenous variable, the structure of the SVAR restrictions remains the same as in the benchmark model, and the transmission through this channel is blocked. On the other hand, by treating the variable as an endogenous variable and allowing dynamic interactions with the other variables, the transmission through this channel is opened. It is assumed that this transmission-related variable is contemporaneously affected by all the other variables in the benchmark model. The augmented SVAR model with four variables takes the form:

$$\begin{bmatrix} \varepsilon_t^{gdp} \\ \varepsilon_t^{wpi} \\ \varepsilon_t^{cr} \\ \varepsilon_t^{channel} \end{bmatrix} = \begin{bmatrix} c(1) & 0 & 0 & 0 \\ c(2) & c(3) & 0 & 0 \\ c(4) & c(5) & c(6) & 0 \\ c(7) & c(8) & c(9) & c(10) \end{bmatrix} \begin{bmatrix} e_t^{gdp} \\ e_t^{wpi} \\ e_t^{cr} \\ e_t^{channel} \end{bmatrix} \quad (28)$$

The strength of each channel is obtained by comparing two sets of impulse responses of inflation and growth to shocks on the policy rate. The first impulse response is from the augmented VAR with the channel-related variable as an endogenous variable. The second impulse response is with the channel-related variable as one of the exogenous variables in the augmented VAR. Thus, there are three sets of variables in the ASVAR viz. purely endogenous, purely exogenous and transmission-related variables which are alternatively considered endogenous and exogenous variables.

In the case of components of aggregate demand, the benchmark model is augmented by including the aggregate demand components as additional variables. Given the five components of aggregate demand, the augmented SVAR model is given as:

$$\begin{bmatrix} \varepsilon_t^{gdp} \\ \varepsilon_t^{wpi} \\ \varepsilon_t^{cr} \\ \varepsilon_t^{demand} \end{bmatrix} = \begin{bmatrix} c(1) & 0 & 0 & 0 \\ c(2) & c(3) & 0 & 0 \\ c(4) & c(5) & c(6) & 0 \\ c(7) & c(8) & c(9) & c(10) \end{bmatrix} \begin{bmatrix} e_t^{gdp} \\ e_t^{wpi} \\ e_t^{cr} \\ e_t^{demand} \end{bmatrix} \quad (29)$$

In this augmented SVAR, GDP excludes that particular component of aggregate demand which is being examined. The fourth equation in this augmented SVAR implies that a given component of aggregate demand responds contemporaneously to the real GDP excluding that component, prices and interest rate.

Empirical Analysis

Table 1 presents the definition and descriptive statistics of the variables used in the study to determine through which channel the monetary policy influences output and prices in India and in which sector (components of aggregate demand) of the economy the impact of monetary policy is felt the most. All variables are expressed in logarithm form. The call rate is more volatile relative to other variables and the mean of loans is the highest among all variables.

Table 1 Descriptive Statistics of Variables

Variable	Description	Mean	SD
lnGDP	Real GDP at constant prices (₹billions)	9.374	0.383
lnWPI	Wholesale price index	4.885	0.286
lnCR	Weighted average call rate - overnight call rate (₹)	6.538	1.602
lnPFCE	Private final consumption expenditure (₹billions)	8.866	0.385
lnGFCF	Gross fixed capital formation (₹billions)	8.186	0.482
lnGFCE	Government final consumption expenditure (₹billions)	7.134	0.309
lnIMPORT	Imports (₹billions)	7.989	0.614
lnEXPORT	Exports (₹billions)	7.735	0.628
lnNPCGDP	GDP excluding the private consumption (billions)	8.452	0.383
lnNIGDP	Non-investment component of GDP (₹ billions)	9.005	0.349
lnNGGDP	Non-government consumption component of GDP (₹billions)	9.260	0.394
lnNMGDP	Non-import component of GDP (₹billions)	9.072	0.324
lnNXGDP	Non-export component of GDP (₹billions)	9.148	0.340
lnLOAN	Bank credit to commercial sector (₹billions)	10.26	0.905
lnSENSEX	S&P BSE sensex	9.468	0.785
lnREER	Real effective exchange rate	4.666	0.062
lnWCPI	World commodity price index	4.817	0.379

ADF Stationarity Test: The ADF test results presented in Table 2 show that the null hypothesis of the presence of unit root can not be rejected for all the variables at levels, except for call rate i.e. all variables except call rate are not stationary at levels. The p-value of the call rate is statistically significant and hence it is stationary at levels and integrated of order 0 i.e. I(0). At first difference, all the variables except loan are stationary and are integrated of order 1 i.e. I (1). The variable loan is stationary at the second difference and is integrated of order 2 i.e. I(2).

Table 2 Augmented Dickey-Fuller Stationarity Test

Variable	Level			First difference			Second difference		
	Constant	Constant + trend	None	Constant	Constant + trend	None	Constant	Constant + trend	None
lnGDP	-0.60	-1.92	10.14	-7.35*	-7.32*	-1.08	-6.71*	-6.67*	-6.77*
	(0.86)	(0.64)	(0.99)	(0.00)	(0.00)	(0.28)	(0.00)	(0.00)	(0.00)
lnWPI	-1.34	-0.78	3.76	-5.71*	-5.85*	-1.18	-6.82*	-6.78*	-6.87*
	(0.61)	(0.96)	(0.99)	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)
lnCR	-3.18**	-3.35	-0.74	-5.06*	-5.01*	-5.09*	-6.76*	-6.72*	-6.80*
	(0.03)	(0.07)	(0.39)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnPFCE	0.14	-2.27	7.01	-8.11*	-8.05*	-0.16	-4.92*	-4.99*	-4.92*
	(0.97)	(0.45)	(0.99)	(0.00)	(0.00)	(0.62)	(0.00)	(0.00)	(0.00)
lnGFCF	-1.62	-1.11	4.64	-10.05*	-10.21*	-2.84*	-6.96*	-6.92*	-7.01*
	(0.47)	(0.93)	(0.99)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnGFCE	-0.58	-2.51	2.02	-6.42*	-6.38*	-2.08**	-8.03*	-7.97*	-8.09*
	(0.87)	(0.32)	(0.99)	(0.00)	(0.00)	(0.03)	(0.00)	(0.00)	(0.00)
lnIMPORT	-1.49	-1.32	3.57	-9.15*	-9.24*	-1.36	-7.55*	-7.50*	-7.60*
	(0.53)	(0.88)	(0.99)	(0.00)	(0.00)	(0.16)	(0.00)	(0.00)	(0.00)
lnEXPORT	-2.50	-1.05	2.90	-7.02*	-7.31*	-4.11*	-6.89*	-6.85*	-6.94*
	(0.11)	(0.93)	(0.99)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnNPCGDP	-1.03	-1.68	5.26	-8.79*	-8.81*	-2.39**	-5.25*	-5.20*	-5.29*
	(0.74)	(0.75)	(0.99)	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)
lnNIGDP	1.24	-4.45*	6.63	-6.53*	-6.73*	-0.66	-7.02*	-6.97*	-7.08*
	(0.99)	(0.00)	(0.99)	(0.00)	(0.00)	(0.42)	(0.00)	(0.00)	(0.00)
lnNGGDP	-0.64	-1.96	7.51	-11.33*	-7.55*	-1.23	-7.52*	-7.49*	-7.58*
	(0.86)	(0.61)	(0.99)	(0.00)	(0.00)	(0.20)	(0.00)	(0.00)	(0.00)
lnNMGDP	0.21	-3.40	-4.58	-8.44*	-8.41*	-6.78*	-5.61*	-5.28*	-5.66*
	(0.97)	(0.97)	(0.99)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnNXGDP	0.98	-2.76	3.81	-3.11**	-3.32	-0.48	-3.99*	-3.94*	-4.03*
	(0.99)	(0.22)	(0.99)	(0.03)	(0.07)	(0.50)	(0.00)	(0.00)	(0.00)
lnLOAN	-1.68	-0.43	1.90	-2.52	-3.04	-1.14	-15.24*	-15.14*	-15.33*
	(0.44)	(0.98)	(0.99)	(0.12)	(0.13)	(0.23)	(0.00)	(0.00)	(0.00)
lnSENSEX	-0.95	-2.59	2030	-4.98*	-4.96*	-5.52*	-6.65*	-6.65*	-6.65*
	(0.76)	(0.29)	(0.99)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lnREER	-0.36	-2.01	1.09	-4.74*	-4.84*	-4.61*	-5.42*	-5.37*	-5.47*
	(0.91)	(0.58)	(0.93)	(0.00)	(0,00)	(0.00)	(0.00)	(0.00)	(0.00)
lnWCPI	-1.86	-1.76	0.42	-5.55*	-5.54*	5.55*	-7.03*	-7.01*	-7.08*
	(0.35)	(0.72)	(0.80)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Note: Figures are t-values. Figures in parentheses are p-values. Probability based on Mackinnon (1996) one-sided p-values. *, ** significant at 1, 5% levels.

VAR Optimal Lag Length Selection: Table 3 presents the results of the VAR lag order selection criteria. According to the LR, SIC and HQ criteria, the optimal lag length is 1, whereas on the basis of FPE and AIC criteria, the optimal lag length is 2. Since the lag length of 1 quarter is too short to capture the underlying dynamics of the system, the lag length of 2 quarters is selected.

Table 3 Optimal Lag Length

Lag	LogL	LR	FPE	AIC	SIC	HQC
0	290.701	NA	4.63e-08	-8.373	-8.178	-8.296
1	335.508	83.024*	1.62e-08	-9.427	-8.937*	-9.233*
2	344.658	16.148	1.61e-08*	-9.4311*	-8.648	-9.121
3	347.595	4.922	1.94e-08	-9.258	-8.176	-8.826
4	355.104	11.926	2.05e-08	-9.209	-7.838	-8.666
5	358.278	4.762	2.46e-08	-9.037	-7.373	-8.378
6	362.318	5.703	2.91e-08	-8.892	-6.933	-8.116
7	372.748	13.804	2.88e-08	-8.934	-6.682	-8.041
8	383.377	13.130	2.85e-08	-8.982	-6.436	-7.973

Note: * indicates lag order selected by the criteria at 5% significance level.

Johansen Cointegration Test: The Johansen Cointegration test was performed to test the cointegration between the variables output (GDP) and prices (WPI) in the long term and then to identify the appropriate model VECM or VAR to be used in the empirical analysis. The trace and maximum eigen statistics presented in Table 4 suggest no cointegration and hence there is no long-run relationship among the series. This implies that if there are shocks to the system, the model is not likely to converge in the long run. Since there is no cointegration, only the short-run model i.e.VAR model is to be used.

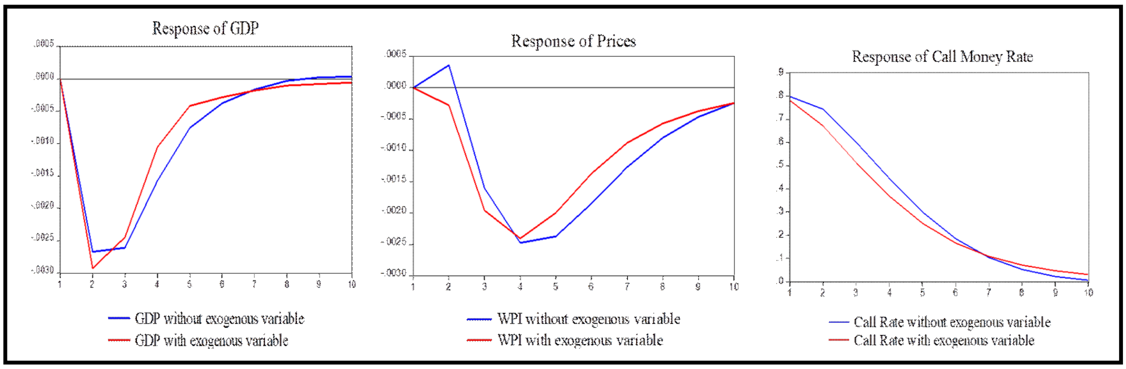
Table 4 Johansen Cointegration Test

Hypothesised no. of CE(s)	Eigen value	Trace statistic	5% critical value	Prob.*	Max Eigen S statistic	5 % critical value	Prob.*
None	0.061	4.621	15.495	0.848	4.613	14.26	0.79
At most 1	0.001	0.008	3.842	0.930	0.008	3.841	0.93

Note: * Rejection of the hypothesis at the 5% level. Mackinnon-Haug-Michelis (1999) p-values.

Benchmark/Baseline VAR Model: Figure 1 depicts the dynamic response of GDP, prices and call money rate to a positive one standard deviation call money rate shock under two baseline VAR estimates, with and without the external exogenous variable. A contractionary monetary policy creates a decline in GDP. The GDP bottoms out in the third quarter and shows a V-shaped response. With the inclusion of an exogenous variable, the peak negative impact on GDP is felt faster in the second quarter but the impact dissipates almost at the same time, with or without the inclusion of an exogenous variable. The prices also decline in response to a positive call money rate shock after an initial peak impact. The maximum decline in prices is achieved in the fourth quarter. The initial positive response of prices to a monetary policy shock seems somewhat contradictory, but is commonly found in the literature and has been dubbed the 'price puzzle'. The price puzzle may be that central banks have information on expected prices based on some variables that are not included in the model. The price puzzle disappears, and the impact dissipates a little faster, after the inclusion of the exogenous variable. The response of the call rate to its own shock falls continuously till it converges to the baseline. It takes almost the same time to converge to the baseline with or without an exogenous variable.

Figure 1 Impulse Response Functions - Benchmark VAR Model



Decomposition: The results of variance decomposition of the base VAR model reported in Table 5 show that the call rate accounts for 7.02 to 7.53% fluctuations in real GDP between one to three years, with own shock accounting for over 87.28%. With regard to prices, interest rate accounts for about 12.30% and real GDP for about 2.41% of total fluctuations, with own shock explaining over 85.29%. Prices and real GDP have a moderate influence on interest rates accounting for about 8.24% and 1.96% respectively of the total variation in call rate.

Table 5 Variance Decomposition - Base VAR Model

Variable	Period	DlnGDP	DlnWPI	DlnCR
DlnGDP	3	88.321	4.6596	7.0189
	6	87.324	5.1547	7.5212
	10	87.282	5.1776	7.540
DlnWPI	3	2.229	94.542	3.229
	6	2.4116	86.101	11.487
	10	2.4086	85.287	12.304
DlnCR	3	1.7388	6.9630	91.298
	6	1.9468	8.1608	89.892
	10	1.9609	8.2415	89.798

Monetary Transmission Channels

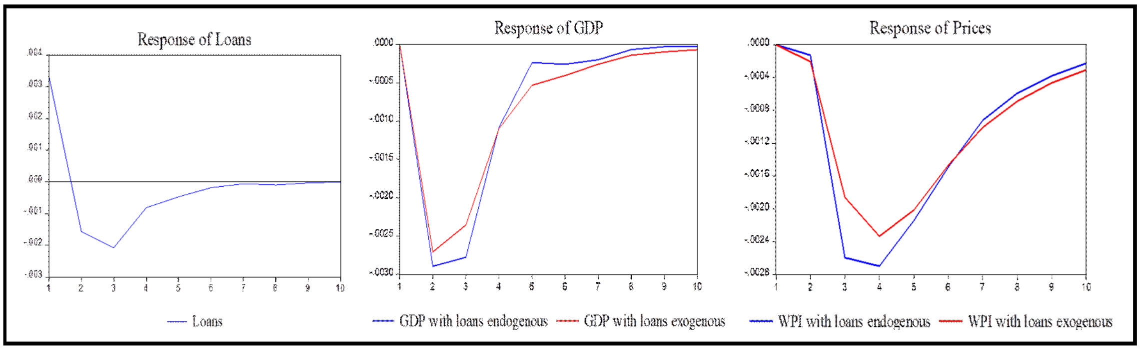
Credit (Bank Lending) Channel

The credit channel transmission of monetary policy works through the bank lending channel. In the bank lending channel, the effects of a monetary policy tightening propagate through changes in bank lending and the interest rate on bonds and loans which determine investment and aggregate demand as the monetary policy tightening reduces not only the supply of deposits but also the supply of credit. Thus, a contractionary monetary policy that decreases bank reserves and bank deposits will have an impact through its effect on the borrowings. Schematically, the monetary policy effect through the bank lending channel can be described as:

$$M \downarrow \Rightarrow bank\ deposits \downarrow \Rightarrow bank\ loans \downarrow \Rightarrow investment \downarrow \Rightarrow output \downarrow \qquad (30)$$

The significance of the bank lending channel in the monetary policy transmission is analysed in two steps: first, the effects of a monetary policy tightening on bank loans and second, given that a monetary policy tightening reduces the aggregate demand, how much of the effects of monetary policy tightening pass through bank lending. Therefore, along with the GDP, prices, and call money rate the bank credit to the commercial sector i.e. loans is added to the vector of endogenous variables. Figure 2 depicts the dynamic responses of GDP, commodity prices and bank loans to an unanticipated positive call money rate shock. The monetary policy tightening initially decreases bank loans to the commercial sector by 0.2% below the baseline. The GDP bottoms out in the second quarter at 0.29% below the baseline.

Figure 2 Impulse Response Functions - Credit (Bank Lending) Channel



In order to calibrate the importance of the bank lending channel in the transmission of monetary policy shocks, the model is reestimated after exogenising the bank loans. Such a model resembles the traditional money channel where the monetary policy shocks are transmitted to the real sector without any role of bank lending. The response of GDP to positive call money rate innovations is reduced after exogenising the bank loans although the reduction is not much significant. At the end of the 10th quarter, the accumulated response in the bank lending channel is 47.32% whereas the accumulated response after exogenising the bank loans is 47.9%. Therefore, at the end of the 10th quarter, the accumulated response when the bank lending channel is blocked is about 0.58% higher than when it is allowed to operate. This insignificant difference between the two responses of GDP to positive call money rate innovations suggests that the bank lending channel in India is not that important. The response of prices to a monetary policy tightening is almost similar. However, as compared to the impact on GDP, the impact is less pronounced on commodity prices.

The variance decomposition of the bank lending transmission mechanism reported in Table 6 shows that the call rate accounts for 7.32 to 7.88% fluctuations in real GDP between one to three years, with own shock accounting for over 81.91%. With regard to prices, interest rate accounts for about 15.67% and real GDP for about 2.42% of total fluctuations, with own shock explaining over 81.12%. Commodity prices and real GDP have a moderate influence on interest rates accounting for about 6.52% and 1.47% respectively of the total variation in call rate. The bank loans have a moderate influence of 5% on real GDP and a very weak influence on prices and interest rates. The call rate and prices have a moderate influence on loans accounting for about 6.63% and 6.07% respectively, while the impact of real GDP on loans is very weak accounting for about 1.88% of total fluctuations.

Table 6 Variance Decomposition - Credit (Bank Lending) Channel

Variable	Period	DlnGDP	DlnWPI	DlnCR	DlnLoan
DlnGDP	3	82.5419	5.226	7.375	4.857
	6	81.937	5.270	7.860	4.931
	10	81.906	5.283	7.876	4.934
DlnWPI	3	2.223	91.508	5.436	0.833
	6	2.423	81.917	14.852	0.804
	10	2.419	81.118	15.666	0.797
DlnCR	3	1.355	5.606	92.911	0.128
	6	1.464	6.468	91.925	0.142
	10	1.469	6.515	91.873	0.143
DlnLoan	3	0.772	3.457	6.449	89.321
	6	1.866	4.051	6.628	87.455
	10	1.884	4.065	6.629	87.421

Asset Price Channel

The asset price channel transmission of monetary policy works through the prices of assets that involves Tobin's q theory of investment and wealth effects on consumption. A contractionary monetary policy lowers the equity prices leading to a lower q and thus lowering investment. The monetary policy effect through Tobin's q theory can be described as:

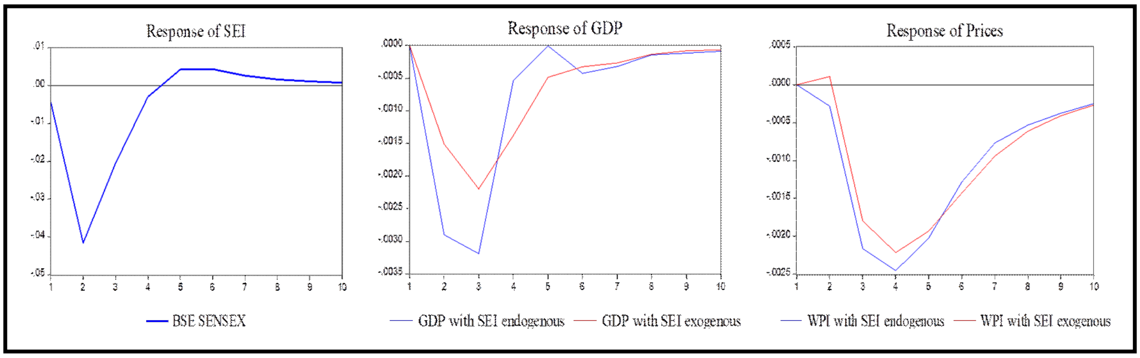
$$M \downarrow \Rightarrow asset\ price \downarrow \Rightarrow Tobin's q \downarrow \Rightarrow investment \downarrow \Rightarrow output \downarrow \qquad (31)$$

In the alternative monetary transmission channel, wealth effects on consumption work through the decreases in the value of financial wealth and lifetime resources of consumers. The contractionary monetary policy effect through wealth effects on consumption can be described as:

$$M \downarrow \Rightarrow asset\ price \downarrow \Rightarrow wealth \downarrow \Rightarrow consumption \downarrow \Rightarrow output \downarrow \quad (32)$$

The significance of the asset price channel in the monetary policy transmission is analysed through the effects of a positive call money rate shock on GDP that passes through the asset prices. Figure 3 depicts the dynamic responses of GDP, commodity prices and asset prices to an unanticipated positive call money rate shock. In response to a monetary policy tightening, the BSE Sensex decreased initially to 4.16% below the baseline. The GDP bottoms out in the third quarter at 0.32% below the baseline. To calibrate the importance of the asset price channel in the transmission of monetary policy shocks, the model is reestimated after exogenising the BSE Sensex. With exogenous BSE Sensex, the model represents the traditional money channel with no role in asset price. The response of GDP to positive call money rate innovations is significantly reduced after exogenising the BSE Sensex. At the end of the 10th quarter, the accumulated response of GDP in the asset price channel is 48.31% whereas the accumulated response after exogenising the BSE Sensex is 40.34%. Therefore, at the end of the 10th quarter, the accumulated response of GDP when the asset price channel is blocked is about 7.97% lower than when it is allowed to operate. This significant difference between the two responses of GDP to positive call money rate innovations suggests the importance of the asset price channel as the monetary policy transmission mechanism in India. Commodity prices also show an almost similar response to a monetary policy tightening. However, as compared to the impact on GDP, the impact is less pronounced on commodity prices.

Figure 3 Impulse Response Functions - Asset Price Channel



The variance decomposition of the asset price channel reported in Table 7 shows that the call rate accounts for 8.63 to 8.76% fluctuations in real GDP between one to three years, with own shock accounting for over 82.49%. With regard to prices, interest rate accounts for about 12.35% and real GDP for about 2.34% of total fluctuations, with own shock explaining over 84.96%. Commodity prices and real GDP have a moderate influence on interest rates accounting for about 8.88% and 1.75% respectively of the total variation in call rate. Asset prices have a greater influence on real GDP and a very weak influence on prices and interest rates. The real GDP has a weak influence and commodity prices have a moderate influence on stock prices accounting for about 3.85% and 8.11% respectively, while the impact of call rate on asset prices is very significant accounting for about 21.93% of the total fluctuations.

Table 7 Variance Decomposition - Asset Price Channel

Variable	Period	DlnGDP	DlnWPI	DlnCR	DlnSensex
DlnGDP	3	83.638	5.0364	8.635	2.691
	6	82.573	5.587	8.702	3.137
	10	82.488	5.613	8.759	3.139

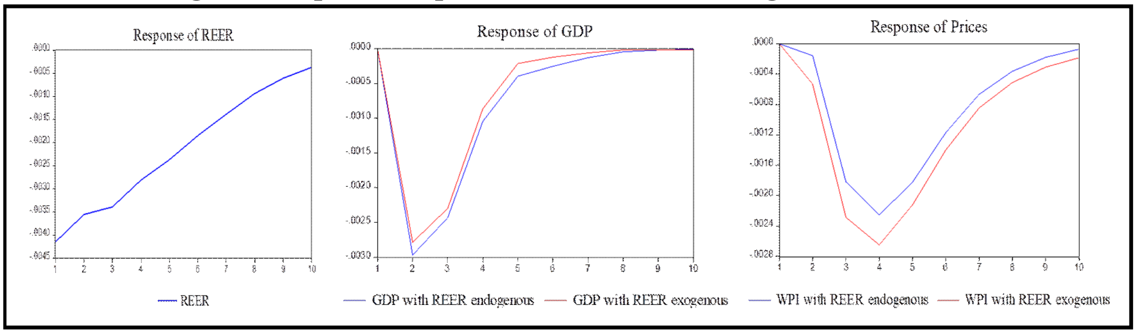
DlnWPI	3	2.087	93.720	3.759	0.433
	6	2.243	85.596	11.700	0.460
	10	2.240	84.956	12.346	0.458
DlnCR	3	1.558	7.339	90.921	0.182
	6	1.738	8.756	89.309	0.196
	10	1.753	8.877	89.173	0.1964
DlnSensex	3	3.502	7.182	21.896	67.419
	6	3.851	8.091	21.854	66.204
	10	3.849	8.113	21.931	66.107

Exchange Rate Channel
The exchange rate channel of the monetary transmission mechanism works through the appreciation of the domestic currency making domestic goods more expensive than foreign goods thereby causing a fall in net exports and hence in aggregate output. The schematic representation of the monetary transmission mechanism operating through the exchange rate is described as:

$$M \downarrow \Rightarrow interest\ rate \uparrow \Rightarrow domestic\ currency \uparrow \Rightarrow net\ exports \downarrow \Rightarrow output \downarrow \quad (33)$$

The significance of the exchange rate channel in the monetary policy transmission is analysed through the effects of a positive call money rate shock on GDP that passes through the exchange rate. Figure 4 depicts the dynamic responses of GDP, commodity prices and real effective exchange rate to an unanticipated positive call money rate shock. In response to monetary tightening, the REER increases continuously from 0.42% below the baseline and it dissipates in about 10 quarters. With and without exogenising the real effective exchange rate, the response of GDP is almost similarly positive to an overnight call money rate innovation. At the end of the 10th quarter, the accumulated response in the exchange rate channel is 45.52% whereas the accumulated response after exogenising the REER is 39.92%. Therefore, at the end of the 10th quarter, the accumulated response when the exchange rate channel is blocked is about 5.6% lower than when it is allowed to operate. The effect of innovations in the call money rate on commodity prices is significantly different under the two scenarios. The response of commodity prices is higher with REER exogenised. Thus, the results suggest that the exchange rate channel of monetary policy transmission is either absent or weak in India.

Figure 4 Impulse Response Functions - Exchange Rate Channel



The variance decomposition of the exchange rate channel reported in Table 8 shows that the call rate accounts for 6.87 to 7.33% fluctuations in real GDP between one to three years, with own shock accounting for over 85.94%. With regard to commodity prices, interest accounts for about 9.77% and real GDP for about 2.31% of total fluctuations, with own shock explaining over 82.83%. Commodity prices have a moderate influence on interest rate accounting for about 9.97%, whereas real GDP has little influence on interest rate accounting for about 2.88% of the total variation in call rate. The REER has a very weak influence on the real GDP accounting for about 1.60% but has a moderate influence on the interest rate and commodity prices accounting for about 3.26% and 4.09% respectively of the total fluctuations. However, commodity prices and call rate have a moderate influence on REER accounting for about 4.51% and 7.77% respectively, while the impact of real GDP on REER is weak accounting for about 3.02% of the total fluctuations.

Table 8 Variance Decomposition - Exchange Rate Channel

Variable	Period	DlnGDP	DlnWPI	DlnCR	DlnREER
DlnGDP	3	86.975	4.584	6.872	1.569
	6	85.991	5.095	7.337	1.577
	10	85.939	5.119	7.340	1.602
DlnWPI	3	2.851	90.966	2.670	3.513
	6	3.267	83.444	9.426	3.862
	10	3.307	82.831	9.774	4.087
DlnCR	3	1.938	8.362	88.606	1.093
	6	2.791	9.894	84.491	2.823
	10	2.882	9.968	83.886	3.263
DlnREER	3	3.071	4.382	5.388	87.159
	6	3.007	4.434	7.399	85.160
	10	3.024	4.509	7.773	84.693

Direct Interest Rate Channel

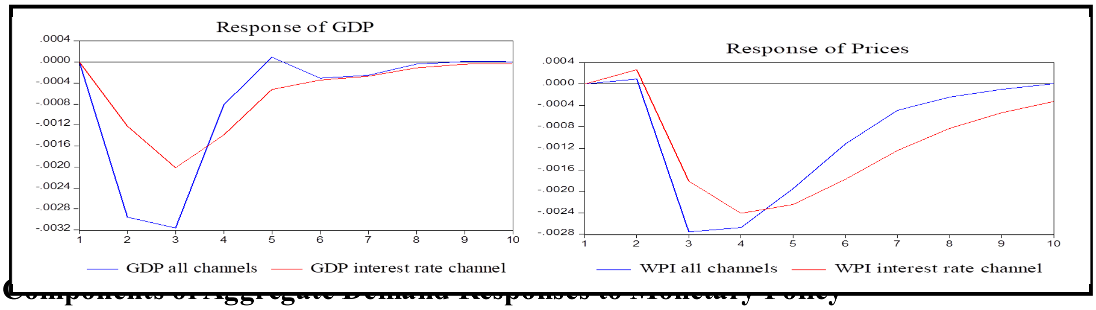
Having analysed more sophisticated ways in which monetary policy affects real economic activity, the focus now shifts to the basic and traditional channel i.e. the direct interest rate effects of monetary shocks. In the interest rate channel, a contractionary monetary shock leads to a rise in real interest rate which raises the cost of capital thereby causing a decline in investment spending and hence a decline in aggregate demand and a fall in output. The traditional Keynesian view of the transmission of monetary tightening to the real economy can be characterised schematically as:

$$M \downarrow \Rightarrow interest\ rate \uparrow \Rightarrow investment \downarrow \Rightarrow output \downarrow \qquad (34)$$

A rough way of observing the direct interest rate channel of the monetary policy transmission mechanism is in terms of the residual impact not explained by the other three channels viz. credit, asset price and exchange rate channels (Disyatat and Vongsinsirikul, 2003). The significance of the interest rate channel in the monetary policy transmission can be assessed either by summing the unexplained portion of accumulated response by the other three channels or by augmenting the baseline SVAR by enogenising all three channels simultaneously and comparing the accumulated response with the corresponding response by exogenising all the three channels together. It is to be noted that the impact of the direct interest rate channel in both cases could contain the impact of other unexplained channels such as the confidence channel, besides these four traditional channels.

Figure 5 depicts the direct effect of an unanticipated positive call money rate shock on GDP and commodity prices obtained from the augmented SVAR. In response to monetary tightening, at the end of the 10th quarter, the accumulated responses of GDP from the three channels together account for about 46.46% of the total responses. Thus, 53.54% of the monetary transmission would be explained directly by the interest rate channel.

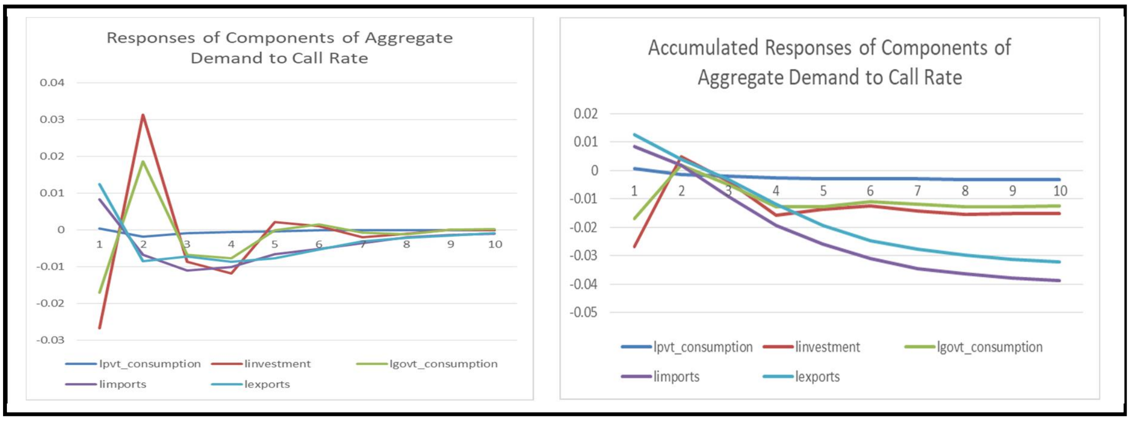
Figure 5 Impulse Response Functions - Interest Rate Channel



Components of Aggregate Demand Responses to Monetary Policy

Given the response of GDP i.e. aggregate demand to monetary policy actions effected mostly through the interest rate transmission mechanism, it is also important to understand which of the components of aggregate demand are most affected by the monetary tightening. To examine this, the benchmark model has been augmented by each of the components of aggregate demand and their impulse responses to the monetary shock in interest rate are compared. Figure 6 depicts the comparative impulse response of the components of aggregate demand along with the accumulated responses. The monetary shock which roughly amounts to a 1.6% increase in call rate has a substantial negative impact on all the components of aggregate demand, although the immediate response of investment and government consumption is initially positive. The overall negative impact dissipates over the 10 quarters. The maximum negative impact is felt on investment and imports, while the impact on private consumption is very small.

Figure 6 Impulse Response Functions - Components of Aggregate Demand



The maximum impact of private consumption is about 0.18% below the baseline in the second quarter and dissipates by the ninth quarter. The accumulated impact after two years is about 0.32% below the baseline. The maximum impact of investment is about 1.2% below the baseline in the fourth quarter and dissipates by the ninth quarter. The accumulated impact after two years is about 1.5% below the baseline. The negative impact of government consumption is seen only in the third and fourth quarters which thereafter turn mildly positive before convergence. The maximum negative impact of government consumption in the fourth quarter is about 0.77% below the baseline and the accumulated response is 1.3% below the baseline. The maximum impact of imports is about 1.1% below the baseline in the third quarter and dissipates after the tenth quarter. The accumulated impact after two years is about 3.9% below the baseline. The maximum impact of exports is about 0.86% below the baseline in the fourth quarter and dissipates after the tenth quarter. The accumulated impact after two years is about 3.2% below the baseline.

Table 9 presents the variance decomposition of components of aggregate demand. The shock-to-call rate accounts for about 1.64% of the total fluctuations of private consumption demand. Commodity price and GDP (excluding private consumption) shocks account for about 1.26 and 15.37 respectively, while own shock explains about 81.73% of the total fluctuations. The results imply that private consumption or household savings in India is less sensitive to interest rate changes. The shock-to-call rate accounts for about 21.30% of the total fluctuations of investment. Commodity price and GDP (excluding investment) shocks account for about 7.81 and 7.90 respectively, while own shock explains about 62.99% of the total fluctuations. The implication is that investment is much more sensitive to interest rates directly as it would raise the cost of capital as well as indirectly through changes in real output and price. The shock-to-call rate accounts for about 8.23% of the total fluctuations of government consumption. Commodity price and GDP (excluding government consumption) shocks account for about 4.91 and 35.87 respectively, while own shock explains about 50.99% of the total fluctuations.

Table 9 Variance Decomposition - Components of Aggregate Demand

Variable	Period	DlnWPI	DlnCR	Components of Aggregate Demand	
Private consumption				DlnPFCE	DlnNPCGDP
DlnPFCE	3	1.037	1.548	82.416	14.999
	6	1.255	1.637	81.755	15.352
	10	1.260	1.638	81.729	15.372
Private investment				DlnGFCF	DlnNIGDP
DlnGFCF	3	7.097	20.688	64.528	7.686
	6	7.750	21.298	63.114	7.838
	10	7.809	21.297	62.994	7.901
Government consumption				DlnGFCE	lnNGGDP
DlnGFCE	3	4.215	7.964	52.753	35.068
	6	4.878	8.230	50.998	35.893
	10	4.914	8.226	50.988	35.871
Imports				DlnIMPORT	DlnNMGDP
DlnIMPORT	3	7.076	6.421	34.631	51.872
	6	7.366	10.348	32.659	49.626
	10	7.428	10.763	32.466	49.342
Exports				DlnEXPORT	DlnNXGDP
DlnEXPORT	3	8.711	10.890	55.325	25.073
	6	8.993	15.793	51.401	23.813
	10	8.988	16.265	50.998	23.749

The shock-to-call rate accounts for about 10.76% of the total fluctuations of imports. Commodity price and GDP (excluding imports) shocks account for about 7.43 and 49.34 respectively, while own shock explains about 32.46% of the total fluctuations. The shock-to-call rate accounts for about 16.27% of the total fluctuations of exports. Commodity price and GDP (excluding exports) shocks account for about 8.99 and 23.75 respectively, while own shock explains about 51% of the total fluctuations. Part of the higher impact on imports than exports may be explained by the decline in investments that have a high import content in India. A greater decline in imports than exports implies higher net exports/lower net imports, which would reduce the monetary policy impact on aggregate demand through a hike in interest rate.

Robustness Check

Robustness is the share of the probability density distribution that falls within the 95% confidence interval of the baseline model. As a robustness check, the GDP and components of aggregate demand models are reestimated ±2SE confidence intervals after blocking off each channel. Figure 7 depicts the impulse responses of GDP to a positive call money rate shock within the channels and after blocking off the channels with a ±2SE confidence interval. The response of GDP to a positive call money rate shock is statistically significant in all the channels suggesting the robustness of the transmission channels and validating the importance of asset price and interest rate channels in India.

Figure 7 Impulse Response Functions - Robustness of GDP Response to a Positive Shock in Call Money Rate

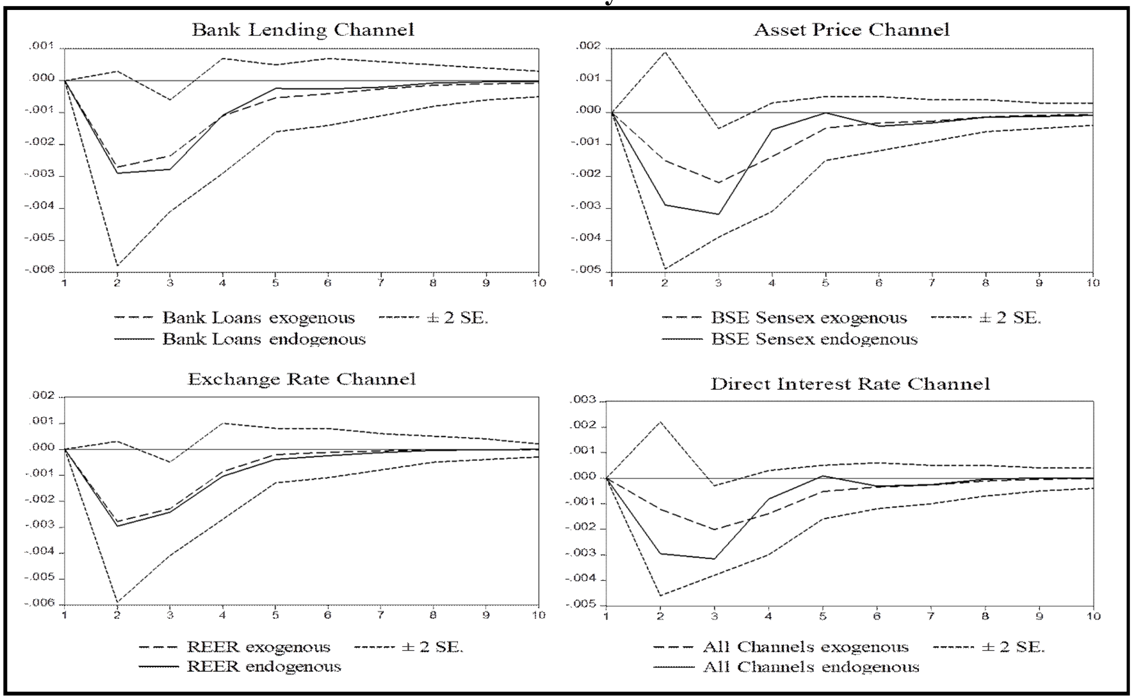
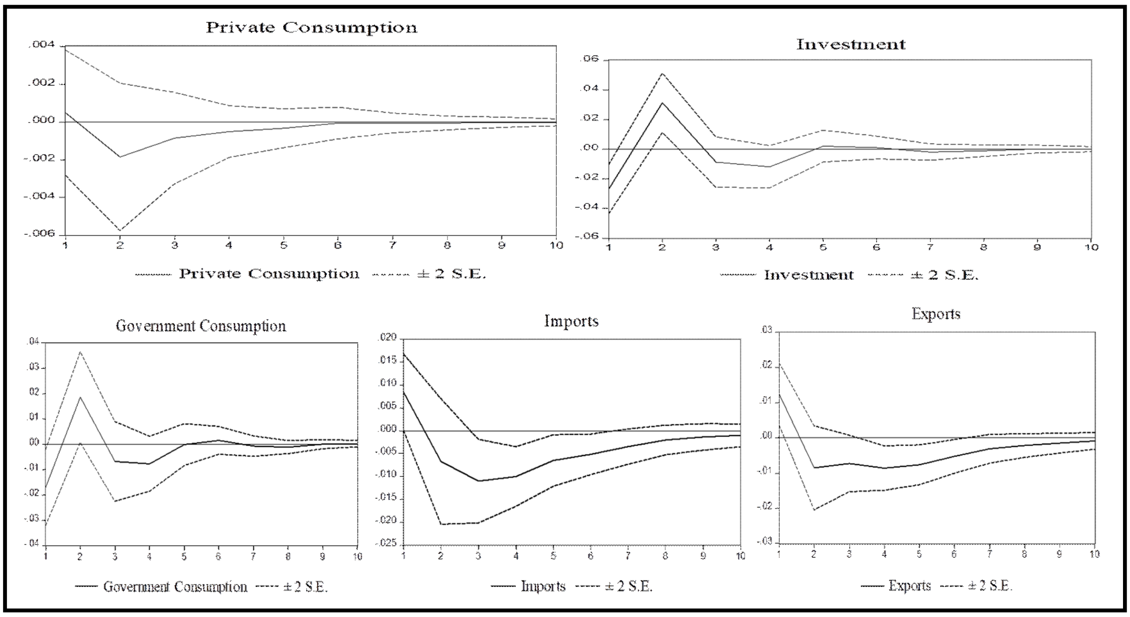


Figure 8 depicts the impulse responses of the components of aggregate demand to a positive call money rate shock within the channels and after blocking off the channels with a ±2SE confidence interval. The impulse responses are statistically significant at the standard level in around the periods where the maximum impacts are felt for investment, government consumption, imports and exports. The impulse responses are insignificant throughout for private consumption.

Figure 8 Impulse Response Functions - Robustness of Responses of Components of Aggregate Demand to a Positive Shock in Call Money Rate



Conclusion

The monetary policy of the central bank uses various monetary instruments to control aggregate demand and commodity prices. Such monetary mechanisms that primarily alter the interest rate affect the real economy effecting consumption and investment changes and operate through various transmission channels such as credit, asset price, exchange rate and interest rate. The transmission of monetary shocks by these channels alters the costs of borrowing, supply of loans, asset prices and valuation of equities, net financial income and net wealth of economic agents, private consumption and investment, valuation of domestic currency, exchange rate, imports and exports. In essence, the link between monetary policy and aggregate demand is through some transmission mechanism through which monetary shock propagates to the real economy affecting the aggregate demand and aggregate spending.

This paper empirically analyses the monetary transmission mechanism in India during the first two decades of the millennium from 2000Q1 to 2023Q4 using quarterly data applying the structural vector autoregression (SVAR) estimation method. A series of SVAR models are estimated to examine the four transmission channels of monetary policy. The benchmark SVAR model is composed of a vector of endogenous and exogenous variables. Restriction on the contemporaneous effects of endogenous variables is imposed to have an exact identification of the benchmark SVAR model. The results of the benchmark SVAR model suggest that a contractionary monetary policy shock has transitory effects on the call money rate. Commodity price and GDP decline after contractionary call money rate shock. The commodity prices start declining after a decline in GDP. Among the monetary policy transmission channels, the empirical results of this study show the significance of interest rate and asset price channels in transmitting monetary shocks to the real economy in India, while credit and exchange rate channels are weak.

The overall impact of the call money rate shock on aggregate demand is further decomposed to observe the differential impact among the various components. A disaggregated analysis of the components of aggregate demand shows that the maximum impact is borne by investment demand and imports. Part of the impact on imports can be explained by the decline in investments with high import content in India. Impacts on government consumption and exports are far more subdued and there is hardly any cumulative impact on private consumption as the marginal fall is very low. The variance decomposition analysis indicates that interest rate accounts for a significant percentage of the fluctuations in the components of aggregate demand, except private consumption. The robustness check shows that all the channels of monetary policy are robust and all the components of aggregate demand except for private consumption are robust around the period where the impacts are felt the most.

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