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# A Monetary Business Cycle Model for India

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March 5, 2018

## Abstract

We build and calibrate a New Keynesian monetary business cycle model to the Indian economy to understand *why* the aggregate demand channel of monetary transmission is weak. Our main finding is that base money shocks have a larger and more persistent effect on output than an interest rate shock, as in the data. We show that financial repression, in the form of a statutory liquidity ratio and administered interest rates, does not weaken monetary transmission. This is contrary to the consensus view in policy discussions on Indian monetary policy. We show that the presence of an informal sector hinders monetary transmission.

**Keywords** : Monetary Business Cycles, Monetary Transmission, Inflation Targeting.

**JEL Codes** : E31, E32, E44, E52, E63.

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# 1 Introduction

With the formal adoption of inflation targeting by the Reserve Bank of India, monetary policy in India has undergone a major overhaul. With clearly defined objectives, clear operating procedures, and a nominal anchor that the public understands, the transmission mechanism of monetary policy has become much more transparent. India is now a flexible inflation targeter, where a newly convened monetary policy committee (as of September 2016) is tasked to maintain a medium term CPI-headline inflation at 4%, within a floor of 2% and a ceiling of 6%.

Despite major changes in monetary policy however, monetary transmission has found to be partial, asymmetric and slow (Das (2015); Mishra, Montiel and Sengupta (2016); and Mohanty and Rishab (2016)). Decomposing monetary transmission through the bank lending channel in two steps - from policy rates to bank lending rates - and then from lending rates to aggregate demand, Mishra, Montiel and Sengupta (2016) find that not only is pass through from the policy rate to the bank lending rates incomplete, but there is little empirical support for any effect of monetary policy shocks on aggregate demand.[1] Consistent with this, the "Report of the Expert Committee to Strengthen the Monetary Policy Framework" (2014)[2], also known as the Urjit Patel Committee Report, highlights several structural factors that hinder monetary transmission in India, such as the role of financial repression in the form of SLR[3], small savings schemes (with administered interest rates), and the presence of a large informal sector to name a few. The Urjit Patel Committee Report (2014) also notes that "... the conduct of liquidity management (is) often mutually inconsistent and conflicting. Often, increases in the policy rate have been followed up with discretionary measures to ease liquidity conditions (page 36)". Shocks to autonomous drivers of liquidity, such as currency demand, bank reserves (required plus excess), government deposits with the Reserve Bank of India, and net foreign market operations, complicate the alignment of the policy repo rate - the short term signalling rate - with the overnight weighted average call rate (WACR) under the liquidity adjustment facility.[4]

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[1] Both Mishra, Montiel and Sengupta (2016) and Mohanty and Rishab (2016) provide recent surveys of monetary transmission in India and emerging market and developing economies (EMDEs) respectively.

[2] https://rbi.org.in/scripts/BS_PressReleaseDisplay.aspx?prid=30446

[3] The SLR, or the statutory liquidity ratio, provides a captive market for government securities and helps to artificially suppress the cost of borrowing for the Government, dampening the transmission of interest rate changes across the term structure. See the Urjit Patel Committee Report (2014).

[4] Since 2001, the Reserve Bank of India has conducted monetary policy through a corridor system called the LAF (liquidity adjustment facility). The LAF essentially allows banks to undertake collateralized lending and borrowing to meet short term asset-liability mismatches. The Repo rate is the rate at which banks borrow money from the RBI by selling short term government securities to the RBI, and then "repurchases" them back. A reverse repo operation takes place when the RBI borrows money from banks by lending securities. See Mishra, Montiel and Sengupta (2016, pages 73-74).

This paper develops a New Keynesian monetary business cycle model of the Indian economy to understand *why* the aggregate demand channel of monetary transmission is weak. The aggregate demand channel is important because consumption and investment constitute roughly 87% of Indian GDP.

Our goal is four-fold. First, while there are a large number of empirical papers and policy reports that study the strength of monetary transmission channels in the Indian context, there are very few studies on monetary transmission in India using a DSGE framework.[5] Our paper fills this gap. Second, as will be shown in Section 2, from an impulse response function exercise generated from an atheoretical VAR, we show that if we define monetary policy as a change in the monetary base, monetary transmission does not appear to be that weak. In contrast, the confidence band of output with respect to a policy rate shock is either not robust, or weaker than the money base shock in generating a persistent effect on output. We highlight this as a key stylized fact in the model that not only disciplines our calibration exercise, but requires a theoretical understanding of how base money shocks get transmitted to the rest of the economy. As we will show later, base money shocks are inflationary and lead to a positive expansion in economic output. However, a fall in the policy rate has a weak effect on the economy. Third, motivated by the role of financial repression in hindering monetary transmission, our model embeds financial repression in monetary policy making in India by incorporating two key features endemic to the Indian financial sector (i) SLR requirements for banks, and (ii) administered interest rate setting by the government. Allowing for such frictions provides a more realistic description of banking intermediation in the transmission of monetary impulses in the Indian context. And fourth, in an extended version of the model, we differentiate between a "banked" population, that intermediates through the formal banking system, and an "unbanked" population, that uses cash as a medium of transaction. Our rationale for adding an unbanked population is to proxy for a large informal sector in India, and study how this affects transmission of monetary policy.

## 1.1   Description of the model

Our core model is a monetary RBC model with sticky prices and a banking sector. The economy is populated by households and wholesale entrepreneurs, each group having unit mass. Households consume, work, and accumulate savings in risk-free bank deposits as well as postal deposits with a fixed government set interest rate. We assume that households own the banks. On the production side, wholesale entrepreneurs produce homogenous intermediate goods using capital, bought from capital goods producers, loans obtained from banks,

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[5]See Gabriel et al. (2012) for an early attempt. Banerjee and Basu (2017) develop a small open economy DSGE model for India but do not study the monetary transmission mechanism.

and hired labor from households. Similar to other papers in this literature (see Gerali et al. (2010)), capital goods producers are introduced to derive a market price for capital. A monopolistically competitive retail sector buys intermediate goods from wholesale entrepreneurs, and produces a single final good. Retail prices are sticky and indexed to steady state inflation. This allows monetary policy to have real effects. Retailers also face a quadratic price adjustment cost *a la* Rotemberg.

Banks in the current set-up are assumed to be perfectly competitive.[6] Banks maximize cash flows in every period, offer savings deposits to households and loans to wholesale entrepreneurs, subject to the constraints that a fixed fraction of deposits in every period are set aside for (i) a statutory liquidity requirement (SLR) and (ii) the reserve requirement. We allow for the stochastic withdrawal of deposits in each period as in Chang et al. (2014). At date $t$, if the withdrawal exceeds bank reserves (cash in vault), banks fall back on the Central Bank for emergency loans at a penalty rate mandated by the central bank. The presence of SLR requirements and administered interest rates capture the essence of financial repression in the Indian economy.

We assume that the central bank is a flexible inflation targeter, as in India. In the baseline, there is no currency in the model, and so the supply of reserves equals the monetary base. The central bank lets the monetary base, or the supply of reserves increase by a simple rule that is perturbed in every period by base-money shocks, or autonomous liquidity shocks. In addition to these shocks, the economy is also hit in every period by total factor productivity shocks, fiscal policy shocks, investment specific technology (IST) shocks, and interest rate shocks. To deal with the inflationary consequences of autonomous liquidity shocks, the central bank has one instrument at its disposal: the short term interest rate on government bonds, which we interpret as the policy rate, and which is governed by a conventional Taylor rule. The economy is hit periodically with autonomous liquidity, or base money shocks, which are inflationary, and therefore warrant a monetary policy response using the Taylor rule.[7] On the fiscal side, the government spending is stochastic. The government issues public debt held by banks to cover the difference between government spending and lump sum taxes. Administered postal deposits, which attract a government set interest rate in the Indian economy, are directly assumed to augment government revenues in every period.

In an extended version of the model, we introduce currency as a medium of transaction. We retain the wholesale entrepreneur of the baseline model, but assume that risk neutral forward looking entrepreneurs hire from two groups of workers: forward looking households

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[6]Market power in the banking industry in Gerali et al. (2010) is modelled using a Dixit-Stiglitz framework for retail and credit deposit markets.

[7]The transmission from the Repo rate to short maturity T-Bills (up to 2 years) is immediate in India. Hence, we will interpret the short term T-bill rate as the policy rate in the rest of the paper.

who supply labor as a credit good (Ricardian consumers), and households who supply labor as a cash good (Rule of thumb consumers). The rule of thumb consumers do not make deposits in banks, and are therefore "unbanked", and have to be paid in cash. The standard inter-temporal substitution effect does not apply for unbanked households. Entrepreneurs however face a cash in advance constraint. Because of the payment friction, the wages across both groups will not be the same. In the steady state, we show that higher inflation will depress the rule of thumb consumer's wage, and create more wage inequality. Overall, there are two novelties to this extension: (i) it provides a natural justification for the transaction demand for money and (ii) it gives rise to the distributional effects of monetary policy, which in turn affects monetary transmission. Because an inflationary monetary policy depresses the real wage of the rule of thumb consumers, their consumption falls. Monetary transmission therefore worsens through the aggregate demand channel.

In the calibration exercise, we first specify the baseline parameterization of the model. We then calibrate the shock structure to match empirical moments, report the variance decomposition results for the baseline model and the extended model, and undertake sensitivity experiments on the different structural and policy factors affecting monetary transmission. We also explain the impulse response properties of the baseline and extended model.

## 1.2   Main results

Our calibrated baseline model allows us to highlight nine main results. First, we identify the propagation mechanism of autonomous liquidity shocks, or autonomous base money shocks, to the rest of the economy. We show that an expansionary base money shock stimulates consumption, investment, hours worked, capital accumulation, and opens up a positive output gap on impact. An increase in base money is also inflationary. The rise in inflation and the output gap leads to a rise in the policy rate via the Taylor rule, which targets the short term interest rate on government bonds. On the other hand, a fall in the government bond rate, via the Taylor rule, also has similar expansionary effects on the economy, but the effects are rather weak.

Second, our baseline model shows that about half of the fluctuation (variance) in output are explained by TFP shocks and approximately 30% is explained by fiscal shocks. Monetary policy in terms of interest rate shocks and base money shocks explain a small fraction of output variation comparatively - approximately 17%. Within this, monetary base accounts for 13.8%. Inflation (71.76%) and the bank lending rate (63.48%) are also largely driven by shocks to total factor productivity.

Third, a similar pattern of variance decomposition is observed in the extended model.

The relative importance of money shocks (money base and policy rate) however declines to approximately 14%, with the loss picked up by the fiscal shock. The presence of an unbanked channel "clogs" the regular pass-through of monetary transmission to aggregate demand. The existence of rule of thumb consumers amplifies the fiscal spending shock contribution to output fluctuations. Overall though, as in the baseline model, the horse race on shocks is preserved. Also, we uncover why transmission weakens when we add an informal sector to the model. Because the standard inter-temporal substitution of consumption effect does not apply to the unbanked population, an inflationary monetary policy shock - which affects their real wages - lowers their real wage when inflation rises. The unbanked population is unable to use to the real interest rate to smooth their consumption. Under the parameterization used in the model, because their consumption is equal to the real wage, their consumption demand falls with an inflationary base money shock one-for-one.

Fourth, our sensitivity experiments with respect to structural and policy parameters indicate that the household's preference for commercial bank deposits vs deposits with administered interest rates have small effects on monetary transmission as measured by the forecast error variance of output due to autonomous monetary shocks. More importantly, the statutory liquidity ratio and administered interest rates, the financial repression parameters, have small effects on monetary transmission. This observation goes against the consensus view on financial repression and monetary transmission in India. This shows that financial repression, either in the form of administered interest rates or SLR cause weak monetary transmission in the economy as is widely believed.

Fifth, and not surprisingly, with low price adjustment costs ($\phi_p$) and a higher degree of past inflation indexation ($\theta_p$) in the retail sector, monetary transmission becomes weaker. Lower values of the nominal friction and the lack of forward looking price setting behavior limits the real effects of a monetary policy shock via the expectation channel.

Sixth, the mark-down factor ($\zeta$) for the deposit interest rate has a major implication for monetary transmission driven by the money base. The transmission of monetary base shock becomes conspicuously higher as seen by the error variance decomposition and money-output correlation while the transmission of interest rate shock is remarkably diminished. The intuition for this stems from the fact that a lower $\zeta$ marks down the interest rate on deposit which discourages the household to accumulate bank deposits. Since reserve demand is proportional to bank deposits (see eq 27), banks hold fewer reserves and extend more loans. Thus the propagation of a shock to monetary base becomes stronger through the bank lending channel because banks hold less reserves. On the other hand, as $i_t^L$ is largely determined by inflation, a lower $\zeta$ widens the spread between borrowing and lending rates, $(i_t^L - i_t^D)$, and the policy rate accounts for less variation in output.

Seventh, less aggressive inflation targeting (lower $\varphi_\pi$) and less output stabilization (lower $\varphi_y$) raises the pass through of monetary base shock to output, inflation and the nominal loan rate.

Eighth, a comparison of output impulse responses of monetary base versus policy rate shocks reveals that the output response is much more prolonged for a positive shock to the monetary base as opposed to a negative shock to the interest rate. The impact effect of output with respect to a monetary base shock is significantly bigger than the output response with respect to a negative policy rate shock. In addition, the positive effect lasts more than 20 quarters for a monetary base shock, while for the interest rate shock it dissipates after 10 quarters. The punch-line of this exercise is that a shock to monetary base has a far stronger and persistent effect on output than the shock to policy interest rate. This agrees well with the empirical VAR impulse responses reported in Section 2.

Ninth, the smoothing coefficient of the policy rate Taylor rule has a noteworthy implication for monetary transmission. A higher smoothing coefficient significantly enhances the monetary transmission of the policy rate as evidenced by the variance decomposition of output. The policy rate accounts for 15.25% as opposed to 3.73% of output variation when the smoothing coefficient rises. The greater response of output is due to more persistent variation in the interest rate in response to a policy shock which translates into more persistent output fluctuations.

# 2    Stylized facts

In this section, we present a set of impulse response plots of output and inflation with respect to the shocks to monetary policy instruments namely, monetary base and the policy interest rate. We deploy an atheoretical Vector Autoregressive (VAR) framework with four variables: growth rate of money reserves, 91 day treasury bill rate, de-trended real GDP and inflation measured as year-on-year change of the Consumer Price Index (CPI).[8] We consider two types of impulse response functions. The first is based on a Cholesky ordering. The second is the generalized impulses approach suggested by Pesaran and Shin (1998). The Cholesky ordering is extensively used in the literature to examine the effects of a monetary shock on various macroeconomic variables (Iacoviello, 2005). However, this identification scheme is sensitive

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[8]In Appendix E, we have provided the details on the data sources and the transformations used of the relevant macroeconomic variables for our analysis. In the VAR model, we have incorporated two time dummy variables, one is for money growth rate and the other is for the treasury bill rate. We also include government spending to control for its influence on movements in the short-term government bond interest rate. Using information criteria, we have chosen lags of four quarters for the analysis. The AR roots of the VAR model specification satisfies the stability condition.

to the ordering of variables. For robustness therefore, we use the generalized impulses for identification, which is independent of ordering. The impulse response plots are displayed in Figure 1 and 2. The shaded areas show the statistically significant periods in the reaction of output to policy shocks. The effects of a policy shock on CPI inflation is found to be statistically insignificant in all the cases.
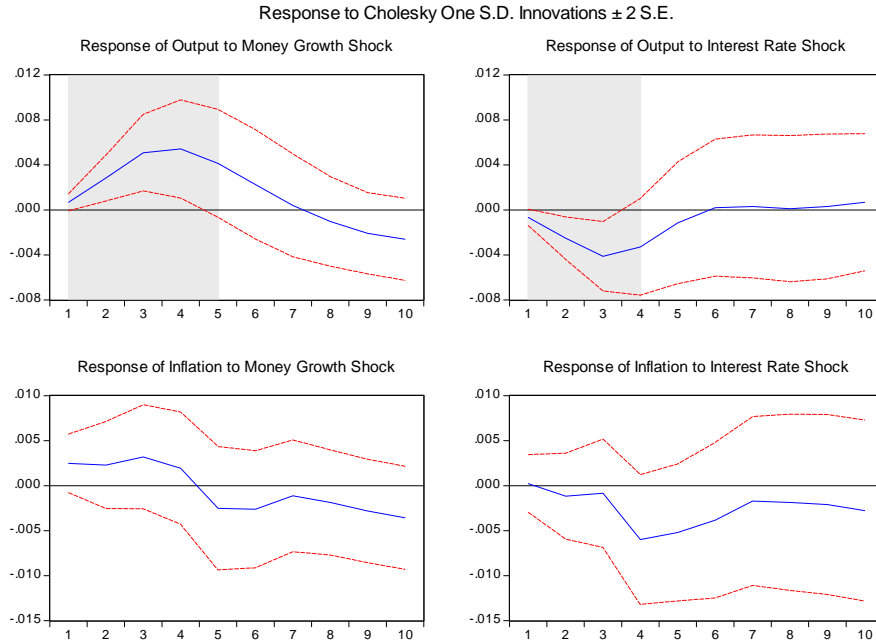
Response to Cholesky One S.D. Innovations ± 2 S.E.

Figure 1: Impulse Responses under Cholesky-type Identification

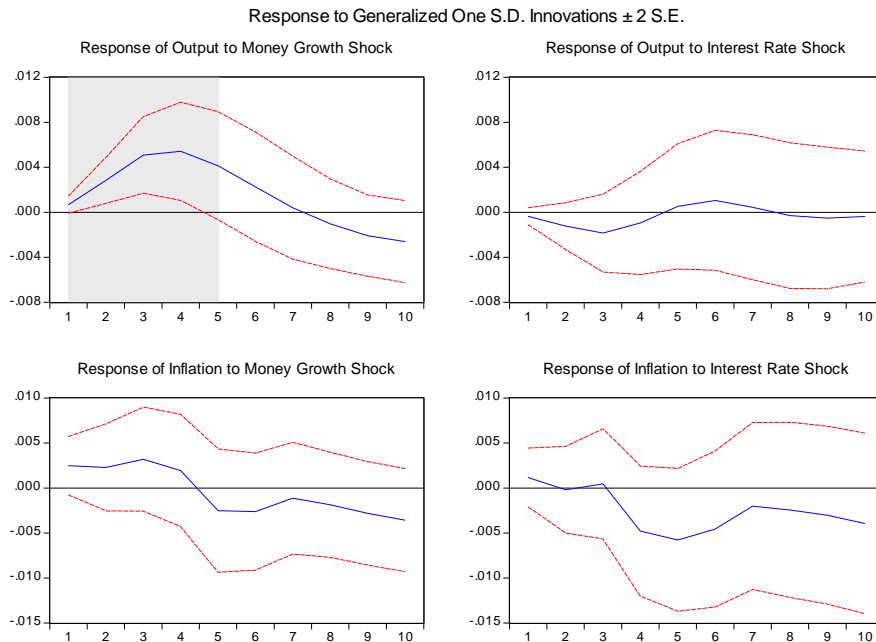Response to Generalized One S.D. Innovations ± 2 S.E.

Figure 2: Impulse Responses under Pesaran-type Identification

The main finding is that the interest rate policy shock has a weaker effect on GDP than the monetary base shock. This is validated by both the Cholesky and Pesaran type identification schemes. Under the Cholesky type identification, responses of output to base money growth shocks and interest rate shocks are statistically significant for five and three quarters, respectively. Over a one year horizon, the accumulated effect on output of a money growth shock is thirty two per cent higher than that of the interest rate shock. In case of the generalized Pesaran type identification, the response of output to the interest rate shock turns out to be statistically insignificant although it remains statistically significant for the money growth shock.[9]

To summarize, the empirically observed impulse response functions (IRF) reveal that monetary policy transmission is weak in India if we look at it from the perspective of transmission via the policy rate. However, if we define monetary policy as a change in the monetary base, the monetary transmission does not appear to be that weak. Money base has a significant effect on output as evidenced by the statistically significant confidence bands of its IRFs for output. In contrast, the confidence band of output with respect to policy rate shocks is either not robust or weaker than the money base shock to generate a persistent effect on output. These results confirm previous findings in the literature highlighted in the introduction, and set the motivation for us to develop a monetary business cycle model for the Indian economy to understand monetary transmission.

# 3  The Model

## 3.1  Household

The economy is populated by infinitely lived households of unit mass. The representative household maximizes expected utility.

$$\max_{C_t, H_t, D_t, D_t^a} E_t \sum_{s=0}^{\infty} \beta^s [U(C_{t+s}) - \Phi(H_{t+s}) + V(D_{t+s}/P_{t+s}, D_{t+s}^a/P_{t+s})] \tag{1}$$

which depends on hours worked, $H_t$, consumption of the final good, $C_t$, and saving in the form of risk-free bank and postal deposits, $D_t$, and $D_t^a$ respectively. Household choices must

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[9]Effect of the interest rate shock on output is insignificant since the confidence band of the IRF includes both positive and negative quadrants.

obey the following budget constraint (in nominal terms)

$$P_t \left( C_t + T_t \right) + D_t + D_t^a \leq W_t H_t + (1 + i_t^D)D_{t-1} + (1 + i^a) D_{t-1}^a + \Pi_t^k + \Pi_t^r + \Pi_t^b \quad (2)$$

The left hand side of equation (2) represents the flow of expenses which includes current consumption (where $P_t$ is the aggregate price index and $T_t > 0$ denote lump-sum taxes), nominal bank deposits, $D_t$ and postal deposits, $D_t^a$. Resources consist of wage earnings, $W_t H_t$, where $W_t$ is the wage rate, payments on deposits made in the previous period, $t-1$, where $i_t^D > 0$ is the rate on one-period deposits (or savings contracts) in the banking system, and $i^a > 0$ is the fixed government administered interest rate on postal deposits made by households. $\Pi_t^k$ is the rebate given back to households from capital goods firms. $\Pi_t^r$ denote nominal profits rebated back from the retail goods sector, and $\Pi_t^b$ are rebates given back to households from banks.[10] As in Gali (2008), all profits are net of taxes and transfers.

Using $D_t/P_t = d_t$ and $D_t^a/P_t = d_t^a$, and substituting out for $U'(C_t) = \lambda_t P_t$, we can re-write the household's optimality conditions as:

$$D_t: \ U'(C_t) = V_1'(d_t, d_t^a) + \beta E_t \left\{ U'(C_{t+1})(1 + i_{t+1}^D)(P_t/P_{t+1}) \right\}, \quad (3)$$

$$D_t^p: \ U'(C_t) = V_2'(d_t, d_t^a) + \beta E_t \left\{ U'(C_{t+1})(1 + i^a)(P_t/P_{t+1}) \right\} \quad (4)$$

$$\Phi'(H_t) = (W_t/P_t)\, U'(C_t). \quad (5)$$

Equation (3) is the standard Euler equation for bank deposits. Equation (4) is the Euler equation for postal deposits which attract the administered interest rate, $i^a$. Equation (5) is the standard intra-temporal optimality condition for labor supply.

## 3.2   Capital good producing firms

Our description of the capital goods producing firms is standard. Perfectly competitive firms buy last period's undepreciated capital, $(1 - \delta_k)K_{t-1}$, at (real) price $Q_t$ from wholesale-entrepreneurs (who own the firms) and $I_t$ units of the final good from retailers at price $P_t$. The transformation of the final good into new capital is subject to adjustment costs, $S_t$.[11] Capital goods producing firms maximize

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[10]Please refer to Appendix A for all derivations.

[11]We assume that

$$S \left( \frac{I_t}{I_{t-1}} \right) = (\kappa/2) \left( \frac{I_t}{I_{t-1}} - 1 \right)^2.$$

$$\max_{I_t} E_t \sum_{j=0}^{\infty} \Omega_{t,t+j} P_{t+j} \left[ Q_{t+j} I_{t+j} - \left\{ 1 + S\left( \frac{I_{t+j}}{I_{t+j-1}} \right) \right\} I_{t+j} \right] \tag{6}$$

$$\text{s.t.} \quad K_t = (1 - \delta_k) K_{t-1} + Z_{x,t} I_t \tag{7}$$

where $\Omega_{t,t+j}$ is the stochastic discount factor and $Z_{x,t}$ is an investment specific technology (IST) shock that follows an AR(1) process:

$$\ln Z_{xt} - \ln \bar{Z}_x = \rho_{z_x} \left( \ln Z_{xt-1} - \ln \bar{Z}_{zx} \right) + \xi_t^{zx}$$

where $\xi_t^{zx}$ is an i.i.d shock.

The first order condition is

$$\frac{\partial (.)}{\partial I_t} = \Omega_{t,t} P_t Q_t - \Omega_{t,t} P_t \left\{ 1 + S\left( \frac{I_t}{I_{t-1}} \right) \right\} - \Omega_{t,t} P_t S'\left( \frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} + \Omega_{t,t+1} P_{t+1} S'\left( \frac{I_{t+1}}{I_t} \right) \left( \frac{I_{t+1}}{I_t} \right)^2 = 0. \tag{8}$$

which yields the capital good pricing equation,

$$Q_t = 1 + S\left( \frac{I_t}{I_{t-1}} \right) + S'\left( \frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} - \beta E_t \frac{U'(C_{t+1})}{U'(C_t)} \left[ S'\left( \frac{I_{t+1}}{I_t} \right) \left( \frac{I_{t+1}}{I_t} \right)^2 \right]. \tag{9}$$

### 3.3 Wholesale good producing firms

Wholesale, or intermediate goods firms are run by risk neutral entrepreneurs who produce intermediate goods for the final good producing retailers in a perfectly competitive environment. The entrepreneurs hire labor from households and purchase new capital from the capital good producing firms. They borrow an amount $L_t > 0$ of loans from the bank in order to meet the value of new capital, $Q_t K_t$, where $K_t$ is the capital stock. We assume that all capital spending is debt financed. Used capital at date $t + 1$ is sold at the resale market at the price $Q_{t+1}$. The balance sheet condition of a representative wholesale firm is:

$$Q_t K_t = \left( \frac{L_t}{P_t} \right). \tag{10}$$

In the steady state $Q_t = 1$ which means $l_t = \frac{L_t}{P_t} = K_t$, i.e., all capital is intermediated. The production function for a representative wholesale goods producer is given by

$$Y_t^W = A_t K_{t-1}^{\alpha} H_t^{1-\alpha} \tag{11}$$

with $0 < \alpha < 1$. $A_t$ denotes stochastic total factor productivity, and follows an $AR(1)$ process:

$$\ln A_t - \ln \bar{A} = \rho_a \left( \ln A_{t-1} - \ln \bar{A} \right) + \xi_t^A$$

where $\xi_t^A$ is an i.i.d shock.

The (real) wage rate, $\frac{W_t}{P_t}$, is given by

$$W_t/P_t = \underbrace{(P_t^W/P_t)}_{\text{Real Price of Wholesale Output}} MPH_t = (1-\alpha) \frac{(P_t^W/P_t)Y_t^W}{H_t}, \tag{12}$$

where $P_t^W/P_t$ is the real price of wholesale output. This allows us to obtain the rate of return from capital, $1 + r_{t+1}^k$, as

$$
\begin{aligned}
1 + r_{t+1}^k &= \frac{(P_{t+1}^W/P_{t+1})Y_{t+1}^W - (W_{t+1}/P_{t+1})H_{t+1} + (1-\delta_k) K_t Q_{t+1}}{Q_t K_t} \\
&= \frac{(P_{t+1}^W/P_{t+1})\left(\frac{Y_{t+1}^W}{K_t}\right) - (1-\alpha)\frac{(P_{t+1}^W/P_{t+1})Y_{t+1}^W}{H_{t+1}}\left(\frac{H_{t+1}}{K_t}\right) + (1-\delta_k) Q_{t+1}}{Q_t} \\
&= \frac{(P_{t+1}^W/P_{t+1})MPK_{t+1} + (1-\delta_k)Q_{t+1}}{Q_t}
\end{aligned}
$$

The optimality condition for a firms' demand for capital is given by the following arbitrage condition,

$$1 + r_{t+1}^k = \left(1 + i_{t+1}^L\right) \frac{P_t}{P_{t+1}}. \tag{13}$$

This yields,

$$(1 + i_{t+1}^L) = \frac{P_{t+1}^W MPK_{t+1} + (1-\delta_k) P_{t+1} Q_{t+1}}{P_t Q_t}$$

$$1 + i_{t+1}^L = \left[ \left( \frac{P_{t+1}^w}{P_{t+1}} \right) \frac{MPK_{t+1}}{Q_{t+1}} + 1 - \delta_k \right] \left[ \frac{P_{t+1}Q_{t+1}}{P_t Q_t} \right]. \tag{14}$$

## 3.4  Final good retail firms

Retailers buy intermediate goods at price $P_t^W$ and package them into final goods and operate in a monopolistically competitive environment as in Bernanke, Gertler, and Gilchrist (1999). They convert the $i^{th}$ variety of the intermediate good, $y_t^W(i)$, into $y_t(i)$ one-to-one and differentiate goods at zero cost. Each retailer sells his unique variety of final product after applying a markup over the wholesale price, and factoring in the market demand condition

which is characterized by price elasticities $\left(\varepsilon^Y\right)$. Retailer's prices are sticky and indexed to past and steady state inflation as in Gerali et al. (2010). If retailers want to change their price over and above what indexation allows, they have to bear a quadratic adjustment cost given by $\phi_p$.

Retailers choose $\{P_{t+j}(i)\}_{j=0}^{\infty}$ to maximize present value of their expected profit.

$$\max_{P_t(i)} E_t \sum_{s=0}^{\infty} \Omega_{t,t+s} \left\{\Pi_{t+s|t}^r\right\} \tag{15}$$

subject to the demand constraint, $y_{t+j|t}(i) = \left(\frac{P_{t+j}(i)}{P_{t+j}}\right)^{-\varepsilon^Y} y_{t+j}$, where the profit function of the $i^{th}$ retailer is given by,

$$\Pi_t^r(i) = P_t(i) y_t(i) - P_t^W(i) y_t^W(i) - \frac{\phi_p}{2} \left[ \left\{ \frac{P_{t+j}(i)}{P_{t+j-1}(i)} - (1+\pi_{t-1})^{\theta_p}(1+\bar{\pi})^{1-\theta_p} \right\}^2 P_t y_t \right], \tag{16}$$

$\phi_p > 0$, $0 < \theta_p < 1$, and

$$y_t = \left[ \int_0^1 y_t(i)^{\frac{\varepsilon^Y-1}{\varepsilon^Y}} \, di \right]^{\frac{\varepsilon^Y}{\varepsilon^Y-1}} \quad \text{where } \varepsilon^Y > 1.$$

Note that $\theta_p$ is an indexation parameter. This price adjustment cost specification is borrowed from Gerali et al. (2010). The first order condition after imposing a symmetric equilibrium is standard:

$$1 - \varepsilon^Y + \varepsilon^Y \left(\frac{P_t}{P_t^W}\right)^{-1} - \phi_p \left\{1 + \pi_t - (1+\pi_{t-1})^{\theta_p}(1+\bar{\pi})^{1-\theta_p}\right\} = 0. \tag{17}$$

From equation (17), a rise in $\pi_t$ leads to a rise in $\frac{P_t^W}{P_t}$ or real marginal costs (since $\varepsilon^Y > 1$). Hence, real marginal costs and inflation co-move in the same direction. As we will show later, a positive base money shock, by increasing inflation, increases $\frac{P_t^W}{P_t}$. This raises the value of the marginal product of labor $(VMP_L)$ and the value of the marginal product of capital $(VMP_K)$, making the demand for labor and capital increase, leading to an output expansion.

In the steady state, when $\pi_{t+1} = \pi_t = \pi$, the steady state mark-up is,

$$\frac{P}{P^W} = \frac{\varepsilon^Y}{\varepsilon^Y - 1}. \tag{18}$$

## 3.5 Banks

The representative bank maximizes cash flows by offering savings contracts (deposits) and borrowing contracts (loans). The banking sector is assumed to be competitive. Banks are also mandated to keep reserves with the central bank. In India, and many other emerging market economies (EMEs), banks are also constrained to buy government debt from deposit inflows as mandated by a statutory liquidity ratio (SLR). In every period, following Chang et al.(2014), we assume that banks face a stochastic withdrawal of deposits at the end of each period, $t$. At date $t$, if the withdrawal (say $\widetilde{W_{t-1}}$) exceeds bank reserve (cash in vault), banks fall back on the Central Bank for emergency loans at a penalty rate $i^p$ mandated by the Central Bank (CB). Banks pay back the emergency borrowing to the CB at the end of the period. This withdrawal uncertainty necessitates a demand for excess reserve by the banks.

Define $i_t^L$ to be the interest rate on loans, $L_{t-1}$, $i^R$ to be the interest rate on reserves, $M_t^R$, mandated by the central bank, and $\widetilde{W_t}$ is the stochastic withdrawal. $D_t$ denotes deposits. We assume that bank has a SLR equal to $\alpha_q \in [0,1]$.

The bank's cash flow at date $t$ can be rewritten as:

$$\Pi_t^b = (1+i_t^L)L_{t-1} + (1+i^R)M_{t-1}^R + \underbrace{\alpha_q(1+i_t^G)D_{t-1}}_{SLR \text{ on last period's deposits}} - \underbrace{(1+i_t^D)D_{t-1}}_{\text{Cost of Funds of Last period's Deposits}}$$

$$(19)$$

$$- (1+i^p)\chi_t(\widetilde{W_{t-1}} - M_{t-1}^R, 0) - (1-\chi_t)\widetilde{W_{t-1}} + \underbrace{D_t}_{\text{Current Deposits}} - \underbrace{\alpha_q D_t}_{SLR \text{ this period}} - L_t - M_t^R$$

where $\chi_t$ is an indicator function which is unity if $\widetilde{W_{t-1}} - M_{t-1}^R > 0$ and zero otherwise. The timing of decisions is crucial in our setting to make the bank's problem meaningful.[12] At date t, banks make decisions about loans ($L_t$) and reserve ($M_t^R$) after observing the deposit ($D_t$). On the other hand, depositors could partially withdraw their deposit randomly.[13] This

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[12] The withdrawal of deposits happens at the end of the period. If the withdrawal exceeds reserve by $x$ rupees at the end of the day, the Central Bank charges a $y$ percent penalty rate. Thus the bank's penalty is $x(1+y)$ rupees which includes the principal and the penalty interes .which the bank has to pay at the end of the period or the start of the next period. On the other hand if the withdrawal $x$ is less than existing reserve, the bank does not incur any penalty but it still loses $x$ from its cash flow. Taking this into consideration, the bank chooses its reserve holding optimally at the start of date $t$.

[13] We do not model here the withdraw decision of households and assume that the withdrawal, $\widetilde{W_t}$ is random i.i.d process and it cannot exceed deposits. This basically rules out a sudden stop with a full bank run. This random withdrawal makes the cash flow of the bank risky. This cash flow is ploughed back as a transfer ($TR_t$) to the household.

basically gives a motivation to banks to hold excess reserve as in Chang et al. (2013). The first two terms on the right hand side correspond to the interest earned in time $t$ on loans disbursed in time $t - 1$, and interest on reserves in the previous period, $M_{t-1}^R$. Since the bank is forced to hold government debt as a constant fraction, $\alpha_q$, of incoming deposits, $\alpha_q(1 + i_t^G)D_{t-1}$, denotes the interest earnings on SLR debt holdings by banks. As described above, banks also face a penalty, at a constant penal rate, $i^p > 0$, for stochastic withdrawals over and above their bank reserves. The penalty amount is $(1+i^p)(\widetilde{W_{t-1}} - M_{t-1}^R)$. We assume that banks offer a deposit rate, $i_t^D$, which is a mark-down of the interest rate that it receives on government bonds, $i_t^G$. In other words, $1 + i_t^D = \zeta(1 + i_t^G)$ where $0 < \zeta < 1$. We do not model the mark-down, $\zeta$, but calibrate it. Rewrite the cash flow in equation (19) as

$$\begin{aligned} \Pi_t^b = {} & (1 + i_t^L)L_{t-1} + (1 + i^R)M_{t-1}^R - (\zeta - \alpha_q)(1 + i_t^G)D_{t-1} \\ & - (1 + i^p)\chi_t(\widetilde{W_{t-1}} - M_{t-1}^R, 0) - (1 - \chi_t)\widetilde{W_{t-1}} \\ & + (1 - \alpha_q)D_t - L_t - M_t^R \end{aligned} \tag{20}$$

The representative bank maximizes discounted cash flows in two stages. It first solves for its optimal demand for reserves, $M_t^R$. Next, it chooses the loan amount, $L_t$. Specifically, banks maximize

$$\underset{M_t^R, \ L_t}{Max} \ E_t \sum_{s=0}^{\infty} \Omega_{t,t+s}^b \Pi_{t+s}^b$$

subject to the statutory reserve requirement:

$$M_t^R \geqq \alpha_r D_t \tag{21}$$

where $\Omega_{t,t+s} = \frac{\beta^s U'(c_{t+s})}{U'(c_t)} \cdot \frac{P_t}{P_{t+s}}$ is the inflation adjusted stochastic discount factor.

The Euler equation is given by[14]

$$E_t \Omega_{t,t+1}\left[(1 + i^R) + (1 + i^p)\int_{M_t^R}^{D_t} f(\widetilde{W_t})d\widetilde{W_t}\right] + \lambda_t = \ 1 \tag{22}$$

The first term in the square bracket in equation (22) is the bank's interest income from reserves. The second term is the expected saving of penalty because of holding more reserves $\lambda_t$ is the Lagrange multiplier associated with the reserve constraint (21). The Kuhn Tucker condition states that

$$\frac{M_t^R}{D_t} = \alpha_r \text{ if } \lambda_t > 0.$$

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[14]See Technical Appendix A.

Assume that the reserve requirement is not binding, which implies that $\lambda_t = 0$ (i.e., banks hold excess reserves). Assuming a rectangular distribution for $\widetilde{W}_t$ over $[0, D_t]$[15], (22) reduces to:

$$M_t^R : 1 = E_t\Omega_{t,t+1}\left[(1 + i^R) + (1 + i^p)(1 - \frac{M_t^R}{D_t})\right]. \tag{23}$$

We solve $\frac{M_t^R}{D_t}$ as follows:

$$\frac{M_t^R}{D_t} = 1 - \frac{1 - (1 + i^R)E_t\Omega_{t,t+1}}{(1 + i^p)E_t\Omega_{t,t+1}}, \tag{24}$$

which is the same as writing

$$\frac{x_t}{d_t} = 1 - \frac{1 - (1 + i^R)E_t\Omega_{t,t+1}}{(1 + i^p)E_t\Omega_{t,t+1}} \tag{25}$$

where $x_t = M_t^R/P_t$ and $d_t = D_t/P_t$. It is straightforward to verify that given the stochastic discount factor, $\Omega_{t,t+1}$, a higher $i^R$ or $i^p$ means a higher $M_t^R$ as expected.

Once the bank's reserve demand problem is solved, we next turn to optimal loan disbursement. Note that the bank solves a recursive problem of choosing $L_{t+s}$ given $L_{t+s-1}$ which was chosen in the previous period. This is a dynamic allocation problem. The first order condition with respect to $L_t$ is given by,

$$\Omega_{t,t}(-1) + E_t\Omega_{t,t+1}(1 + i^L_{t+1}) = 0.$$

This gives the loan Euler equation:

$$L_t : \ 1 = E_t\Omega_{t,t+1}(1 + i^L_{t+1}) \tag{26}$$

Substituting out for $E_t\Omega_{t,t+1}$ in equation (26) and putting it into equation (24), we see the following connection between the loan market premium and the reserve demand of bank:

$$\frac{x_t}{d_t} = 1 + \frac{1 + i^R}{1 + i^p}\left[1 - \frac{E_t\frac{1+i^L_{t+1}}{1+i^R}}{1 - cov_t(\Omega_{t,t+1}, (i^L_{t+1} - i^R))}\right] \tag{27}$$

The negative of the covariance term in the denominator picks up the risk premium associated

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[15] Since $\widetilde{W}_t$ follows a rectangular distribution, over $[0, D_t]$

$$\int_{M_t^R}^{D_t} f(\widetilde{W}_t)d\widetilde{W}_t = \frac{D_t - M_t^R}{D_t} = 1 - \frac{M_t^R}{D_t}.$$

with the risky loan of banks relative to the risk-free interest rate on reserves. If the bank loan is not risky, this covariance term is zero in which case a higher loan rate discourages the holding of bank reserves.[16]

## 3.6 Monetary policy

The Central Bank follows a simple money supply rule. It lets the monetary base $(M_t^B)$, or the supply of reserves, $M_t^R$ (since currency is zero), increase by the following rule:

$$\frac{M_t^B/M_{t-1}^B}{1+\bar{\pi}} = \left(\frac{M_{t-1}^B/M_{t-2}^B}{1+\bar{\pi}}\right)^{\rho_\mu} \exp(\xi_t^\mu) \tag{28}$$

where $\rho_\mu$ is the policy smoothing coefficient and $\xi_t^\mu$ is the money supply shock, which follows an AR (1) process. We view a shock to the monetary base as an autonomous liquidity shock. Money market equilibrium implies that

$$M_t^R = M_t^B \quad \text{for all} \quad t.$$

Such a money supply process imposes restriction on the short run growth rate of real reserve and inflation as follows:

$$\frac{(1+\pi_t)(x_t/x_{t-1})}{1+\pi} = \left(\frac{(1+\pi_{t-1})(x_{t-1}/x_{t-2})}{1+\pi}\right)^{\rho_\mu} \exp(\xi_t^\mu) \tag{29}$$

Since real reserves are proportional to deposits as shown in the bank's reserve demand function, (25), this also imposes a restriction on the dynamics of deposits, interest rate on loans and consumption.

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[16]One may wonder whether there is any borrowing-lending spread because banks are not monopolistic. Curiously a steady state borrowing-lending spread still emerges in this model because deposit appears in the utility function and provides a liquidity service (convenience yield) to the household. Bank deposit provides some transaction utility to the household. Thus the household wishes that the banks do not loan out all their deposits which would make them illiquid. This convenience yields (alternatively a liquidity premium) gives rise to credit rationing which gives rise to a positive borrowing-lending spread in the steady state. To see this, combine (3) and (26) to get the following steady state borrowing-lending spread.

$$i^L - i^D = \frac{(1+\pi)}{\beta} \frac{V_1'(d, d^p)}{U'(c)} > 0$$

This convenience yield is akin to forward-spot spread in finance.

## 3.7   Interest rate policy

The short term interest rate on government bonds $(i_t^G)$ can be broadly interpreted as a policy rate. We give it an inflation targeting Taylor rule as follows:

$$\frac{(1 + i_t^G)}{(1 + i^{\bar{G}})} = \left( \frac{(1 + i_{t-1}^G)}{(1 + i^{\bar{G}})} \right)^{\rho_{iG}} \left[ \left( \frac{1 + \pi_{t-1}}{1 + \pi} \right)^{\varphi_\pi} \left( \frac{Y_t}{Y} \right)^{\varphi_y} \right]^{(1 - \rho_{iG})} \exp(\xi_t^G) \tag{30}$$

The parameters $\phi_p > 0$ , and $\phi_y > 0$ are the inflation, and output gap sensitivity parameters in the Taylor Rule. $Y_t$ denotes GDP, and therefore $\frac{Y_t}{Y}$ denotes the output gap. $\rho_{iG}$ is the interest rate smoothing term and $\xi_t^G$ is the policy rate shock.

We shall see later in the quantitative analysis section that the strength of monetary transmission of a money base shock is significantly influenced by the parameters of the Taylor rule. It should also be noted that while the central bank follows a simple money supply rule, and short term government bonds follow a Taylor rule, both variables are not simultaneously endogenous. Base money shocks, by impacting inflation, raise interest rates via the Taylor rule. Money market equilibrium is restored from equation (25) via the stochastic discount factor (since $i^R$ and $i^P$ are constant). On the other hand, shocks to the policy rate in (30), given price stickiness, impacts output through the standard NK channel. Since the monetary base is exogenous, the change in the policy rate has no effect on the monetary base.

## 3.8   Fiscal policy

The government budget constraint (in nominal terms) is given by,

$$P_t G_t + \left( 1 + i_t^G \right) B_{t-1} + (1 + i^R) M_{t-1}^R + (1 + i^a) D_{t-1}^a = P_t T_t + B_t + M_t^R + D_t^a + (1 + i^p) E_t \max(\widetilde{W}_t - M_t^R, 0) \tag{31}$$

where $G_t$ corresponds to real government purchases, and $B_t$ denotes the stock of public debt. The left hand side of equation (31) denotes total expenditures by the government (nominal government purchases + interest payments on public debt + interest rates on reserves + interest payments on administered postal deposits).[17] The right hand side of equation (31) denotes the total resources available to the government (nominal lump sum taxes + new debt + new reserves + administered deposits + interest payments from withdrawal penalties).[18]

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[17]We think of the government as a combined fiscal-monetary entity.

[18]Note that on the right hand side of the government budget constraint, we have the expected penalty income not the actual. The government makes a forecast of the penalty revenue that it will generate at the end of date $t$. Once the actual penalty income is realized, there could be a forecast error in government's prediction of penalty income. Given a mandated government spending, the government has to adjust taxes to such a prediction error. For example, if the penalty income is under-predicted, the government would end

Government spending (or government purchases) evolves stochastically according to:

$$\ln G_t - \ln \bar{G} = \rho_G \left( \ln G_{t-1} - \ln \bar{G} \right) + \xi_t^G.$$

$\xi_t^G$ denotes the shock to government spending, and follows an AR(1) process.

# 4   Rule of thumb ($RT$) consumers

An unrealistic feature of our baseline model is that there is no transaction demand for money. Bank deposits play the role of money in this setting. This could be viewed as an over-simiplification while modelling the Indian economy, where a vast section of the population is in the informal sector uses cash as a medium of transaction. In this section, we extend the model to add a transaction demand for money. We change the risk neutral wholesale producers hiring workers from two groups of households: (i) who supply labor as a credit good; (ii) rule of thumb ($RT$) workers who supply labor as cash goods. To pay the second group of workers, the wholesaler needs to carry over some cash. Note that since wholesalers carry over cash, his problem must be dynamic as opposed to the static problem in Section 3.3. The dynamic cash flow problem facing the risk neutral producers is as follows:

$$Max \sum_{t=0}^{\infty} \lambda_t' [L_t + M_{t-1}^T + (1-\delta_k)P_t Q_t K_{t-1} + P_t^w Y_t^w - M_t^T - W_t^{RT} H_t^{RT} - W_t^F H_t^F - (1+i_t^L)L_{t-1} - Q_t P_t K_t]$$
(32)

where all symbols are the same as before , $L_t$ is new nominal loan and $M_t^T$ is non-interest bearing cash (different from interest bearing bank reserve $M_t^R$, $Y_t^w$ is subject to the production function (11). $\lambda_t'$ is an inflation adjusted discount factor which will be specified later. New notations are $H_t^{RT}, H_t^F$ which are the labor demanded from $RT$ and forward looking households respectively. Production function is now: $Y_t^W = \xi_t^a K_{t-1}^\alpha (H_t^{RT} + H_t^F)^{1-\alpha}$. These two types of labor (which come in the proportion, $\phi/(1-\phi)$) are assumed to be perfectly substitutable. Their wages, however, are not the same because of the payment friction for the $RT$ group.[19] The labor market is segmented because a group of workers are unbanked and want cash for work. Their wage will be subject to an inflation tax while for banked workers, no such inflation tax appears.

Wholesale producers are subject to a borrowing constraint as follows:

$$P_t Q_t K_t \ \leq \ L_t$$
(33)

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up taxing the household less.

[19]Thus, the usual labor mobility story does not apply here.

We assume that this borrowing constraint binds. Since wholesalers have to pay the rule of thumb workers in cash, we introduce a cash in advance constraint:

$$W_t^{RT} H_t^{RT} \leq M_{t-1}^T \tag{34}$$

The present value Lagrangian is given by:[20]

$$L_t'^P = E_t \sum_{s=0}^{\infty} \lambda_s' [L_{t+s} + M_{t+s-1}^T + (1-\delta_k) P_{t+s} Q_{t+s} K_{t+s-1} + P_{t+s}^w Y_{t+s}^w - M_{t+s}^T$$

$$- W_{t+s}^{RT} H_{t+s}^{RT} - W_{t+s}^F H_{t+s}^F - (1+i_{t+s}^L) L_{t+s-1} - Q_{t+s} P_{t+s} K_{t+s}]$$

$$+ \sum_{s=0}^{\infty} \mu_{t+s}' \left[ M_{t+s-1}^T - W_{t+s}^{RT} H_{t+s}^{RT} \right] + \sum_{t=0}^{\infty} \nu_{t+s}' \left[ L_{t+s} - P_{t+s} Q_{t+s} K_{t+s} \right].$$

where $\mu_t'$, $\nu_t'$ are respective lagrange multipliers.

The first order conditions are given by:

$$M_t^T : \quad -\lambda_t' + \lambda_{t+1}' + \mu_{t+1}' = 0 \tag{35}$$

$$H_t^{RT} : \quad \lambda_t' \left[ P_t^W MPH_t^{RT} - W_t^{RT} \right] - \mu_t' W_t^{RT} = 0 \tag{36}$$

$$H_t^F : P_t^W MPH_t^F - W_t^F = 0 \tag{37}$$

$$K_t' : \quad -\lambda_t' Q_t P_t + \lambda_{t+1}' [P_{t+1}^w MPK_t + (1-\delta_k) P_{t+1} Q_{t+1}] - \nu_t' Q_t P_t = 0 \tag{38}$$

$$L_t : \lambda_t' - \lambda_{t+1}' (1+i_{t+1}^L) + \nu_t' = 0 \tag{39}$$

Since the borrowing constraint binds ($\nu_t' > 0$), substitute out $\nu_t'$ from (38) and (39) and verify that the basic return equation (14) holds meaning

$$1 + i_{t+1}^L = \left[ \left( \frac{P_{t+1}^w}{P_{t+1}} \right) \frac{MPK_{t+1}}{Q_{t+1}} + 1 - \delta_k \right] \left[ \frac{P_{t+1} Q_{t+1}}{P_t Q_t} \right]. \tag{40}$$

Effectively a binding borrowing constraint means that wholesalers virtually rent capital from banks as in Chari, Kehoe and McGrattan (1995).

Next rewrite (36) as:

$$\frac{\lambda_t'}{\mu_t'} = \frac{(W_t^{RT}/P_t)}{[(P_t^w/P_t) MPH_t^{RT} - (W_t^{RT}/P_t)]}$$

---

[20]We ignore expectations temporarily because we want to make sure that a recursive steady state exists.

Using (35),

$$\frac{\lambda_t'}{\lambda_{t-1}' - \lambda_t'} = \frac{\left(W_t^{RT}/P_t\right)}{[(P_t^w/P_t)MPH_t^{RT} - (W_t^{RT}/P_t)]}.$$

Equation (41) which can be rewritten as:

$$\frac{1}{[(\lambda_{t-1}'/\lambda_t') - 1]} = \frac{\left(W_t^{RT}/P_t\right)}{[(P_t^w/P_t)MPH_t^{RT} - (W_t^{RT}/P_t)]} \tag{41}$$

## 4.1 Specification of the discount factor $\lambda_t'$

The wholesaler's discount factor $\lambda_t'$ is given by the sequence of loan rates. In other words,

$$\lambda_t' = \frac{1}{(1 + i_0^L)} \cdot \frac{1}{(1 + i_1^L)} \cdot \frac{1}{(1 + i_2^L)} \cdots \cdots \frac{1}{(1 + i_t^L)}$$

which means:

$$\lambda_t'/\lambda_{t-1}' = \frac{1}{(1 + i_t^L)}$$

which after plugging into (41) yields,

$$\left(\frac{1}{i_t^L}\right) = \frac{\left(W_t^{RT}/P_t\right)}{[(P_t^w/P_t)MPH_t^{RT} - (W_t^{RT}/P_t)]} \tag{42}$$

The loan rate $i_t^L$ can be pinned down by (26). Plugging this and rearranging (42) we get:

$$\frac{W_t^{RT}}{P_t} = \frac{\beta U'(C_t)}{U'(C_{t-1})} \cdot \frac{P_{t-1}}{P_t} \cdot \frac{P_t^w}{P_t} \cdot MPH_t$$

which is the $RT$ labor demand equation of the dynamic wholesaler. Since the wage bill is subject to the last period cash constraint, the real wage is subject to an inflation tax. Hiring a worker today also entails use of cash available today which means less cash available for wage disbursement tomorrow, hence the discounting of marginal product of labor.

In addition, the wholesaler has a usual labor demand function for $F$ households given by:

$$(P_t^W/P_t)MPH_t^F - (W_t^F/P_t) = 0 \tag{43}$$

## 4.2 Labor supplies of $RT$ and Ricardian households

$RT$, or unbanked consumers, solve the following static maximization problem:

$$\max\ U(C_t^{RT}) - \Phi(H_t^{RT})$$

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s.t.
$$P_t C_t^{RT} = W_t H_t^{RT}$$

which gives rise to the following labor supply function of $RT$ consumers:

$$U'(C_t^{RT})(W_t/P_t) = \Phi'(H_t^{RT}) \tag{44}$$

It is easy to verify that with the utility function $lnC_t^{RT} - H_t^{RT}$, the optimal labor supply of $RT$ consumers is given by:

$$H_t^{RT} = 1 \tag{45}$$

For $F$ consumers, the labor supply is infinitely elastic at $\frac{W_t^F}{P_t}$ given by (5).

## 4.3   Labor market equilibrium

There are two segmented labor markets. Due to the payment friction, in the $RT$ sector, two real wages will prevail in equilibrium. In the technical appendix, we show how this happens in a steady state equilibrium.

## 4.4   Government budget constraint

The government now has seigniorage as an additional source of revenue because of the use of paper money by the rule of thumb household. The government budget constraint changes to:

$$P_t G_t + \left(1 + i_t^G\right) B_{t-1} + (1 + i^R)M_{t-1}^R + (1 + i^a)D_{t-1}^a + M_{t-1}^T \tag{46}$$

$$= P_t T_t + B_t + M_t^R + M_t^T + D_t^a + (1 + i^p)E_t \max(\widetilde{W}_t - M_t^R, 0) \tag{47}$$

## 4.5   Monetary policy

Money supply is now augmented to include paper currency. In other words, the money supply (define it as $M_t^s$) is given by

$$M_t^s = M_t^T + M_t^R$$

The law of motion of money supply is given by the following stochastic process for $M_t^s$ :

$$\frac{M_t^s/M_{t-1}^s}{1 + \bar{\pi}} = \left(\frac{M_{t-1}^s/M_{t-2}^s}{1 + \bar{\pi}}\right)^{\rho_\mu} \exp(\xi_t^\mu) \tag{48}$$

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# 5  Quantitative analysis

The objective of our quantitative analysis is to understand why monetary transmission mechanism is weak in India using the baseline and extended models. We also want to replicate the key stylized fact in Section 2 where we show that base money shocks have a stronger impact on output than policy rate shocks.

We refer to the baseline model as 'Model 1' and its extended version with the presence of an unbanked population as 'Model 2'. Monetary transmission is defined as the process through which monetary policy action impacts the aggregate economy (real GDP and inflation). The aggregate demand channel operates in the model economy via two layers: from policy instruments to bank lending rate, and then, from lending rate to output (including its components of consumption and investment) and inflation. In order to study these channels of transmission, we focus on the standard instruments of monetary policy used by an inflation targeting central bank. These policy instruments are the money base and the short term interest rate (which is the government bond rate in our model). The magnitude of transmission of the shocks from policy instruments to policy targets is measured using the variance decomposition results of key macroeconomic variables of the model. In our analysis, we specify the baseline parameterization of the model, calibrate the shock structure to match empirical moments, report the variance decomposition results and sensitivity experiments on the different structural and policy factors in the monetary transmission, and explain the impulse response properties of the baseline and extended model.

## 5.1  Calibration

Following the DSGE literature on India and using Indian data on the macroeconomic variables, we calibrate the structural and policy parameters of our models. The share of capital in production process is set as 0.3 (Banerjee and Basu, 2017). The discount factor is taken as 0.98 (Gabriel et al., 2012). Household's preference for holding bank deposits is calibrated based on the share of commercial bank deposits to total deposits which is approximately 84%. Depreciation of physical capital is chosen as 2.5% on a quarterly basis. The investment adjustment cost parameter is set to 2 from Banerjee and Basu (2017). The mark down factor, $\zeta$, for the deposit interest rate is taken as 0.97 in order to match the savings account deposit rate at the steady state of 3.8%. The price adjustment cost parameter is taken as 118 from Anand et al. (2010) and indexation of past inflation is set to 58% following Sahu (2013). The proportion of rule of thumb consumers in population is set to 35% as estimated by Gabriel et al. (2012).

We set policy parameters for the Taylor rule stabilizer following Gabriel et al. (2012)

and Banerjee and Basu (2017), where the interest rate smoothing coefficient is 0.8, inflation stabilizing coefficient is 1.2 and output gap stabilizing coefficient is 0.5. The long run inflation target is set to 4% as proposed by the Urjit Patel Committee Report of RBI (2014). The steady state value of the policy rate is set to 7% in line with the time average over the period of last five-years. In India, the statutory liquidity requirement of the commercial banks is 21.5%, and the value of $\alpha_q$ is set accordingly. The government administered postal interest rate is set to 4% as observed from the savings account in the Indian Postal Service. The steady state value of the penalty rate is set to 6.5%, which is approximately the average of the marginal standing facility rate in the LAF corridor. The steady state value of productivity and policy shocks are normalized to one. Table 1 summarizes the baseline values of the structural and policy parameters.

Table 1: Structural and Policy Parameters of Baseline Models

| Parameters | Description | Value | Source |
|---|---|---|---|
| $\alpha$ | Share of capital | 0.30 | Banerjee & Basu, 2017 |
| $\beta$ | Discount rate | 0.98 | Gabriel et al., 2011 |
| $\eta$ | Preference for holding bank deposit | 0.84 | RBI database |
| $\delta_k$ | Depreciation rate of capital | 0.025 | Banerjee & Basu, 2017 |
| $\kappa$ | Investment adjustment cost | 2 | Banerjee & Basu, 2017 |
| $\zeta$ | Mark-down factor for Deposit rate | 0.97 | Set to match the savings account rate |
| $\varepsilon^Y$ | Price elasticity of demand | 7 | Gabriel et al., 2011 |
| $\phi_p$ | Price adjustment cost | 118 | Anand et al., 2010 |
| $\theta_p$ | Past inflation indexation | 0.58 | Sahu J. P., 2013 |
| $\rho_{i^G}$ | Interest rate smoothing parameter | 0.80 | Banerjee & Basu, 2017 |
| $\varphi_\pi$ | Inflation Stabilizing Coefficient | 1.20 | Gabriel et al., 2011 |
| $\varphi_y$ | Output Stabilizing Coefficient | 0.50 | Banerjee & Basu, 2017 |
| $\alpha_q$ | Statutory Liquidity Ratio | 21.5% | RBI Website |
| $\pi$ | Long-run inflation target | 4% | Urjit Patel Committee Report, 2013 |
| $i^G$ | Steady state policy rate | 7% | RBI Database |
| $i^a$ | Steady state administered rate | 4% | Indian Postal Service Website |
| $i^p$ | Steady state penalty rate | 6.5% | RBI Database |

For baseline parameterization of the exogenous shock processes, we broadly follow a method of moments approach. In Data Appendix E, we have provided the list of relevant macroeconomic and financial variables and the method of data transformation used in order to make the empirical moments comparable with the theoretical moments of interest. We target nine moments from the data and calibrate nine unknown parameters of shock processes in order to match the observed moments.[21] Having done this, we then examine how some relevant over-identified moments (which we call non-targeted moments) from the model compare with the data. Our nine targets are three volatility targets, namely, (i) standard deviations of output, inflation and the lending rate, and (ii) six cross correlation targets, namely, correlations of output with consumption, investment, bank deposit, correlation of the lending rate with inflation, and correlations of the administered deposit rate with the policy interest rate and the bank lending rate. For the volatilities, output and CPI inflation

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[21]There are nine moments because there are four shock processes with two parameters required to be calibrated for each. The error term in the interest rate process is however i.i.d., meaning that only one parameter needs to be calibrated for this equation.

are considered to be key objectives for inflation targeting central banks. Bank lending rate is the key variable for transmitting monetary impulses. In case of cross-correlations, we choose targets according to the strengths of statistical significance. All the correlations are significant at 5% level of significance.

Table 2 summarizes the baseline values of all the second moment parameters of the shock processes. The calibrated shock parameters are broadly in line with the data and the relevant literature. For instance, first order persistence and standard error of TFP (0.82 and 0.016 respectively) and fiscal policy (0.59 and 0.026 respectively) shocks are close to the estimates provided by Anand et al. (2010). For the IST shock, the estimates for AR (1) coefficient and standard error (0.63 and 0.133 respectively) are in line with Banerjee and Basu (2017). In case of the autonomous shock to money base, our calibrated numbers of persistence coefficient and standard error (0.48 and 0.021 respectively) fits modestly with the business cycle component of the growth rate of real reserve. The standard error of the policy rate shock is set to 0.002, which is slightly on the lower side compared to the estimate of Anand et al. (2010).

Table 2: Baseline Parameterization of Shock Processes

| Parameters | Description | Values | Literature | Source |
|---|---|---|---|---|
| $\rho_a$ | Persistence coefficient of TFP shock | 0.82 | $\left[0.658, 0.959\right]$ | Anand et al. 2010 |
| $\rho_{Z_x}$ | Persistence coefficient of IST shock | 0.63 | $\left[0.483, 0.690\right]$ | Banerjee & Basu, 2017 |
| $\rho_G$ | Persistence coefficient of Fiscal shock | 0.59 | $\left[0.465, 0.821\right]$ | Anand et al. 2010 |
| $\rho_\mu$ | Persistence coefficient of Money base shock | 0.48 | 0.29 | OLS (point) estimate of AR(1) Coefficient |
| $\sigma_a$ | Standard error of TFP shock | 0.016 | $\left[0.001, 0.009\right]$ | Anand et al. 2010 |
| $\sigma_{Z_x}$ | Standard error of IST shock | 0.133 | $\left[0.559, 0.833\right]$ | Banerjee & Basu, 2017 |
| $\sigma_G$ | Standard error of Fiscal shock | 0.026 | $\left[0.052, 0.083\right]$ | Anand et al. 2010 |
| $\sigma_\mu$ | Standard error of Money base shock | 0.021 | 0.066 | OLS (point) estimate of SE |
| $\sigma_{iG}$ | Standard error of Interest rate shock | 0.002 | $\left[0.002, 0.007\right]$ | Anand et al. 2010 |

## 5.2 Model validation by matching moments

While targeting nine business cycle statistics to minimize the difference between empirical and theoretical moments, we subsequently check if this exercise can produce a reliable baseline parameterization of the model. In order to do that, we compare the non-targeted moments of the business cycle properties of Indian data and our baseline model. Table 3A and 3B report the data and model comparison for Model 1 and 2 with respect to targeted and non-targeted moments.[22]

The output and lending rate volatilities are quite accurately predicted by both models in terms of the respective standard deviations. The inflation volatility is somewhat under-predicted.

For the non-targeted moments, the model generated first order persistence coefficients of output and inflation are in line with their data counterparts. The cross correlations in both models predict the signs correctly. Few important observations are in order. First, the correlation between output and monetary base growth is positive in both the data and our models which is indicative of monetary transmission emanating from the changes in the monetary base. Second, the correlation between the policy rate and the lending rate is strongly positive in the data and predicted reasonably by the model. One may be tempted to conclude from this observation that the lending channel of monetary transmission is strong. However, the correlation between the policy rate and output shows a different picture. It is positive in the data and model which goes contrary to the conventional Taylor rule based wisdom that a lower policy rate would raise output.

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[22] For model validation, we use reserve money as the monetary base for Model 1. For Model 2, we consider both interest bearing reserves and non-interest bearing cash in the definition of monetary base. This is because in Model 2 base money includes both paper currency in circulation and reserve money. For this reason, correlations of $[y, (x_t/x_{t-1})]$, $[d, (x_t/x_{t-1})]$, and $[i, (x_t/x_{t-1})]$ are marginally different between Table 3A and 3B.

Table 3A: Results of Moment Matching between Data and Model 1

| Targeted Moments | | | Non-targeted Moments | | |
|---|---|---|---|---|---|
| Moment | Data | Model | Moment | Data | Model |
| std. dev $(y)$ | 0.02 | 0.02 | correl $[y, (x_t/x_{t-1})]$ | 0.39 | 0.25 |
| std. dev $(\pi)$ | 0.03 | 0.01 | correl $[y, i^G]$ | 0.34 | 0.12 |
| std. dev $(i^L)$ | 0.02 | 0.02 | correl $[i^G, i^L]$ | 0.68 | 0.37 |
| correl $[y, c]$ | 0.38 | 0.39 | correl $[d^a, \pi]$ | -0.37 | -0.84 |
| correl $[y, i]$ | 0.79 | 0.53 | correl $[d, (x_t/x_{t-1})]$ | 0.38 | 0.22 |
| correl $[i^L, \pi]$ | 0.59 | 0.65 | correl $[d, i]$ | 0.49 | 0.33 |
| correl $[y, d]$ | 0.69 | 0.54 | correl $[i, (x_t/x_{t-1})]$ | 0.33 | 0.13 |
| correl $[d^a, i^G]$ | -0.32 | -0.92 | AR(1) coefficient of $y$ | 0.87 | 0.79 |
| correl $[d^a, i^L]$ | -0.56 | -0.47 | AR(1) coefficient of $\pi$ | 0.84 | 0.92 |

Regarding the interpretation of cross correlation results, an important caveat is in order. This moment matching exercise essentially gives us a broad guidance how the model performs in matching India's business cycle statistics. One can not necessarily infer the degree of monetary transmission or the efficacy of the lending channel of monetary policy by looking at these cross correlations alone. The reason is that these correlations represent reduced form relationships and reflect co-movement of two series in response to all five shocks driving the economy. Hence, even if the correlation between the policy rate and output goes against the conventional Taylor rule wisdom, it does not necessarily tell us that the interest rate channel of monetary transmission is weak. For doing a comprehensive analysis, one needs to look at the variance decomposition of output with respect to the monetary base and policy rate shocks to which we turn now.

Table 3B: Results of Moment Matching between Data and Model 2

| Targeted Moments | | | Non-targeted Moments | | |
|---|---|---|---|---|---|
| Moment | Data | Model | Moment | Data | Model |
| std. dev $(y)$ | 0.02 | 0.02 | correl $[y, (x_t/x_{t-1})]$ | 0.37 | 0.21 |
| std. dev $(\pi)$ | 0.03 | 0.01 | correl $[y, i^G]$ | 0.34 | 0.11 |
| std. dev $(i^L)$ | 0.02 | 0.02 | correl $[i^G, i^L]$ | 0.68 | 0.36 |
| correl $[y, c]$ | 0.38 | 0.40 | correl $[d^a, \pi]$ | -0.37 | -0.84 |
| correl $[y, i]$ | 0.79 | 0.52 | correl $[d, (x_t/x_{t-1})]$ | 0.32 | 0.23 |
| correl $[i^L, \pi]$ | 0.59 | 0.64 | correl $[d, i]$ | 0.49 | 0.34 |
| correl $[y, d]$ | 0.69 | 0.52 | correl $[i, (x_t/x_{t-1})]$ | 0.26 | 0.14 |
| correl $[d^a, i^G]$ | -0.32 | -0.93 | AR(1) coefficient of $y$ | 0.87 | 0.78 |
| correl $[d^a, i^L]$ | -0.56 | -0.45 | AR(1) coefficient of $\pi$ | 0.84 | 0.92 |

## 5.3 Variance decomposition results from baseline model

Table 4 reports the variance decomposition of our five fundamental shocks for both models. For Model 1, it is found that monetary policy shocks (adding both autonomous money base shock and shock to short term policy rate) explains 16.8% of output fluctuations in which the monetary base accounts for 13.08%. The lion share (50.78%) of output fluctuations is explained by the shock to total factor productivity as argued in the literature (Banerjee and Basu, 2017). In addition, it is noticeable that government spending shocks make a significant contribution to cyclical variations (30.05%) in output. Inflation (71.76%) and the bank lending rate (63.48%) are also largely been driven by shocks to total factor productivity.

A similar pattern in the variance decomposition is also observed for Model 2 along with a new feature. The relative importance of monetary policy shocks decline to 13.92% while the fiscal policy shock becomes more important compared to Model 1. The presence of an unbanked population chokes off the channels of pass-through of monetary transmission to aggregate demand. Instead, as non-Ricardian household are present, they amplify the fiscal spending shock's impact on output fluctuations.

Table 4: Variance Decomposition Results for Major Macroeconomic Variables

| List of Variables | $\xi^a$ | | $\xi^{Z_x}$ | | $\xi^G$ | | $\xi^\mu$ | | $\xi^{i^G}$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| $y$ | 50.78 | 50.11 | 2.36 | 2.10 | 30.05 | 33.87 | 13.08 | 10.91 | 3.72 | 3.01 |
| $c$ | 43.37 | 48.53 | 28.09 | 28.77 | 9.75 | 8.59 | 13.74 | 10.29 | 5.05 | 3.82 |
| $i$ | 32.69 | 31.12 | 55.41 | 55.91 | 3.71 | 3.88 | 6.91 | 7.77 | 1.29 | 1.32 |
| $\pi$ | 71.76 | 70.04 | 0.21 | 0.19 | 0.47 | 0.46 | 26.91 | 28.67 | 0.66 | 0.64 |
| $i^L$ | 63.48 | 62.26 | 1.19 | 1.05 | 5.96 | 6.01 | 20.06 | 21.61 | 9.31 | 9.06 |
| $i^G$ | 31.11 | 30.06 | 0.68 | 0.68 | 2.87 | 3.21 | 59.67 | 60.00 | 5.68 | 6.05 |
| $\left(i^L - i^D\right)$ | 55.88 | 55.44 | 1.26 | 1.05 | 8.08 | 8.25 | 16.91 | 17.85 | 17.87 | 17.42 |
| $d$ | 32.23 | 32.60 | 0.25 | 0.24 | 0.14 | 0.15 | 67.23 | 66.85 | 0.16 | 0.16 |
| $d^a$ | 53.94 | 51.38 | 0.85 | 0.86 | 4.40 | 4.79 | 36.19 | 38.12 | 4.62 | 4.84 |
| $TD$ | 49.71 | 50.65 | 0.13 | 0.11 | 0.47 | 0.53 | 49.15 | 48.13 | 0.54 | 0.58 |
| $x$ | 33.38 | 33.81 | 0.24 | 0.23 | 0.12 | 0.13 | 66.12 | 65.69 | 0.14 | 0.14 |

## 5.4 Sensitivity experiments for monetary transmission

In Table 5, we present the results of sensitivity experiments which are conducted for a variety of structural and policy parameters of Models 1 and 2. We decrease the baseline values of these parameters one at a time by 10%. We then check how such a perturbation affects the

transmission of autonomous shocks to the monetary base and the policy rate compared to baseline values.

Table 5: Sensitivity Experiments for Monetary Transmission to Output

| Sensitivity Experiments | Share of $\xi^\mu$ in FEVD in $y$ | | Share of $\xi^{i^G}$ in FEVD in $y$ | | correl $[y, (x_t/x_{t-1})]$ | | correl $[y, i^G]$ | |
|---|---|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| Baseline | 13.08 | 10.91 | 3.72 | 3.01 | 0.247 | 0.213 | 0.116 | 0.105 |
| $\eta = 0.756$ | 13.08 | 10.95 | 3.72 | 3.01 | 0.247 | 0.214 | 0.116 | 0.106 |
| $i^a = 0.036$ | 13.08 | 10.91 | 3.72 | 3.01 | 0.247 | 0.213 | 0.116 | 0.105 |
| $\alpha_q = 0.194$ | 13.08 | 10.91 | 3.72 | 3.01 | 0.247 | 0.213 | 0.116 | 0.105 |
| $\zeta = 0.873$ | 44.25 | 42.00 | 0.84 | 0.65 | 0.499 | 0.441 | 0.554 | 0.561 |
| $\phi_p = 106$ | 11.57 | 9.52 | 3.44 | 2.75 | 0.241 | 0.207 | 0.081 | 0.072 |
| $\theta_p = 0.522$ | 14.53 | 12.16 | 3.94 | 3.20 | 0.248 | 0.214 | 0.153 | 0.143 |
| $\varphi_\pi = 1.08$ | 15.93 | 13.62 | 3.90 | 3.18 | 0.273 | 0.238 | 0.176 | 0.167 |
| $\varphi_y = 0.45$ | 13.37 | 11.17 | 3.72 | 3.03 | 0.252 | 0.218 | 0.108 | 0.097 |
| $\rho_{i^G} = 0.72$ | 12.12 | 9.67 | 1.83 | 1.41 | 0.213 | 0.183 | 0.142 | 0.129 |

A few observations are in order. First, a change in the preference parameter ($\eta$) for commercial bank deposit holding ($d$), causes no change in the baseline values of the monetary transmission indicators. Second, changes in the financial repression parameter, $\alpha_q$ (the SLR requirement) and $i^a$ (the administered interest rate) have a negligible impact on monetary transmission. Third, not surprisingly, with low price adjustment costs ($\phi_p$) and a higher degree of past inflation indexation ($\theta_p$) in the retail sector, monetary transmission becomes weaker. Lower values of the nominal friction and the lack of forward looking price setting behavior limits the real effects of a monetary policy shock via the expectation channel. Fourth, the mark-down factor ($\zeta$) for the deposit interest rate has a major implication for monetary transmission driven by the money base. The transmission of monetary base shock becomes conspicuously higher as seen by the error variance decomposition and money-output correlation while the transmission of interest rate shock is remarkably diminished. The intuition for this stems from the fact that a lower $\zeta$ marks down the interest rate on deposits which discourages the household to accumulate bank deposits. Since reserve demand is proportional to bank deposits (see equation 27), banks hold fewer reserves and extend more loans. Thus the propagation of a shock to monetary base becomes stronger through the bank lending channel because banks hold less reserves. On the other hand, since a lower $\zeta$ widens the spread between borrowing and lending rates ($i_t^L - i_t^D$), the pass through from a policy rate shock to the bank lending rate ($i_t^L$), and $i_t^L$ is largely determined by inflation, transmission becomes weaker which explains why the policy rate accounts for

less variation in output. Fifth, the smoothing coefficient of the policy rate Taylor rule has a noteworthy implication for monetary transmission. A lower $\rho_{iG}$ significantly reduces monetary transmission of the policy rate as evidenced by the variance decomposition of output. The policy rate accounts for 1.83% as opposed to 3.72% of output variation when the smoothing coefficient drops. The lower response of output is due to the lower degree of persistent variation in the interest rate in response to a policy shock which translates into less persistent output fluctuations. Finally, not surprisingly, less aggressive inflation targeting (lower $\varphi_\pi$) and less output stabilization (lower $\varphi_y$) raises the pass through of monetary base shock to output, inflation and the nominal loan rate.

## 5.5 Impulse response analysis of the monetary transmission mechanism

Following the reliability check of the baseline model with data, we study the propagation mechanism of the shocks to monetary policy instrument given that the Taylor-type stabilizer is in place. As mentioned earlier, there are two types of policy shocks in action. First, the shocks to base money growth which are akin to autonomous liquidity shocks and may be beyond the control of the central bank. Second, the shocks to the short-term policy interest rate by the central bank are a conscious effort to impact the real and/or financial target variables according to a policy mandate. What is the propagation mechanism of such shocks to base money and policy interest rate in the model? We investigate that using the properties of impulse response plots given in Figure 3 to 6.[23]

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[23]The IRF plots of monetary policy shocks in Model 2 are similar to Model 1 except for minor quantitative differences.
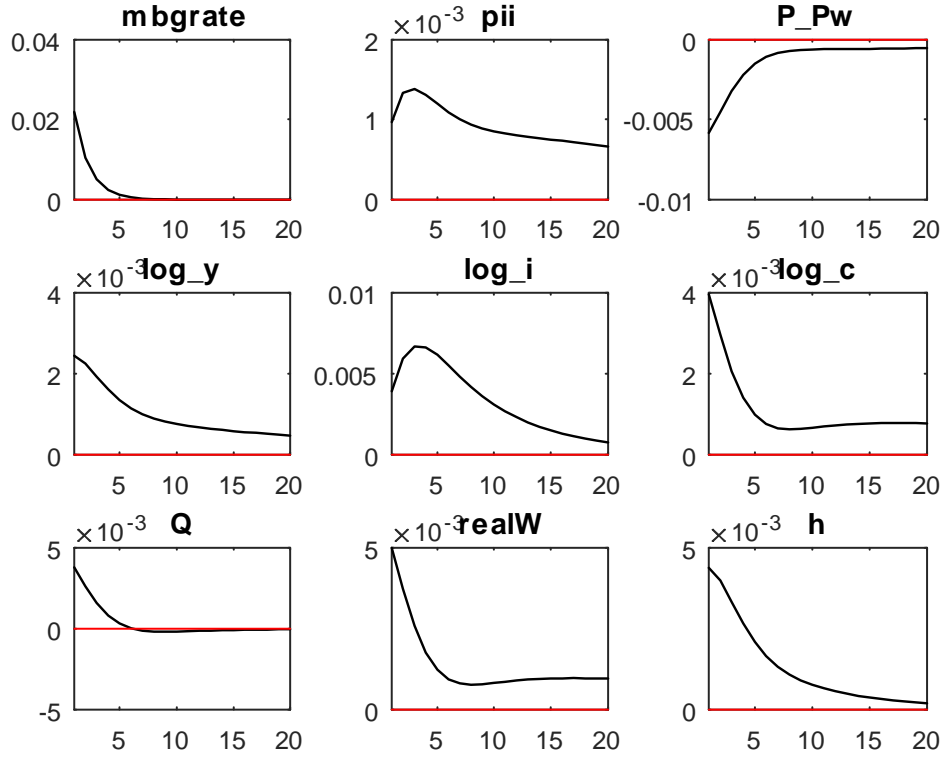
Figure 3: Effects of Shock to Money Base

A positive shock to monetary base immediately translates into positive inflation via the monetary base rule of equation (27) which translates into a higher real marginal cost ($P_w/P$) via the staggered price adjustment cost equation (17). Higher real marginal cost makes firms expand output along the standard new Keynesian channel. Higher real marginal costs also translate into a higher implicit rental price of capital which promotes investment. Thus, a Tobin type effect works for stimulating investment in response to an inflationary monetary shock. Real consumption rises because of higher output and real wage (a wealth effect). Output expansion of the wholesale firms increases the demand for labor, leads to a higher real wage, and encourages workers to supply more labor in the production process. Higher inflation raises the policy rate ($i^G$) via the Taylor rule which acts as a built in stabilizer for our policy experiment. A positive shock to the monetary base has thus an unambiguously stimulative effect on the economy.
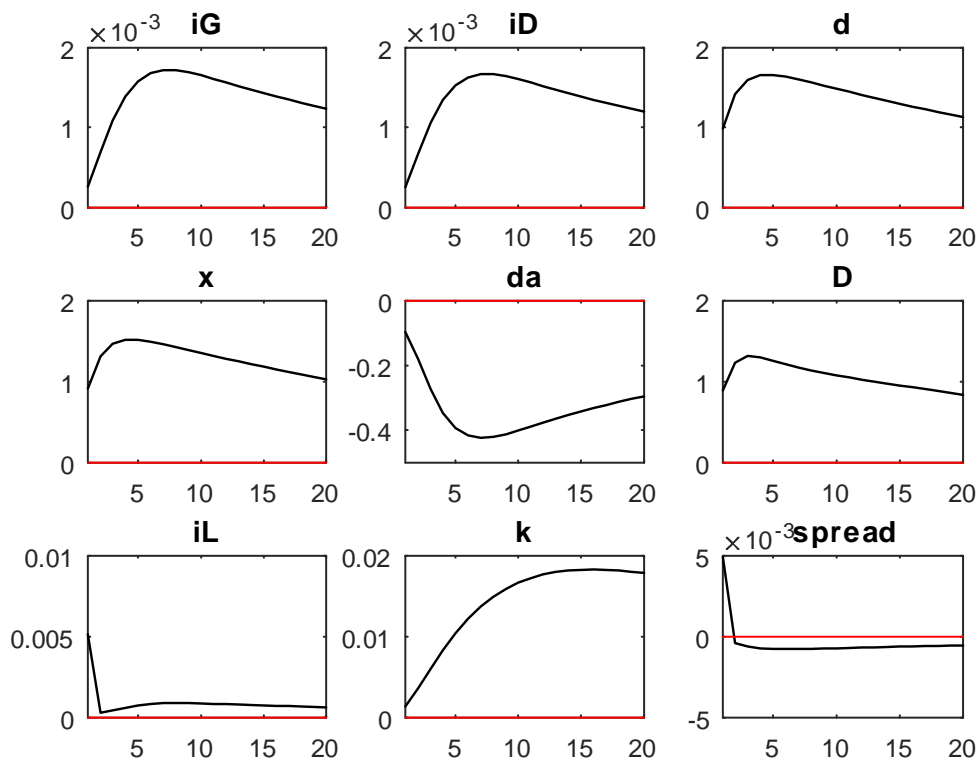
Figure 4: Effects of Shock to Money Base

In the banking sector, the interest rate on deposits rise $(i^D)$ because it is set in proportion to the government bond rate $i^G$, which positively responds to inflation via the interest rate feedback rule. A higher deposit rate encourages depositors to hold more bank deposits which means real deposits in commercial banks $(d)$ rise. Since, demand for real reserves by banks $(x)$ is proportional to its deposits $(d)$, as given in the bank's reserve demand equation (24), a higher money base raises real reserves although the ratio of money to deposit $(x/d)$ falls. This facilitates more bank lending, more investment and greater accumulation of the capital stock which contributes further to a rise in the real wage. The nominal loan rate rises momentarily due to a higher inflation rate which is well known as Fisher effect. The higher interest rate on deposits due to the interest rate stabilizer makes bank deposits by households increase while deposits in administered postal deposits, i.e. $d^a$, fall. This happens because depositors substitute away from postal to bank deposits, although total deposits rise. Although the deposit rate rises due to the interest rate stabilizer, the borrowing-lending spread still widens, which means that the loan rate rises more than the deposit rate.

In a similar vein, we next examine the effects of a negative shock to the short-term policy interest rate. A negative shock to the policy interest rate generates an expansionary impact on output in the economy through the standard new Keynesian channel via the interest rate

policy rule (30). Because inflation and real marginal costs go up, a similar Tobin effect is at work which raises investment. Households reduce the holding of bank deposits due to a low deposit rate. They consume more and also switch to administered deposits. Shortage of loanable funds raises the interest rate on loan.
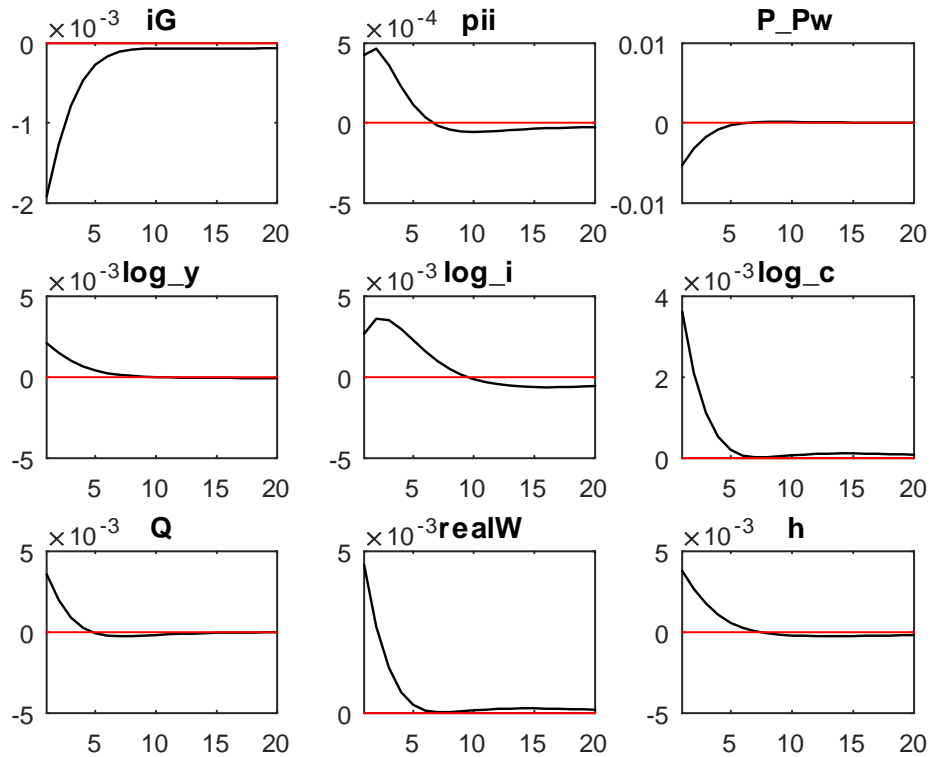


Figure 5: Effects of Shock to Policy Interest Rate

Due to inflationary pressure, the nominal interest rate on bank lending goes up sharply on impact. However, this rise of the bank lending rate does not last for long, and comes down in subsequent periods, and follows the movement of the policy interest rate. Following the decline of the policy interest rate, the marked down interest rate for bank deposits also falls which motivates the households to reshuffle their deposit holding from the commercial banks to postal service for a relatively higher return from the administered rate. So, bank deposits decline and administered deposits increase. As a consequence of declining bank deposits, real reserves fall.
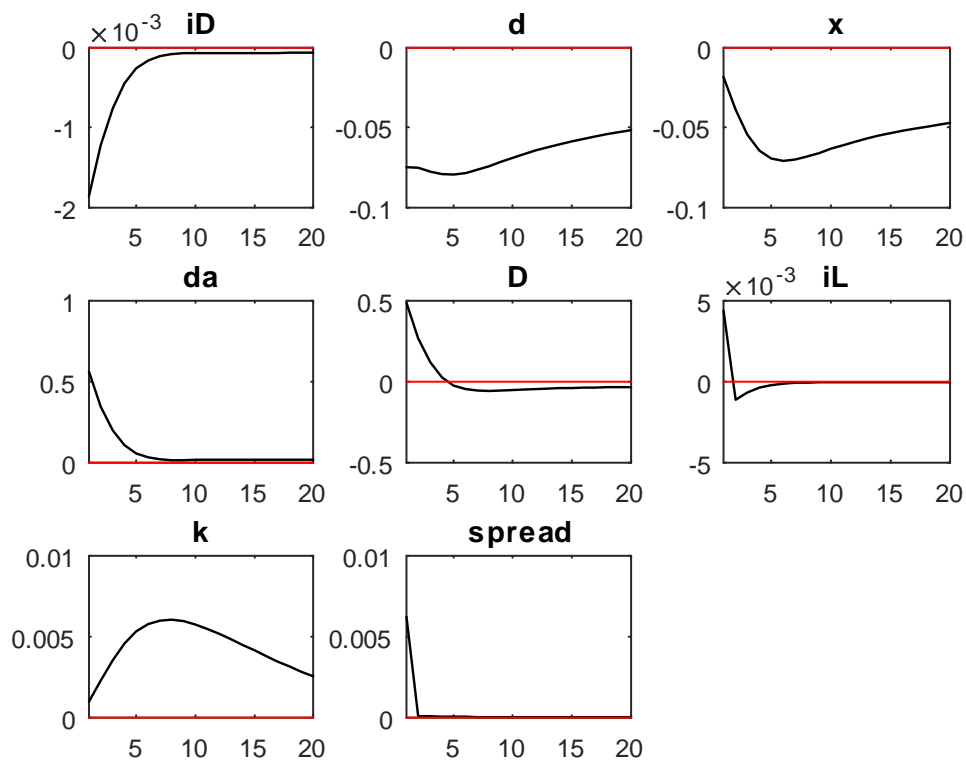
Figure 6: Effects of Shock to Policy Interest Rate

The comparison of output impulse responses of monetary base versus policy rate shocks reveals that the output response is much more prolonged for a positive shock to monetary base as opposed to the interest rate. The impact effect of output with respect to a monetary base shock is significantly bigger than the output response with respect to a negative policy rate shock. In addition, the positive effect lasts more than 20 quarters for a monetary base shock (Figure 3), while for the interest rate shock, it dissipates after 10 quarters (Figure 5). The punch-line of this exercise is that a shock to monetary base has a far stronger and persistent effect on output than the shock to policy interest rate. This agrees well with the empirical VAR impulse responses reported in Section 2.

## 5.6    Impulse response analysis from the extended model

The impulse responses of Model 2 are similar to Model 1 (see Appendix D, Figures 11-14, for the IRF plots) except for output and consumption. Figure 7 compares the output responses of a positive money shock in both models. Regarding the impact effect, an expansionary monetary policy raises output in both models but much less in Model 2. From the second period, output rises discretely in Model 2 and then declines. The capital stock is predeter-

mined in the first period of the shock while aggregate employment rises less than model 1 because the employment of RT consumers is fixed at unity by construction. This feeble rise in employment translates into a weak impact on output in the first period of the monetary shock in Model 2 compared to Model 1. In the second period, the Tobin effect of a higher inflation picks up which boosts output via the capital stock. From date 3 onward output starts reverting to the mean. The response of output to a negative interest rate shock is similar to a money base shock and thus are not reported for brevity.

Figures 9 and 10 report the response of consumption of $F$ and $RT$ consumers to a positive money base shock and a negative policy rate shock in Model 2. The $RT$ consumers suffer a sharp drop in consumption in response to either form of monetary stimulus while the forward looking consumers experience a rise in consumption. Two countervailing effects are at work here. First is the inflation tax and the second is the output effect. The inflation tax lowers the real wage of $RT$ consumers which lowers their consumption immediately. The subsequent rise in consumption happens due to a sharp rise in output which happens via the Tobin effect mentioned earlier. This positive output effect explains why $RT$ consumers experience a higher consumption in the second period. Monetary policy has stark distributional consequences because an inflationary monetary policy hurts $RT$ consumers most. This negative consumption effect also hinders monetary transmission from the demand side as seen by the weak impact effect of an easy monetary policy.
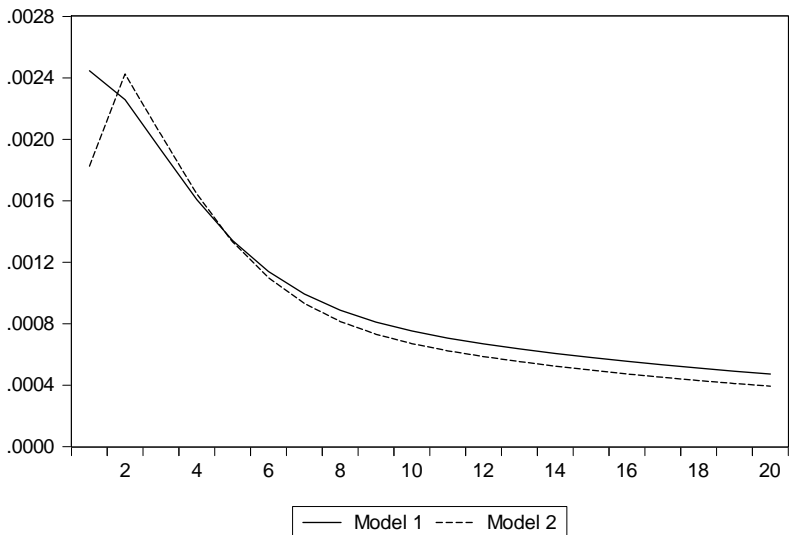


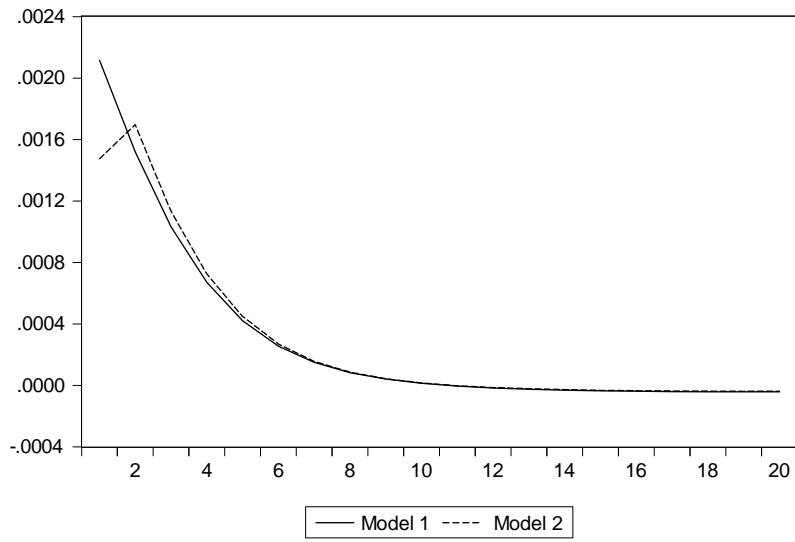Figure 7: Output response to a positive money shock in both models

Figure 8: Output response to a negative policy rate shocks in two models
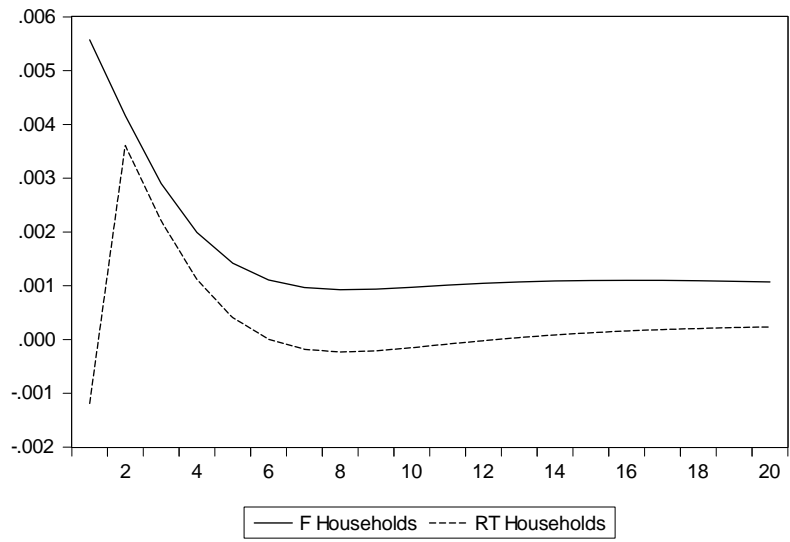


Figure 9: Responses of $RT$ and $F$ household consumption to a monetary shock in Model 2
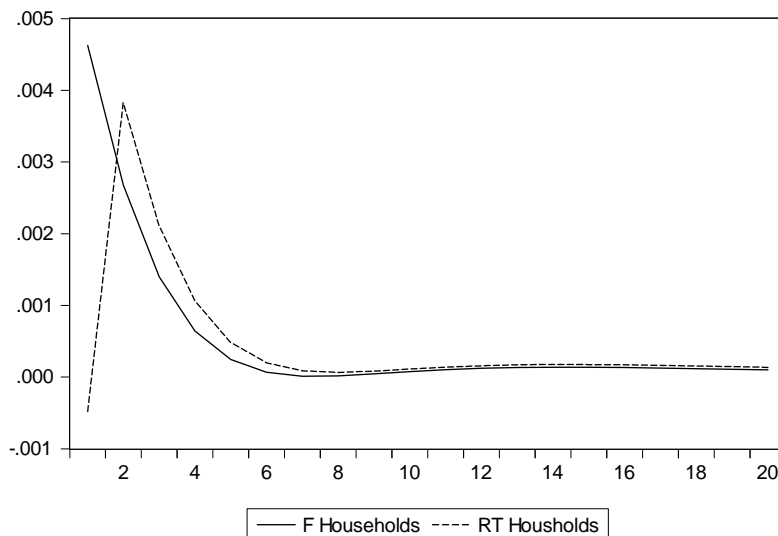
Figure 10: Responses of *RT* and *F* consumption to policy rate shock in Model 2

# 6    Conclusion

The key research question of this paper is: *what explains weak monetary policy transmission mechanism in India?* We construct a monetary business cycle model with sticky prices calibrated to the Indian economy to address this question. We focus on the aggregate demand channel for monetary transmission. The baseline model shows that the major part of output fluctuations are explained by real shocks to the economy (TFP shocks) rather than nominal shocks (base money and interest rate shocks from the Taylor rule). Fiscal policy shocks have a fairly large role to play in explaining output variation, but a lesser role in other macroeconomic aggregates. IST shocks have a negligible role in explaining output fluctuations in the economy. In an extended version of the model with a transaction demand for money, we show that the importance of fiscal shocks increases relative to the baseline model. An inflationary monetary policy reduces real wages of the rule of thumb consumers, which reduces their consumption. This adversely effects monetary policy transmission. Overall, our model is able to quantify the extent to which particular shocks matter in the transmission process.

In a comparison of output impulse responses of monetary base versus policy rate shocks, we show that the output response is much more prolonged for a positive shock to the monetary base as opposed to the interest rate. The impact effect of output with respect to a monetary base shock is significantly bigger than the output response with respect to a negative policy rate shock. In addition, the positive effect lasts more than 20 quarters for a

monetary base shock, while for the interest rate shock it dissipates after 10 quarters. The punch-line of this exercise is that a shock to monetary base has a far stronger and persistent effect on output than the shock to policy interest rate. This agrees well with the empirical VAR impulse responses reported in Section 2.

Finally, our paper also addresses a long standing hypotheses in the policy discussion on the impediments to monetary transmission. A prominent hypothesis is that the existence of an administered banking sector could undermine the role of monetary policy. A second hypothesis is that financial repression, in the form of a statutory liquidity ratio, raises the cost of funds facing banks, which weakens the efficacy of monetary policy. The calibrated baseline model does not lend support to either of these two hypotheses. The impulse response and variance decompositions of monetary policy shock are robustly invariant to changes in the administered postal rate, allocation of deposits between these two savings institutions, and to changes in the statutory liquidity ratio.

The lesson is that we need to understand the instruments of monetary control better, as well as the nature of real-monetary interactions, before we make any serious predictions about monetary transmission.

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# A Technical appendix

- The Lagrangian for the household problem is given by,

$$L_t = E_t \sum_{s=0}^{\infty} \beta^s [U(C_{t+s}) - \Phi(H_{t+s}) + V(D_{t+s}/P_{t+s}, D_{t+s}^a/P_{t+s}) - \tag{A.1}$$

$$\lambda_t(P_{t+s}C_{t+s} + P_{t+s}T_{t+s} + D_{t+s} + D_{t+s}^a - W_{t+s}H_{t+s} -$$

$$\left(1 + i_{t+s}^D\right) D_{t+s-1} - (1 + i^a) D_{t+s-1}^a - \Pi_{t+s}^k - \Pi_{t+s}^r - \Pi_{t+s}^b)]$$

The household's optimal choices are given by

$$\frac{\partial L_t}{\partial C_t} = U'(C_t) - \lambda_t P_t = 0$$

$$\frac{\partial L_t}{\partial H_t} = \Phi'(H_t) - \lambda_t W_t = 0$$

$$\frac{\partial L_t}{\partial D_t} = \frac{V_1(D_t/P_t, D_t^a/P_t)}{P_t} - \lambda_t + \beta E_t \left\{ \lambda_{t+1} \left(1 + i_{t+1}^D\right) \right\} = 0$$

$$\frac{\partial L_t}{\partial D_t^a} = \frac{V_2(D_t/P_t, D_t^a/P_t)}{P_t} - \lambda_t + \beta E_t \left\{ \lambda_{t+1} \left(1 + i^a\right) \right\} = 0.$$

- To obtain equation (9), set $\Omega_{t,t} = 1$ in (8), and solve for $Q_t$,

$$0 = P_t Q_t - P_t \left\{ 1 + S\left(\frac{I_t}{I_{t-1}}\right) \right\} - P_t S'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_t}{I_{t-1}} + \Omega_{t,t+1} P_{t+1} S'\left(\frac{I_{t+1}}{I_t}\right) \left(\frac{I_{t+1}}{I_t}\right)^2$$

$$P_t Q_t = P_t \left\{ 1 + S\left(\frac{I_t}{I_{t-1}}\right) \right\} + P_t S'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_t}{I_{t-1}} - \Omega_{t,t+1} P_{t+1} S'\left(\frac{I_{t+1}}{I_t}\right) \left(\frac{I_{t+1}}{I_t}\right)^2$$

$$Q_t = \left\{ 1 + S\left(\frac{I_t}{I_{t-1}}\right) \right\} + S'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_t}{I_{t-1}} - \Omega_{t,t+1} \frac{P_{t+1}}{P_t} S'\left(\frac{I_{t+1}}{I_t}\right) \left(\frac{I_{t+1}}{I_t}\right)^2$$

Note that $\Omega_{t,t+1} = \beta E_t \left[ U'(C_{t+1}) / U'(C_t) \right] \left[ P_t / P_{t+1} \right]$. Substituting this, we get equation (9)

- To derive equation (24), the Lagrangian is given by

$$E_t \sum_{s=0}^{\infty} \Omega_{t,t+s} \left\{ \begin{bmatrix} (1+i_t^L)L_{t+s-1} + (1+i^R)M_{t+s-1}^R - (\zeta - \alpha_q)(1+i_{t+s}^G)D_{t+s-1} \\ -(1+i^p)\chi_{t+s}(\widetilde{W_{t+s-1}} - M_{t+s-1}^R) - (1-\chi_{t+s})\widetilde{W_{t+s-1}} \\ +(1-\alpha_q)D_{t+s} - L_{t+s} - M_{t+s}^R \\ +\lambda_{t+s}\left[M_{t+s}^R - \alpha_r D_{t+s}\right] \end{bmatrix} \right\}$$

The first order condition with respect to $M_t^R$ is given by[24]

$$(-1)\Omega_{t,t} + \Omega_{t,t}\lambda_t + E_t\Omega_{t,t+1}(1+i^R) + E_t\Omega_{t,t+1}(1+i^p)\int_{M_t^R}^{D_t} f(\widetilde{W}_t)d\widetilde{W}_t = 0. \qquad \text{(A.2)}$$

Setting $\Omega_{t,t} = 1$, the Euler equation for $M_t^R$ is given by equation (22)

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[24]Note that
$$\frac{d}{dM_t^R}\left[\int_{M_t^R}^{D_t}\left[\widetilde{W}_t - M_t^R\right]f(\widetilde{W}_t)dW_t - \int_0^{M_t^R}\widetilde{W}_t f(\widetilde{W}_t)dW_t\right]$$
$$= -\int_{M_t^R}^{D_t} f(\widetilde{W}_t)d\widetilde{W}_t$$

# B   Technical appendix

The short run system has 19 endogenous variables:

$$\Omega_{t,t+1} \quad i_t^L \quad K_t \quad H_t \quad Y_t \quad C_t \quad I_t \quad d_t \quad d_t^p \quad x_t \quad i_t^D \quad i_t^G \quad T_t \quad \pi_t \quad Q_t \quad W_t/P_t \quad G_t \quad P_t/P_t^w \quad A_t \ .$$

There are four interest rate parameters, $i^R, i^a, i^G, i^D,$ and note that $i^a = i^G = i^D = \bar{i^s}$. The 18 equations are given by.

$$1. \ \Omega_{t,t+1} = \frac{\beta u'(c_{t+1})}{u'(c_t)}.(1 + \pi_{t+1})^{-1} \tag{B.3}$$

$$2. \ U'(C_t) = V_1'(d_t, d_t^a) + \beta E_t \left\{ U'(C_{t+1}) \left(1 + i_{t+1}^D\right) (1 + \pi_{t+1})^{-1} \right\} \tag{B.4}$$

$$3. U'(C_t) = V_2'(d_t, d_t^a) + \beta E_t \left\{ U'(C_{t+1}) \left(1 + i^a\right) (1 + \pi_{t+1})^{-1} \right\} \tag{B.5}$$

$$4. \ \Phi'(H_t) = (W_t/P_t) \, U'(C_t). \tag{B.6}$$

$$5. Q_t = 1 + S\left(\frac{I_t}{I_{t-1}}\right) + S'\left(\frac{I_t}{I_{t-1}}\right) \frac{I_t}{I_{t-1}} - \beta E_t \frac{U'(C_{t+1})}{U'(C_t)} \left[ S'\left(\frac{I_{t+1}}{I_t}\right) \left(\frac{I_{t+1}}{I_t}\right)^2 \right]. \tag{B.7}$$

$$6. \ (1 + i_t^L) = \frac{(P_t^W/P_t)MPK_t + (1 - \delta_k)(1 + \pi_t)Q_t}{Q_{t-1}} \tag{B.8}$$

$$7. \ \frac{W_t}{P_t} = (1 - \alpha)\frac{P_t^W Y_t}{P_t H_t} \tag{B.9}$$

$$8. \frac{P_t}{P_t^W} = \frac{\varepsilon^Y}{\varepsilon^Y - 1} \left[ \begin{array}{c} 1 + \frac{\phi_p}{\varepsilon^Y-1}\left(\frac{1+\pi_t}{1+\pi}\right)\left\{\frac{(1+\pi_t)}{(1+\pi)} - 1\right\} \\ -\Omega_{t,t+1}\frac{\phi_p}{\varepsilon^Y-1}\left\{\frac{y_{t+1}}{y_t}\frac{(1+\pi_{t+1})^2}{(1+\pi)}\left[\frac{(1+\pi_{t+1})}{(1+\pi)} - 1\right]\right\} \end{array} \right]^{-1} \tag{B.10}$$

$$9. \ Y_t = AK_{t-1}^\alpha H_t^{1-\alpha} \tag{B.11}$$

$$10. \ C_t + I_t + G_t + \frac{\phi_p}{2}\underbrace{\left[\left\{\frac{1+\pi_t}{(1+\pi)} - 1\right\}^2 y_t\right]}_{price\ adj\ cos\,t} + S\left(\frac{I_t}{I_{t-1}}\right)I_t = A_t K_{t-1}^\alpha H_t^{1-\alpha} \tag{B.12}$$

$$11. G_t + \left(1 + i_t^G\right)\frac{b_{t-1}}{1 + \pi_t} + (1+i_t^R)\frac{x_{t-1}}{1 + \pi_t} + (1+i^a)\frac{d_{t-1}^a}{1 + \pi_t} = T_t + b_t + x_t + d_t^a + (1+i_t^p)d_t E \max(\frac{\widetilde{W}_t}{D_t} - \frac{M_t^R}{D_t}, 0) \tag{B.13}$$

$$12. \; \frac{x_t}{d_t} = 1 - \frac{1 - (1 + i^R)E_t\Omega_{t,t+1}}{(1 + i^p)E_t\Omega_{t,t+1}} \tag{B.14}$$

$$13. \; L_t : \; 1 = E_t\Omega_{t,t+1}(1 + i^L_{t+1}) \tag{B.15}$$

$$14. \; G_t - \bar{G} = \rho_G \left( G_{t-1} - \bar{G} \right) + \xi^G_t \tag{B.16}$$

$$15. \; A_t - \bar{A} = \rho_A \left( A_{t-1} - \bar{A} \right) + \xi^A_t \tag{B.17}$$

$$16. \; K_t = (1 - \delta)K_{t-1} + I_t \tag{B.18}$$

$$17 \; \frac{(1 + \pi_t)(x_t/x_{t-1})}{1 + \pi} = \left( \frac{(1 + \pi_{t-1})(x_{t-1}/x_{t-2})}{1 + \pi} \right)^{\rho_\mu} \tag{B.19}$$

$$18. \; 1 + i^D_t = \zeta(1 + i^G_t) \tag{B.20}$$

$$19. \; \frac{(1 + i^G_t)}{(1 + \overline{i^G})} = \left( \frac{(1 + i^G_{t-1})}{(1 + \overline{i^G})} \right)^{\rho_{iG}} \left[ \left( \frac{1 + \pi_{t-1}}{1 + \pi} \right)^{\varphi_\pi} \left( \frac{Y_t}{Y} \right)^{\varphi_y} \right]^{(1 - \rho_{iG})} \tag{B.21}$$

## B.1 Steady State

In this section, we solve for the steady state values of the endogenous variables. Equation (14) in the steady state is given by,

$$1 + i^L = \left[ \left( \frac{P^W}{P} \right) \frac{MPK}{Q} + 1 - \delta_K \right] (1 + \pi) \tag{B.22}$$

as $\frac{P_{t+1}}{P_t} = 1 + \pi_{t+1}$. Further, from equation (9) and (18) in the steady state, $Q = 1$ and $P^W = \frac{\varepsilon^Y - 1}{\varepsilon^Y}P$, respectively. Also, in the steady state, $Y^W = K^\alpha H^{1-\alpha}$ which implies that $MPK = \frac{\alpha Y^W}{K}$. The above equation thus reduces to,

$$1 + i^L = \left[ \left( \frac{\varepsilon^Y - 1}{\varepsilon^Y} \right) \left( \frac{\alpha Y^W}{K} \right) + 1 - \delta_K \right] (1 + \pi) \tag{B.23}$$

Recalling that in the steady state, the stochastic discount factor is given by $\frac{\beta}{1+\pi}$, substituting this into the steady version of equation (26) yields, $1 + i^L = \frac{(1+\pi)}{\beta}$. From this expression, we can solve for the steady state capital-labor ratio, $K/H$, which is given by

$$\frac{K}{H} = \left\{ \alpha \left[ \frac{\varepsilon^Y - 1}{\varepsilon^Y} \right] \left[ \frac{1}{\frac{1}{\beta} - (1 - \delta_K)} \right] \right\}^{\frac{1}{1-\alpha}} \tag{B.24}$$

which we call $\Lambda$ hereafter.

The national income identity is given by,

$$C + \delta_K K + G = K^\alpha H^{1-\alpha} \tag{B.25}$$

Assume the following functional forms: $\Phi(H_t) = H_t$, $U(C_t) = \ln(C_t)$ and $V(d_t, d_t^a) = \eta \ln d_t + (1-\eta) \ln d_t^a$. Thus in steady state, $\Phi'(H) = 1$, $U'(C) = 1/C$, $V_1'(.,.) = \frac{\eta}{d}$ and $V_2'(.,.) = \frac{(1-\eta)}{d^a}$. Substituting for these values into equation (5), in the steady state we get

$$C = W/P. \tag{B.26}$$

Next note from (12) and (18), $W/P = (1-\alpha) \left( \frac{\varepsilon^Y - 1}{\varepsilon^Y} \right) \left( \frac{K}{H} \right)^\alpha$. Therefore,

$$C = (1-\alpha) \left( \frac{\varepsilon^Y - 1}{\varepsilon^Y} \right) (\Lambda)^\alpha. \tag{B.27}$$

Now, substituting $V_1'(.,.) = \frac{\eta}{d}$ in equation (3), we get,

$$\frac{1}{C} = V_1'(.,.) + \beta \frac{1}{C} \frac{(1 + i^D)}{(1 + \pi)} \tag{B.28}$$

The above can be re-written as,

$$1 + i^D = \frac{1 + \pi - \eta \frac{C}{d}(1 + \pi)}{\beta} \tag{B.29}$$

Similarly substituting $V_2'(.,.) = \frac{(1-\eta)}{d^a}$. in equation (4), we get,

$$1 + i^a = \frac{1 + \pi - (1-\eta) \frac{C}{d^a}(1 + \pi)}{\beta} \tag{B.30}$$

Since $\frac{K}{H} = \Lambda$, equation $(B.25)$ above thus reduces to,

$$C + G = \left[ \Lambda^{-(1-\alpha)} - \delta_K \right] K \tag{B.31}$$

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Recall, from equation (31) the government budget constraint is given by,

$$P_t G_t + \left(1 + i^G\right) B_{t-1} + (1+i^R) M^R_{t-1} + (1+i^a) D^a_{t-1} = P_t T_t + B_t + M^R_t + D^a_t + (1+i^p) E \max(\widetilde{W}_t - M^R_t, 0) \tag{B.32}$$

Dividing throughout by $P_t$ and noting that $\frac{P_t}{P_{t-1}} = 1 + \pi_t$, we get

$$G_t + \left(1 + i^G_t\right) \frac{b_{t-1}}{1 + \pi_t} + (1+i^R_t) \frac{x_{t-1}}{1 + \pi_t} + (1+i^a) \frac{d^a_{t-1}}{1 + \pi_t} = T_t + b_t + x_t + d^a_t + (1+i^p_t) d_t E \max\left(\frac{\widetilde{W}_t}{D_t} - \frac{M^R_t}{D_t}, 0\right) \tag{B.33}$$

where $x_t = M^R_t / P_t$, $d_t = \frac{D_t}{P_t}$, and $b_t = B_t / P_t$.

In the steady state, the above equation becomes

$$G + \left(1 + i^G_t\right) \frac{b}{1 + \pi} + (1+i^R_t) \frac{x}{1 + \pi} + (1+i^a) \frac{d^a}{1 + \pi} = T + b + x + d^a + (1+i^p_t) dE \max\left(\frac{\widetilde{W}_t}{D_t} - \frac{M^R_t}{D_t}, 0\right), \tag{B.34}$$

or,

$$G(1+\pi) + \left(i^G - \pi\right) b + (i^R - \pi)x + (i^a - \pi)d^a = T(1+\pi) + (1+i^p)dE \max\left(\frac{\widetilde{W}_t}{D_t} - \frac{M^R_t}{D_t}, 0\right)(1+\pi) \tag{B.35}$$

Dividing through the above expression by $d$, yields,

$$\frac{G(1+\pi)}{d} + \left(i^G - \pi\right) \alpha_q + (i^R - \pi)\frac{x}{d} + (i^a - \pi)\frac{d^a}{d} = \frac{T}{d} + (1+i^p) E \max\left(\frac{\widetilde{W}_t}{D_t} - \frac{M^R_t}{D_t}, 0\right)(1+\pi) \tag{B.36}$$

since $B/D = \alpha_q$ (which implies $b/d = \alpha_q$) Also, $\frac{x}{d} = \frac{M^R/P}{D/P}$.

We can substitute out for $\frac{d^a}{d}$ in the above equation (B.36) from equation $(B.29)$ and $(B.30)$ nothing that.

$$d \left[1 + \pi - \beta \left(1 + i^D\right)\right] = \eta C(1 + \pi) \tag{B.37}$$

$$d^a \left[1 + \pi - \beta \left(1 + i^a\right)\right] = (1 - \eta) C(1 + \pi) \tag{B.38}$$

or,

$$\frac{d}{d^a} = \frac{\eta}{1 - \eta} \left[\frac{1 + \pi - \beta \left(1 + i^a\right)}{1 + \pi - \beta \left(1 + i^D\right)}\right], \tag{B.39}$$

and

$$\frac{x}{d} = 1 - \frac{1 - (1 + i^R)\frac{\beta}{1+\pi}}{(1 + i^p)\frac{\beta}{1+\pi}}. \tag{B.40}$$

Finally, let us solve for $E\max(\frac{\widetilde{W}_t}{D_t} - \frac{M_t^R}{D_t}, 0)$ in the steady state. Assume $\frac{\widetilde{W}_t}{D_t} = Z_t$, and since $D_t$ is given, $Z_t$ follows an uniform distribution as $\widetilde{W}_t$ but between $[0,1]$. Thus,

$$E_t\max(Z_t - \frac{M_t^R}{D_t}, 0) = \int_{M_t^R/D_t}^1 \left(Z_t - \frac{M_t^R}{D_t}\right) h(Z_t)\, dZ_t$$

Since $h(Z_t) = 1$,

$$
\begin{aligned}
E_t\max(Z_t - \frac{M_t^R}{D_t}, 0) &= \int_{M_t^R/D_t}^1 \left(Z_t - \frac{M_t^R}{D_t}\right) dZ_t \\
&= \left.\frac{Z_t^2}{2}\right|_{M_t^R/D_t}^1 - \frac{M_t^R}{D_t} \left. Z_t\right|_{M_t^R/D_t}^1 \\
&= \left(\frac{1 - \left(\frac{M_t^R}{D_t}\right)^2}{2}\right) - \frac{M_t^R}{D_t}\left(1 - \frac{M_t^R}{D_t}\right) \\
&= \frac{1}{2} + \frac{1}{2}\left[\frac{M_t^R}{D_t}\right]^2 - \frac{M_t^R}{D_t} \\
&= 0.5\left(1 - \frac{M^R}{D}\right)^2
\end{aligned}
\tag{B.41}
$$

where $\frac{M^R}{D}$ is given by (24) evaluated at the steady state.

Continuing from the above government budget constraint $(B.36)$ we get

$$\frac{G(1+\pi)}{d} + \left(i^G - \pi\right)\alpha_q + (i^R - \pi)\frac{x}{d} + (i^a - \pi)\frac{d^a}{d} = \frac{T}{d} + (1+i^p)0.5\left(1 - \left\{1 - \frac{1 - (1+i^R)\frac{\beta}{1+\pi}}{(1+i^p)\frac{\beta}{1+\pi}}\right\}\right)^2$$

$$\tag{B.42}$$

From the above equation, we can solve for steady state lump-sum taxes, $T$. In Technical Appendix B, we summarize the steady state equations in recursive form.

We have 19 steady state equations, which can be written as a recursive system. These are

1. $(1 + i^L) = (1+\pi)/\beta$
2. $(1 + i^L) = \left[\left(\frac{\varepsilon^Y - 1}{\varepsilon^Y}\right)\alpha\left(\frac{K}{H}\right)^{\alpha-1} + 1 - \delta_K\right](1+\pi)$
3. $W/P = (1-\alpha)\left(\frac{\varepsilon^Y - 1}{\varepsilon^Y}\right)(\Lambda)^\alpha$ where $\Lambda = K/H$ solved from the preceding equation
4. $C = W/P$
5. $G = \bar{G}$
6. Using $C + G = \left[\Lambda^{-(1-\alpha)} - \delta_K\right]K$, and steady state $G$, Solve $K$
7. Using $K/H = \Lambda$, solve $H$

8. Using $d\left[1 + \pi - \beta\left(1 + i^D\right)\right] = \eta C(1 + \pi)$, and (5) above solve for $d$.

9. $d^a\left[1 + \pi - \beta\left(1 + i^a\right)\right] = (1 - \eta)\, C(1 + \pi)$, solve for $d^a$

10. $\frac{x}{d} = 1 - \frac{1 - (1 + i^R)\;\Omega}{(1 + i^p)\Omega}$

11. $\frac{P_t}{P_t^W} = \frac{\varepsilon^Y}{\varepsilon^Y - 1}$.

12. $I = \delta K$

13. $\pi = long\ run$ inflation target $(\bar\pi)$ (Note that this is pinned down by the money supply rule (29))

14. $T$ solved from the steady state government budget constraint

15. (Stochastic Discount Factor) $\Omega = \beta/(1 + \pi)$

16. $Y = AK^\alpha H^{1-\alpha}$

17. $A = \bar A$

18. $i^G = \overline{i^G}$

19. $1 + i^D = \zeta(1 + i^G)$

# C   Technical appendix

## C.1   Recursive steady state

Assume the same log utility for consumption.

It is straightforward to verify that the steady state real wage is:

$$\frac{W^{RT}}{P} = \frac{\beta}{1+\pi} \cdot \frac{\varepsilon^Y - 1}{\varepsilon^Y} MPH^{RT} \tag{C.43}$$

In other words, now

$$W^{RT}/P = \frac{\beta}{1+\pi}(1-\alpha)\left(\frac{\varepsilon^Y - 1}{\varepsilon^Y}\right)\left(K/(\phi.1 + (1-\phi)H^F)^\alpha\right)$$

$$\frac{G(1+\pi)}{d} + \left(i^G - \pi\right)\alpha_q + (i^R - \pi)\frac{x}{d} + (i^a - \pi)\frac{d^a}{d} = T + \frac{\pi}{1+\pi}m^T + (1+i^p)E\max(\frac{\widetilde{W}_t}{D_t} - \frac{M_t^R}{D_t}, 0) \tag{C.44}$$

where we have the new term $\frac{\pi}{1+\pi}m^T$ which is the inflation tax revenue from wholesaler's holding of real balance (where $m^T = M^T/P$).

The CIA (34) gives the steady state money demand function:

$$(W^{RT}/P)H^{RT} = \frac{m^T}{1+\pi}$$
$$\Rightarrow m^T = (W^{RT}/P)(1+\pi)H^{RT}$$

Given that $H^{RT} = 1$,
$$m^T = (W^{RT}/P)(1+\pi)$$

The national income identity (equation 6 in Appendix B) changes to:

$$C^F + C^{RT} + G = \left[\Lambda^{-(1-\alpha)} - \delta_K\right]K \tag{C.45}$$

$$\Rightarrow (1-\phi)W^F/P + \phi W^{RT}/P + G = \left[\Lambda^{-(1-\alpha)} - \delta_K\right]K$$

From here we can solve $K$ and then using $\Lambda = K/H$ solve $H$. To sum up: the steady state system thus changes to 22 equations (three extra variables $m^T$, $\frac{W^{RT}}{P}$, and $C^{RT}$).

    1. $(1+i^L) = (1+\pi)/\beta$

2. $(1 + i^L) = \left[\left(\frac{\varepsilon^Y - 1}{\varepsilon^Y}\right)\alpha\left(\frac{K}{\phi H^{RT} + (1-\phi)H^F}\right)^{\alpha-1} + 1 - \delta_K\right](1 + \pi)$

3. $W^{RT}/P = \frac{\beta}{1+\pi}(1-\alpha)\left(\frac{\varepsilon^Y - 1}{\varepsilon^Y}\right)(\Lambda)^\alpha$ where $\Lambda = K/(\phi + (1-\phi)H^F)$ solved from the preceding equation

4. $W^F/P = (1-\alpha)\left(\frac{\varepsilon^Y - 1}{\varepsilon^Y}\right)(\Lambda)^\alpha$

(Note there are two steady state real wages. Higher inflation depresses the RT real wage and creates more wage inequality)

5. $C^F = W^F/P$ from (5) given the assumption that utility function: $\ln C - H$

6. $C^{RT} = (W^{RT}/P)$ because RT consumers FOC dictates $H^{RT} = 1$

7. $m^T = (W^{RT}/P)(1 + \pi)$   (from CIA )

8. $G = \bar{G}$

9. Using $\phi C^{RT} + (1 - \phi)C^F + G = \left[\bar{A}\Lambda^{-(1-\alpha)} - \delta_K\right]K$,  and steady state $G$, Solve $K$ (Modified)

10. Using  $\Lambda = K/(\phi + (1-\phi)H^F)$ solve $H^F$

11. Using $d\left[1 + \pi - \beta\left(1 + i^D\right)\right] = \eta C^F(1 + \pi)$, and (5) above solve for $d$.

12. $d^p\left[1 + \pi - \beta\left(1 + i^a\right)\right] = (1 - \eta)C^F(1 + \pi)$, solve for $d^a$

13. $\frac{x}{d} = 1 - \frac{1 - (1+i^R)\,\Omega}{(1+i^p)\Omega}$

14. $\frac{P_t}{P_t^W} = \frac{\varepsilon^Y}{\varepsilon^Y - 1}$.

15. $I = \delta K$

16. $\pi = long\ run$ inflation target $(\bar{\pi})$ (Note that this is pinned down by the money supply rule (29))

17. $T$ solved from the steady state government budget constraint (C.44) (Modified)

18. (Stochastic Discount Factor)  $\Omega = \beta/(1 + \pi)$

19. $Y = AK^\alpha H^{1-\alpha}$

20. $A = \bar{A}$

21. $i^G = \bar{i^G}$

22. $1 + i^D = \zeta(1 + i^G)$

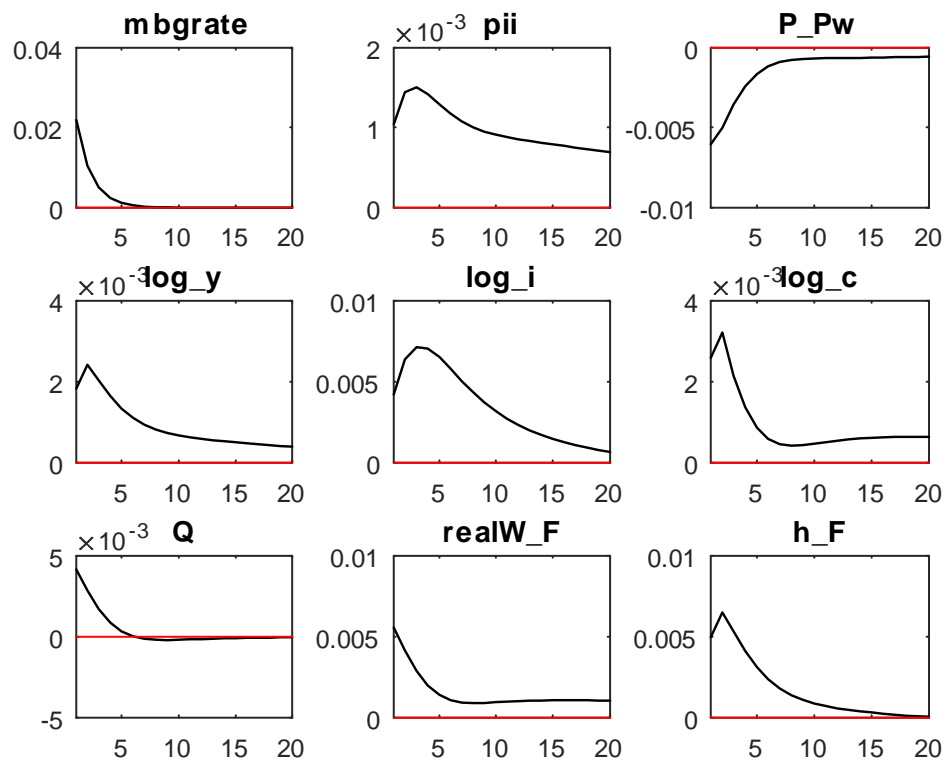# D    Technical appendix: IRF plots of Model 2
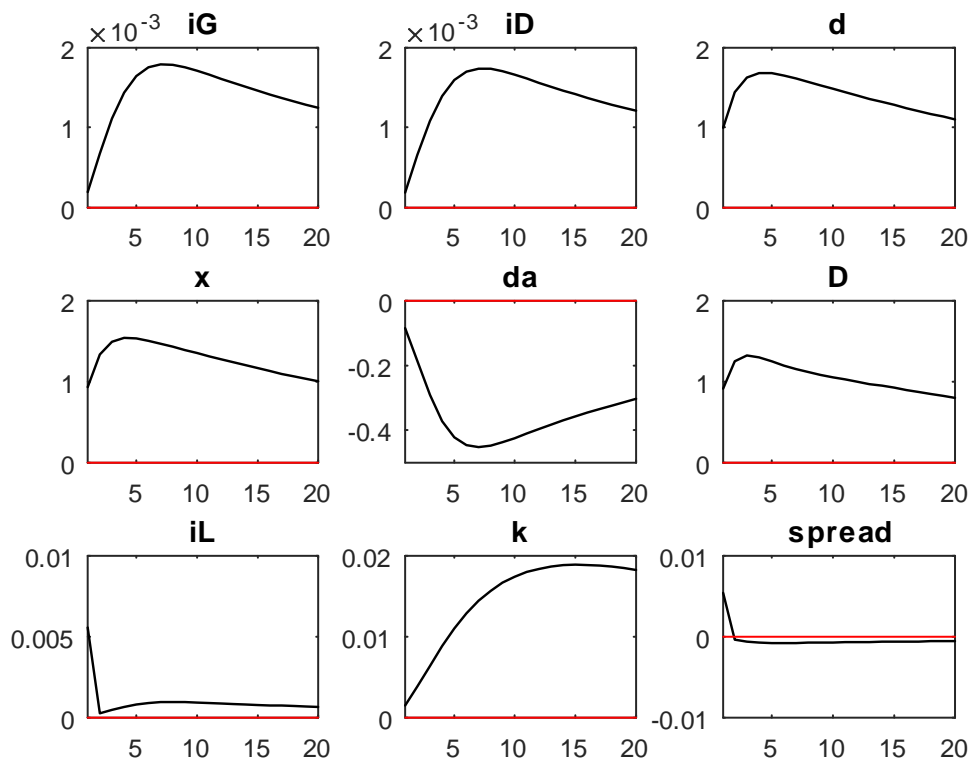


Figure 11: Effects of a Shock to the Money Base

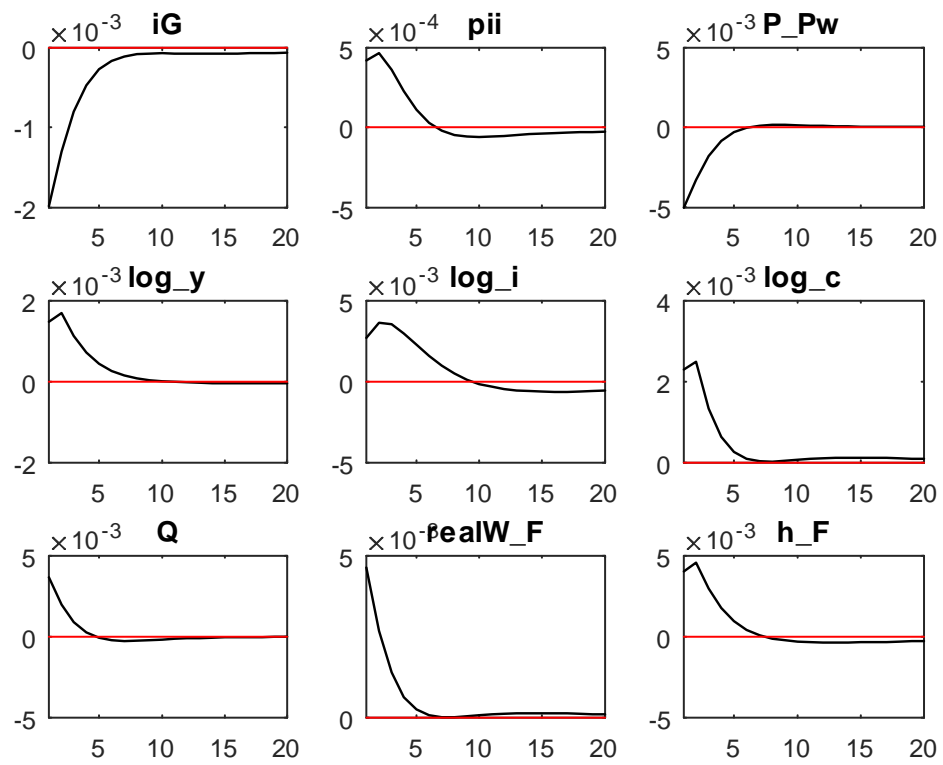Figure 12: Effects of a Shock to the Money Base

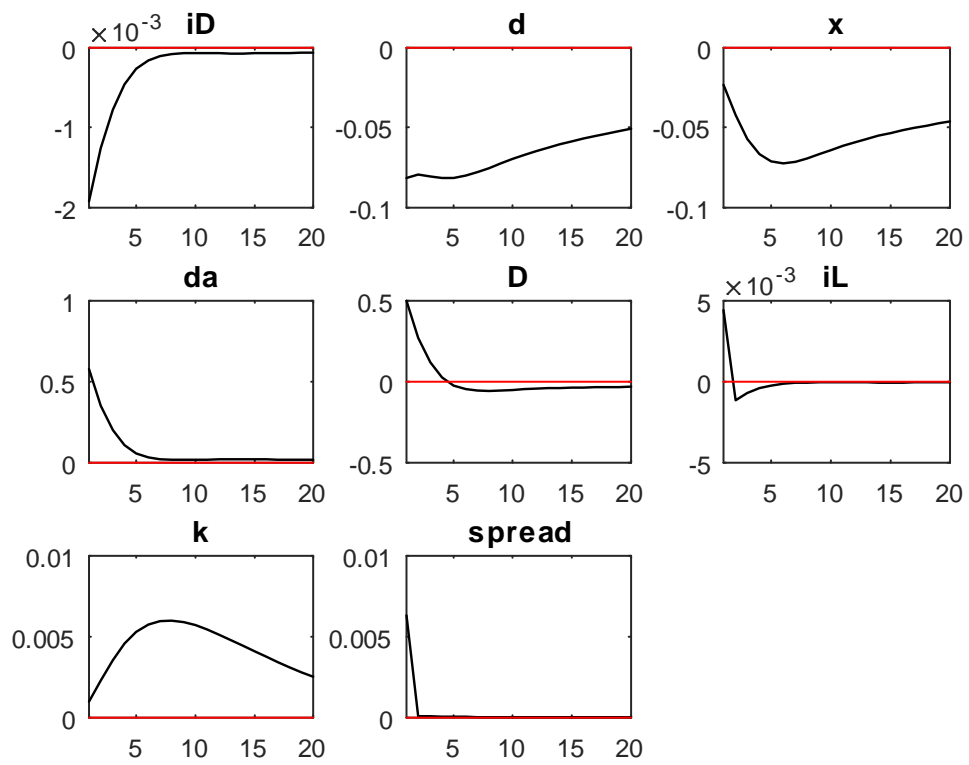Figure 13: Effects of a Shock to the Policy Interest Rate

Figure 14: Effects of a Shock to the Policy Interest Rate

# E    Technical appendix: Data

We use quarterly data of the macroeconomic and financial variables over the sample period of 1996: Q4 to 2016: Q4 both for the atheoretical VAR analysis as well as the model validation exercise (presented in Section 2 and Section 5, respectively). The list of variables include: real GDP, real consumption, real investment, real commercial bank deposits, real postal deposits, the 91 days treasury bill rate, CPI inflation, the bank lending rate, and the growth rate of the monetary base. GDP, consumption, investment, and government spending are measured in constant prices with base year 2011-2012. Except for the Consumer Price Index (CPI), all data are taken from the data base of the Reserve Bank of India (RBI). The Consumer Price Index for all commodities with base year 2010 is obtained from the St. Louis FRED database.

For the purpose of the VAR analysis and moment matching exercise, we make stationary the data series of the variables which are in levels and leave the rate variables (like interest rates and CPI year on year inflation) unchanged. Using the business cycle filtering method proposed by Baxter and King (1999), we de-trend the log-transformed data series of real GDP, real consumption, real investment, real commercial bank deposits, and real postal deposits. The growth rate of the monetary base is computed using two definitions of money base: one is reserve money (comparable for Model 1) and the other is sum of currency and reserve money (comparable for Model 2). The prime lending rate of the State Bank of India (SBI) is used as a proxy measure for the bank lending rate since the SBI group plays a dominant role in the Indian banking system and their lending rate is followed by other competing banks.