Economic Inquiry

A MONETARY BUSINESS CYCLE MODEL FOR INDIA

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A New Keynesian monetary business cycle model is constructed to study why monetary transmission in India is weak. Our models feature banking and financial sector frictions as well as an informal sector. The predominant channel of monetary transmission is a credit channel. 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. The presence of an informal sector hinders monetary transmission. Contrary to the consensus view, financial repression in the form of a statutory liquidity ratio and administered interest rates, does not weaken monetary transmission. (*JEL* E31, E32, E44, E52, E63)

I. INTRODUCTION

With the formal adoption of inflation targeting by the Reserve Bank of India (RBI), monetary policy in India has undergone a major overhaul. 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%.[1] Despite the adoption of flexible inflation targeting, monetary transmission in India is found to be partial, asymmetric and slow. Mishra, Montiel, and Sengupta (2016) find that not only is the 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.[2] Consistent with these findings, the "Report of the Expert Committee to Strengthen the Monetary Policy Framework" (2014), 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 the statutory liquidity ratio

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1. Some form of inflation targeting had become common in several emerging markets by 2005. The shift to market based monetary policy operations also has had the effect of increasing the role of interest rates in the economy. See Mohanty and Rishabh (2016).

2. Both Mishra, Montiel, and Sengupta (2016) and Mohanty and Rishabh (2016) provide recent surveys of monetary transmission in India and emerging market and developing economies (EMDEs), respectively. See also Das (2015).

ABBREVIATIONS

DSGE: Dynamic Stochastic General Equilibrium
EMDE: Emerging Market and Developing Economy
EME: Emerging Market Economy
FEVD: Forecast Error Variance Decomposition
GPD: Gross Domestic Product
IE: Impact Effect
IRF: Impulse Response Function
IST: Investment Specific Technology
LAF: Liquidity Adjustment Facility
MSE: Mean Squared Error
MSF: Marginal Standing Facility
NK: New Keynesian
RBI: Reserve Bank of India
RT: Rule of Thumb
SLR: Statutory Liquidity Ratio
SRVAR: Sign Restricted Structural Vector Autoregression
TFP: Total Factor Productivity
VAR: Vector Autoregression

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(SLR) requirement, small savings schemes (with administered interest rates), and the presence of a large informal sector among others.[3] In addition, shocks to liquidity, or base money, such as currency demand, bank reserves (required plus excess), government deposits with the RBI, and net foreign market operations, complicate the alignment of the policy Repo rate—the short term signaling rate—with the overnight weighted average call rate under the liquidity adjustment facility (LAF).[4]

This paper develops a closed economy New Keynesian (NK) monetary business cycle model of the Indian economy to understand why monetary transmission is weak.[5] Our core framework is a dynamic stochastic general equilibrium (DSGE) model with a banking sector. Following Mishkin (1995), we define monetary transmission as the real effect (particularly, the output effect) of monetary policy. The predominant transmission channel in our model is a credit channel which is activated by a standard New Keynesian sticky price mechanism. A change in monetary policy first impacts inflation and then output via an inflation-real marginal cost channel. The credit channel is then triggered through a novel adjustment of a bank's precautionary reserves. This explains the subsequent dynamics of output. By weak monetary transmission, we mean how frictions in the economy impair these adjustments thereby reducing the full impact of monetary policy on the real economy.[6] Throughout we compare the monetary transmission effects of two policy instruments—a base money shock and an interest rate policy shock—on the real economy. We show that the transmission mechanism differs depending on whether the policy instrument is the monetary base or the policy rate. In general, we find that although monetary transmission is weak when the policy rate is changed, it is relatively stronger when base money is shocked. Our results can be seen to be consistent with the stylized facts that we report in this paper. It is also broadly consistent with several papers on the weak monetary transmission of India including Mishra, Montiel, and Sengupta (2016).

Our baseline framework is a variant of a DSGE model with standard features on the production side which includes capital goods, retail and wholesale sectors. The retail sector has monopolistic power of price setting. Retail prices are sticky due to quadratic price adjustment costs as in Rotemberg (1982) and indexed to steady state inflation as in Gerali et al. (2010). This allows monetary policy to have real effects. There are three new features in our DSGE model. First, it has a competitive commercial banking sector which is subject to a SLR requirement and a reserve requirement. Second, the model has a postal sector which attracts deposits from households at the administered interest rate exogenously set by the government. The presence of SLR and an administered interest rate capture the essence of financial repression in the Indian economy. Third, commercial banks hold precautionary excess reserves because of a withdrawal risk as in Chang, Contessi, and Francis (2014). An endogenous bank reserve demand makes the monetary base an effective demand management tool. In an extended version of the model, we differentiate between a "banked" population, that intermediates through the formal banking system, and an "unbanked" population comprising rule of thumb (*RT*) consumers, that uses cash as a

3. The SLR 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). See https://rbi.org.in/scripts/BS_PressReleaseDisplay.aspx?prid=30446 for the details of the monetary policy committee report.

4. Since 2001, the Reserve Bank of India has conducted monetary policy through a corridor system called the LAF. 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 "re-purchases" them back. A reverse Repo operation takes place when the RBI borrows money from banks by lending securities. See Mishra, Montiel, and Sengupta (2016, 73–4). Banks can also borrow from the RBI for additional liquidity (over and above their Repo borrowings) at the MSF rate.

5. Using a SOE-NK-DSGE setup, Banerjee and Basu (2019) explore the exchange rate channel of monetary transmission in the presence of trade and financial openness for India. They find no evidence in favor of this channel. The Indian banking sector also has limited exposure to foreign economies. As per IMF Country Report No. 17/390, cross border lending and borrowing of Indian banks are small, at 10%, and 14% of GDP, respectively. Hence, we premise our analysis on a closed economy framework, so that we can focus more on domestic attributes that hinder monetary transmission such as the informal sector. See also Eggertsson, Juelsrud, and Wold (2017) for a closed economy model that focuses on monetary transmission.

6. In the Indian context, there are very few studies on monetary transmission using a DSGE framework. See Gabriel et al. (2012) for an early attempt. Banerjee and Basu (2019) develop a small open economy DSGE model for India but do not study monetary transmission. Our paper fills this gap. Other papers that study monetary transmission in the Indian context empirically also find that the credit channel is the strongest channel of monetary transmission in India. See, for instance, Aleem (2010) and Bhatt and Kishor (2013).

medium of transaction. Our rationale for adding an unbanked population is to proxy for a large informal sector in India which is characterized by segmented labor markets. Taken together, these features provide a more realistic description of banking intermediation in the transmission of monetary impulses both in the Indian and EMDE context.

A novel feature of our model is that we allow the short term government bond rate and the monetary base to be treated as two independent monetary policy tools. While the Central Bank follows a simple money supply rule to target long run inflation, the short term government bond rate—which we use as a proxy for the policy rate set by the Central Bank—follows a Taylor rule. In this respect, our model departs from the standard New Keynesian model of Gali (2008). Having two monetary instruments enables us to assess monetary transmission channels for alternative policy rules.

Our calibrated baseline model allows us to highlight three key results. First, we identify the transmission mechanism of a base money shock and policy interest rate shock to the rest of the economy. We show that an expansionary base money shock leads to higher inflation. The rise in inflation raises real marginal costs which leads to a rise in the value of the marginal product of labor and capital. Wholesale firms buy new capital goods financed by commercial bank lending. This stimulates investment, hours worked, and capital accumulation. This is the core transmission mechanism of a base money shock which combines the standard NK real marginal cost-inflation channel with the credit channel. On the other hand, when monetary policy is set using a Taylor rule, a fall in the policy rate (the government bond rate), also has similar expansionary effects on the economy, but the real effects are weaker compared to a money base shock. This happens because the monetary base has a direct and stronger effect on inflation compared to a policy rate shock. Thus the inflation-real marginal cost nexus works more strongly in the case of a base money shock than a policy rate shock. In the calibrated model we show that the impact effect (IE) of output with respect to a monetary base shock is significantly bigger and lasts longer than the output response with respect to a negative policy rate shock. This agrees well with the empirical vector autoregression (VAR) impulse responses reported in Section II.

Second, our baseline model shows that nearly half of the fluctuations (variance) in output are explained by TFP shocks and approximately 32% is explained by fiscal shocks. Monetary policy, in terms of interest rate shocks and base money shocks, explain a moderate fraction of output variation—approximately 21%. Within this, the monetary base accounts for 20%. A similar pattern of variance decomposition is observed in the extended model with an informal sector. The relative importance of monetary policy shocks (money base and policy rate) however declines to approximately 16%, with the loss picked up by the fiscal shock. In the augmented model with an informal sector, when we set the proportion of RT consumers to zero, the contribution of base money shock and policy rate shock to output increases by 32% and 29%, respectively. This result indicates that the existence of RT, or unbanked consumers, poses an obstacle to monetary transmission in India.

Third, our sensitivity experiments with respect to structural and policy parameters indicate that the statutory liquidity ratio and administered interest rates, financial repression parameters in our model, have negligible effects on monetary transmission. This observation goes against the consensus view on financial repression and monetary transmission in India (RBI Patel Committee Report 2014). A sensitivity analysis demonstrates that the transmission of the monetary base shock measured by the forecast error variance decomposition (FEVD) and money-output correlation is stronger in response to: (a) a wider spread between the borrowing and lending rates, (b) higher price adjustment cost, and (c) lower degree of retail inflation indexation. In addition, a higher policy rate inertia, less aggressive inflation targeting and less weightage to output stabilization in the policy rule raises the pass-through of the monetary base shock to output, inflation and the nominal loan rate while it also enhances monetary transmission of the policy rate.

The paper is organized as follows. In Section II, we report some salient stylized facts about the output, credit and inflation effects of monetary policy shocks. Section III lays out the baseline DSGE model. Section IV extends this baseline model to include an informal sector with RT consumers. In Section V, we report the quantitative analysis of the model. Section VI concludes.

II. STYLIZED FACTS

In this section, we present a set of stylized facts based on empirical impulse response plots of output, credit and inflation with respect to the

TABLE 1
Sign Restrictions

Shocks	Output	Credit	Inflation	Policy Instrument
Money base shock	?	?	> 0	>0
Interest rate shock	?	?	> 0	<0

shocks to monetary policy instruments, namely monetary base and the policy interest rate, to provide the basis for our theoretical model. We adopt a sign restricted structural vector autoregression (SRVAR) approach to identify monetary policy shocks and examine their potential effects on key variables to evaluate the strength of the monetary policy transmission. Our SRVAR approach involves minimal sign restrictions on the impulse responses of the underlying structural VAR and does not require more restrictive Cholesky type of exclusion restrictions on the impulse response coefficients. In the spirit of an agnostic identification procedure proposed by Uhlig (2005), we identify the shocks to monetary policy instruments and estimate the SRVAR model with one policy variable at a time.[7]

A. *Data and Methodology*

We estimate a four variable vector autoregression model comprising the monetary policy variable, real gross domestic product (GDP), consumer price inflation and a credit index over the sample period of 1996:Q4 to 2016:Q4. In Technical Appendix E (Supporting information), we have provided more details on the data sources and the transformations used for the relevant macroeconomic variables. The choice of sample period is driven by the availability of the longest possible balanced sample for our analysis. Besides, the choice of four variables in a SRVAR model is guided by the monetary policy transmission story of our DSGE model which is premised on the interaction between inflation and real credit. Except for the monetary policy variables, all other variables are seasonally adjusted. The series of output and credit are passed through a Baxter and King (1999) band pass filter in order to capture the real effects of a monetary policy shock over the business cycle frequency.[8]

In case of the monetary policy variables, the growth rate of money reserves and the 91-day treasury bill rate are chosen as policy instruments. We consider the 91-day treasury bill rate as the policy rate for two reasons. First, this is a fairly common approach taken in the literature (e.g., see Lahiri and Patel 2016; Sterk and Tenreyro 2018). Second, there is strong empirical evidence suggesting that the transmission from the Repo rate to the 91-day treasury bill rate is complete and almost instantaneous (Kapur, John, and Mitra 2019; Singh 2011). Moreover, we find that the correlation between the Repo rate and 91-day treasury bill rate is 0.78 and statistically significant at the 1% level of significance. Hence, the 91-day treasury bill rate can be considered as a good proxy for the policy rate set by the RBI.

We impose weaker restrictions on the sign of the impulse response vector of interest. In our context, this impulse response vector pertains to the monetary policy shock. Following Uhlig (2005), we remain agnostic about the output effect of monetary policy. We also do not impose any sign restriction on the effect of monetary policy shocks on credit. We only impose a minimal positive sign restriction on the impulse response of inflation to an expansionary monetary policy shock which basically means that an expansionary monetary policy is inflationary. Table 1 presents our sign restrictions for the relevant variables.

B. *Key Findings*

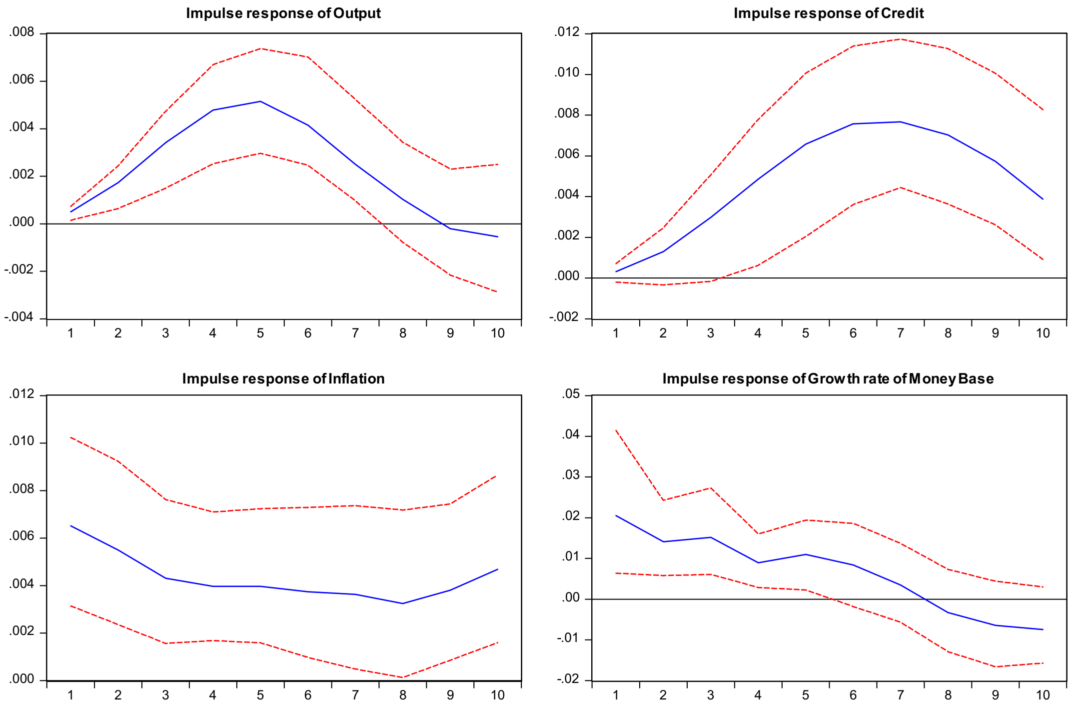
Figures 1 and 2 report the median impulse responses (solid line) for output, credit and inflation for money base and policy rate shocks, respectively. Following Uhlig (2005) we provide the 68% probability bands of impulse responses with respect to a 1% increase in the growth rate of the monetary base and 1% decrease in nominal interest rate from two sets of simulations. Dotted lines show the upper and lower limits of these confidence bands.

From the impulse response function (IRF) plots, we draw the following observations. First, inflation responds to both shocks positively and appears statistically significant following

7. See Kilian and Lutkepohl (2017) for a lucid explanation of the SRVAR approach that we follow here.

8. Following Cantelmo and Melina (2018), we take seasonally adjusted series of the macroeconomic variables namely real output, real credit and CPI inflation. In the spirit of Iacoviello (2005), the real effects of monetary policy shocks are examined with the detrended series of output and credit. We have used the Baxter and King filter for level variables. The key results of our SRVAR analysis are robust when alternative filtering procedures such as the Hodrick-Prescott or Christiano-Fitzgerald filtering procedures are used.

FIGURE 1
SRVAR Impulse Responses to a One Standard Deviation Increase in Growth Rate of Monetary Base



the impact. Second, the expansionary response of credit remains statistically significant from the third to tenth quarter for the money base shock. In case of the interest rate shock, the responsiveness of credit does not appear to be statistically significant. Finally, the response of output is statistically significant starting from the period of impact to the next eight quarters for the money base shock. In contrast, for the interest rate shock, it becomes statistically significant only after the sixth quarter. Furthermore, in terms of the accumulated effects of both shocks over the statistically significant periods of responses, we find that output rises by 2.3% and 1.2% for the money base and interest rate shock, respectively.[9]

To summarize, the empirically observed IRF reveal that monetary policy transmission is weak in India if we look at it from the perspective of transmission from the policy rate. However, if we define monetary policy as a change in the monetary base, there is an improvement in the degree of monetary transmission. Money base has a significant effect on credit and output as evidenced by the confidence bands around the respective IRF plots. The real effects of a money base shock on credit and output are unambiguously higher, more prolonged and persistent compared to an interest rate shock. This is the key stylized fact which motivates our DSGE modeling for the Indian economy to which we turn next.

9. The dominance of the output effect of money base shock over the policy rate shock is a robust finding which survives also in alternative Cholesky decompositions. The details are available from the authors upon request.

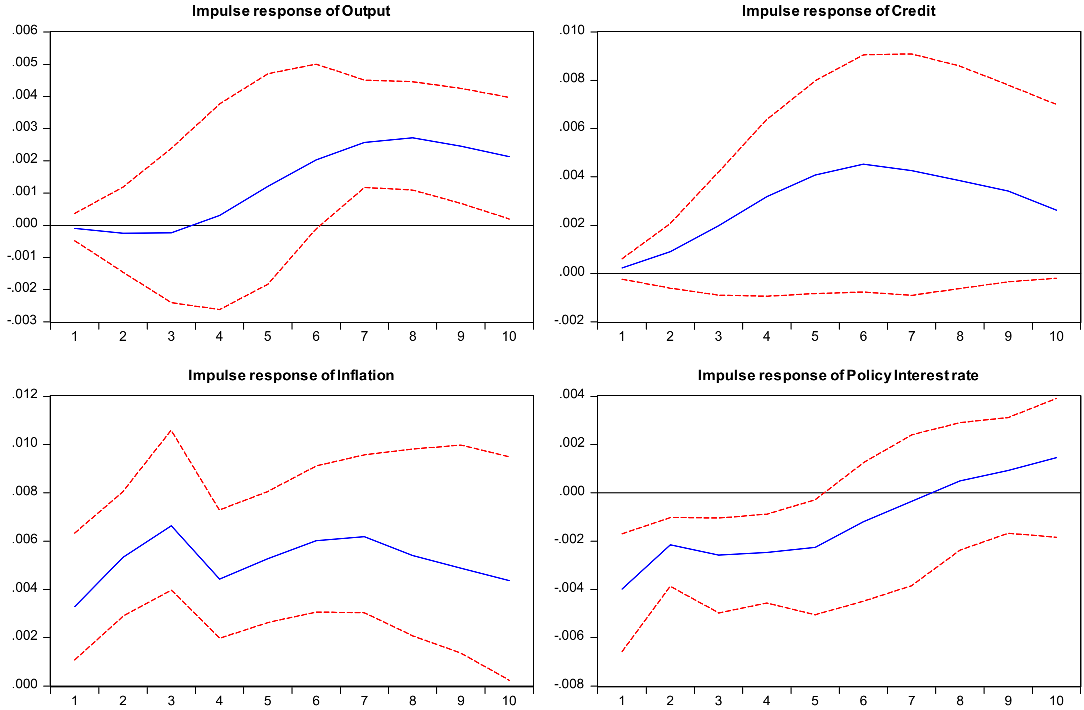
III. THE BASELINE MODEL

A. Environment

There are eight players in the economy: (a) households, (b) capital goods producing firms, (c) intermediate goods firms, (d) final goods firms, (e) commercial banks, (f) a postal deposit sector with the administered interest rate, (g) government and (h) the Central Bank. The representative household consumes final goods, earns wage income from supplying

FIGURE 2

SRVAR Impulse Responses to a One Standard Deviation Decrease in Policy Interest Rate



labor to wholesalers, and saves in the form of both commercial bank and other deposits with administered rates. Wholesale goods firms produce intermediate goods with labor and capital. Physical capital is produced by capital goods firms who buy old refurbished capital from the wholesalers and combine this with final goods to produce new capital and sell it to the wholesalers. Final goods producers costlessly convert wholesale goods to retail goods and supply these to households, capital goods producers, and the government.

In the financial sector, commercial banks finance capital spending of the wholesalers by collecting deposits from households. These banks are subject to a statutory requirement of holding government bonds and are exposed to an exogenous withdrawal risk which may necessitate emergency loans from the Central Bank subject to a penalty. The government owned depository institutions (e.g., post office) collects a part of household savings and offers an administered interest rate to households.

In the policy block, the Central Bank creates high powered money by injecting bank reserves. The Central Bank rebates all the nominal proceeds to the government to finance its exogenous flow of government spending. In addition, the government finances its spending by taxing households lump sum, using administered deposits from households, and borrowing from commercial banks by imposing a statutory requirement to hold government bonds. Figure 3 presents the interactions among the economic agents of the model in a flow chart.

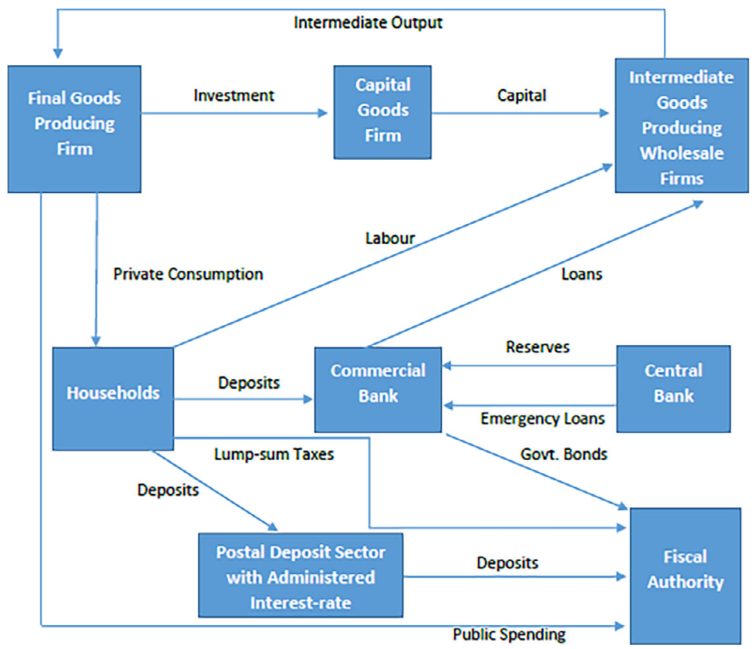
B. Households

The representative household maximizes expected utility:

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

which depends on hours worked, H_t, consumption of the final good, C_t, and saving in the form of risk-free bank and administered deposits, D_t,

FIGURE 3
Model Environment in a Flow Chart



and D_t^a respectively. Household choices must obey the following budget constraint (in nominal terms)

(2)

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

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 nominal administered deposits, D_t^a. Resources consist of wage earnings, W_tH_t, where W_t is the nominal wage rate; payments on deposits made in the previous period, $t-1$, where $i_t^D > 0$ is the interest rate on one-period deposits (or savings contracts) in the banking system; and $i^a > 0$ is the fixed government administered interest rate on administered account deposits made by households. Π_t^k is the rebate given back to households from capital goods firms. Π_t^r denotes nominal profits rebated back from the retail goods sector, and Π_t^b is transfers to households from banks.[10]

10. All derivations are relegated to Technical Appendicies A and B.

Denoting $D_t/P_t = d_t$ and $D_t^a/P_t = d_t^a$, we can re-write the household's optimality conditions as:

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

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

$$(5)\qquad H_t:\ \Phi'(H_t) = (W_t/P_t)U'(C_t).$$

Equation (3) is the Euler equation for real bank deposits. Equation (4) is the Euler equation for administered deposits which attract the interest rate, i^a. Equation (5) is the static efficiency condition for labor supply.[11] Hereafter, we specialize to the following functional forms:

11. In our model, deposits provide liquidity service which is valued by the household and hence its inclusion in the utility function. This utility specification in our model is functionally equivalent to the Calvo and Vegh (1995) liquidity-in-advance approach. As a result of this specification, the price level is determinate in our model. This can be verified by exploiting the property that in our model deposits are proportional to real balances as shown later. In the steady state, the real balances are uniquely pinned down by the inflation target which means the price level at date zero is determinate given the initial money stock.

$\Phi(H_t) = H_t$, $U(C_t) = \ln(C_t)$, and $V(d_t, d_t^a) = \eta \ln d_t + (1-\eta) \ln d_t^a$ where $\eta \in (0, 1)$.

C. Capital Good Producing Firms

Perfectly competitive capital goods producing firms solve a problem as in Peter and Gertler (2013). The capital goods production function follows the standard law of motion:

$$K_t = (1-\delta_k)K_{t-1} + Z_{x,t}I_t \tag{6}$$

where I_t is the date t investment; K_t is the capital stock at date t; δ_k is the physical rate of constant depreciation and $Z_{x,t}$ is an investment specific technology (IST) shock which follows an AR(1) process as given below:

$$\ln Z_{x,t} - \ln \overline{Z}_x = \rho_{Z_x} \left(\ln Z_{x,t-1} - \ln \overline{Z}_x \right) + \xi_t^{Z_x} \tag{7}$$

The transformation of the final good into new capital is subject to a quadratic adjustment cost specified as:

$$S\left(\frac{I_t}{I_{t-1}}\right) = (\kappa/2)\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{8}$$

where $\kappa > 0$.

The capital good pricing equation is given by:

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

where Q_t is the real price of the capital good.

D. Final Good Producing 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). Retailer's prices (P_t) are sticky and indexed to past and steady state inflation as in Gerali et al. (2010) based on the indexation parameter θ_p. If retailers want to change their price over and above what indexation allows, they have to bear a quadratic price adjustment cost parameterized by ϕ_p.[12]

12. As in any standard New Keynesian model, the nominal rigidity is quite crucial for generating real effects of monetary policy.

The first order condition after imposing a symmetric equilibrium is standard:

$$\begin{aligned} & 1 - \epsilon^Y + \epsilon^Y \left(\frac{P_t}{P_t^W}\right)^{-1} \\ & - \phi_p \left\{ 1 + \pi_t - \{1+\pi_{t-1}\}^{\theta_p} \{1+\overline{\pi}\}^{1-\theta_p} \right\} \\ & + \Omega_{t,,t+1} \phi_p \left\{ 1 + \pi_{t+1} - \{1+\pi_t\}^{\theta_p} \{1+\overline{\pi}\}^{1-\theta_p} \right\} \\ & \times (1+\pi_{t+1}) \frac{Y_{t+1}}{Y_t} = 0 \end{aligned} \tag{10}$$

where $(1+\pi_t)$ is the gross inflation rate and defined as $(\frac{P_t}{P_{t-1}})$, $\overline{\pi}$ is the steady state inflation rate and ϵ^Y is the final goods demand elasticity.

E. Wholesale Good Producing Firms

Risk neutral wholesalers produce intermediate goods for the final goods retailers using a production function, $Y_t^W = A_t K_{t-1}^{\alpha} H_t^{1-\alpha}$ with $0 < \alpha < 1$. The stochastic total factor productivity (TFP) term A_t follows an AR(1) process:

$$\ln A_t - \ln \overline{A} = \rho_a \left(\ln A_{t-1} - \ln \overline{A} \right) + \xi_t^A \tag{11}$$

where ξ_t^A is an i.i.d shock and $\overline{A}$ is the steady state level of TFP. These wholesalers borrow an amount $L_t > 0$ of loans from commercial banks in order to meet the value of new capital purchases, $Q_t K_t$, where K_t is the capital stock. Assuming that all capital spending is debt financed, the balance sheet condition of a representative wholesale firm is:

$$Q_t K_t = \left(\frac{L_t}{P_t}\right). \tag{12}$$

where real loans are given by, $l_t = \frac{L_t}{P_t} = Q_t K_t$. Denoting MPK_{t+1} as the marginal product of capital at $t+1$, the following arbitrage condition holds,

$$\left(1 + i_{t+1}^L\right)\left(\frac{P_t}{P_{t+1}}\right) = \left[\left[\frac{P_{t+1}^W}{P_{t+1}}\right] \frac{MPK_{t+1}}{Q_{t+1}} + 1 - \delta_k \right] \left[\frac{Q_{t+1}}{Q_t}\right], \tag{13}$$

where P_t^W is the price of the wholesale good. From Equation (10), a rise in π_t leads to a rise in (P_t^W/P_t) or real marginal costs (since $\epsilon^Y > 1$). Hence, real marginal costs (mc) and inflation co-move in the same direction which is the cornerstone of the NK inflation-real mc channel. We show later that monetary policy has real effects through an interaction between this inflation-real mc and the credit channel because in equilibrium real loans Q_tK_t rise in response to a higher inflation.

F. Banks

The representative bank maximizes cash flows by offering savings contracts (deposits) and borrowing contracts (loans). The banking sector is assumed to be competitive.[13] Banks are required to keep reserves with the Central Bank. In India, and many other emerging market economies (EME), banks are also constrained to buy government debt from deposit inflows as mandated by a SLR that pays them an interest rate i_t^G which is treated as a policy rate.[14] In every period, following Chang, Contessi, and Francis (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 reserves (cash in vault), banks fall back on the Central Bank for emergency loans at the penalty rate $i^p > 0$.[15] Banks pay back the emergency borrowing to the Central Bank at the end of the period. This withdrawal uncertainty necessitates a demand for excess reserves by banks.

Define i_t^L to be the interest rate on loans, L_{t-1}, i^R to be the fixed interest rate on reserves, M_t^R, mandated by the Central Bank, and $\widetilde{W_t}$ is the stochastic withdrawal. 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:

(14)

$$\begin{aligned}\Pi_t^b = {} & \left(1 + i_t^L\right) L_{t-1} + \left(1 + i^R\right) M_{t-1}^R \\ & + \underbrace{\alpha_q(1 + i_t^G)D_{t-1}}_{SLR \text{ on last period's deposits}} \\ & - \underbrace{(1 + i_t^D)D_{t-1}}_{\text{Cost of funds of last period's deposits}} - (1 + i^p - i_t^D) \\ & \chi_t \left(\widetilde{W_{t-1}} - M_{t-1}^R, 0\right) - (1 - \chi_t)\widetilde{W_{t-1}} \\ & + \underbrace{D_t}_{\text{Current deposits}} - \underbrace{\alpha_q D_t}_{SLR \text{ this period}} - L_t - M_t^R\end{aligned}$$

where χ_t is an indicator function which is unity if $\widetilde{W}_{t-1} - M_{t-1}^R > 0$ and zero otherwise. At date t, banks make decisions about loans (L_t) and reserves (M_t^R) after observing the deposit (D_t). On the other hand, depositors could partially withdraw their deposit randomly at the end of the period.[16] This basically provides a motivation to banks to hold excess reserves as in Chang, Contessi, and Francis (2014). The first two terms on the right hand side of Equation (14) 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 required to hold government debt as a constant fraction, α_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 rate, $i^p > 0$, for stochastic withdrawals over and above their bank reserves. The penalty amount is $(1 + i^p - i_t^D)(\widetilde{W_{t-1}} - M_{t-1}^R)$ which nets out the interest payment of banks to depositors who withdraw early. 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,

$$1 + i_t^D = \zeta(1 + i_t^G) \tag{15}$$

where $0 < \zeta < 1$. The parameter ζ proxies the imperfect pass through of the policy rate (i_t^G) to

13. Banks are assumed to be perfectly competitive for simplicity as in Eggertsson, Juelsrud, and Wold (2017). In some papers in the literature, such as in Gerali et al. (2010), market power in the banking industry is modeled using a Dixit-Stiglitz framework for retail credit and deposit markets. Our preliminary analysis with such an extended model shows that the key results of our paper are unaffected by this extension.

14. We choose i_t^G as a proxy for the policy rate for two reasons. First, changes in Repo rate transmit to both short rates (like the overnight call money rate) and longer duration (i.e., 91 day) money market rates almost instantaneously. Second, and more fundamentally, a change in i_t^G affects the costs of funds facing commercial banks. The main such cost is the deposit rate. The impact effect of a rise in the policy rate is a higher cost of funds facing these banks through the imperfect pass-through to the deposit rate after netting out SLR. This will be seen later from the cash flow equation (16).

15. Banks can borrow from the RBI for additional liquidity (over and above their Repo borrowings) at the Marginal Standing Facility (MSF) rate, which is currently 25 basis points higher than the Repo rate. This can be viewed as a "penalty" rate. See, also footnote 4 for the description of the MSF.

16. We do not model here the withdraw decision of households and assume that the withdrawal, $\tilde{W}_t$ is a random i.i.d. process and it cannot exceed deposits. This basically rules out a sudden stop of the economy 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.

the deposit rate.[17] We do not model the markdown, ζ, but calibrate it. We can rewrite the cash flow in Equation (14) as[18]:

$$\Pi_t^b = \left(1+i_t^L\right)L_{t-1} + \left(1+i^R\right)M_{t-1}^R - (\zeta-\alpha_q)\left(1+i_t^G\right)D_{t-1} - (1+i^p-i_t^D)\chi_t(\widetilde{W_{t-1}} - M_{t-1}^R, 0) - (1-\chi_t)\widetilde{W_{t-1}} + (1-\alpha_q)D_t - L_t - M_t^R \tag{16}$$

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:

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

subject to the statutory reserve requirement:

$$M_t^R \geqq \alpha_r D_t \tag{17}$$

where $\Omega_{t,t+s} = \left[\frac{\beta^s U'(C_{t+s})}{U'(C_t)}\left(\frac{P_t}{P_{t+s}}\right)\right]$ is the inflation adjusted stochastic discount factor.

The Euler equation is given by:

$$E_t\Omega_{t,t+1}\left[\left[1+i^R\right]+\left[1+i^p-i_{t+1}^D\right]\int_{M_t^R}^{D_t} f[\widetilde{W}_t]d\widetilde{W}_t\right] + \lambda_{bt} = 1 \tag{18}$$

The first term in the square bracket in Equation (18) is the bank's interest income from reserves. The second term is the expected saving of penalty because of holding more reserves. λ_{bt} is the Lagrange multiplier associated with the reserve constraint (17). Assuming a rectangular distribution for withdrawal over [0, D_t], real reserve demand relative to deposit demand can be written as:

$$\frac{x_t}{d_t} = 1 - \frac{1-\left(1+i^R\right)E_t\Omega_{t,t+1}}{\left(1+i^p-i_{t+1}^D\right)E_t\Omega_{t,t+1}} \tag{19}$$

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. In addition, a higher deposit rate subsidizes the penalty imposed on the bank due to excess withdrawal of deposits because banks do not have to pay interest on this early withdrawal of deposits. Thus, banks hold fewer precautionary reserves relative to deposits.

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 which gives the following loan Euler equation[19]:

$$L_t:\ 1 = E_t\Omega_{t,t+1}\left(1+i_{t+1}^L\right) \tag{20}$$

G. 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 with an inflation target ($\overline{\pi}$) in mind:

$$\frac{M_t^B/M_{t-1}^B}{1+\overline{\pi}} = \left(\frac{M_{t-1}^B/M_{t-2}^B}{1+\overline{\pi}}\right)^{\rho_\mu} \exp\left(\xi_t^\mu\right) \tag{21}$$

where ρ_μ is the policy smoothing coefficient and ξ_t^μ 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

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

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

$$\frac{(1+\pi_t)(x_t/x_{t-1})}{1+\overline{\pi}} = \left(\frac{(1+\pi_{t-1})\left(x_{t-1}/x_{t-2}\right)}{1+\overline{\pi}}\right)^{\rho_\mu} \exp(\xi_t^\mu) \tag{22}$$

17. The imperfect pass-through from the policy rate to deposit rate is motivated by the Urjit Patel committee report of the RBI and other policy papers (e.g. Das 2015; RBI, 2014) which suggest that the deposit rate sluggishly responds to surprise policy rate changes.

18. Note that a higher policy rate i_t^G lowers the cash flow of the banks because the observed $\zeta > \alpha_q$. This adverse cash flow effect is at the heart of the policy rate transmission which will be seen later.

19. A steady state borrowing-lending spread exists 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 yield (alternatively a liquidity premium) gives rise to a positive borrowing-lending spread in the steady state. To see this, combine (3) and (20) to get the following steady state borrowing-lending spread: $i^L - i^D = \frac{(1+\overline{\pi})}{\beta}\frac{V_1'(d,d^a)}{U'(C)} > 0$

Since real reserves are proportional to deposits as shown in the bank's reserve demand function, (19), this money supply process also imposes a restriction on the dynamics of deposits, interest rate on loans, and consumption.

H. Interest Rate Policy

As discussed in Section II, the short term interest rate on government bonds (i_t^G) can be interpreted as the policy rate. We give it an inflation targeting Taylor rule as follows:

(23)
$$\frac{(1+i_t^G)}{(1+\overline{i^G})} = \left(\frac{(1+i_{t-1}^G)}{(1+\overline{i^G})}\right)^{\rho_{i^G}} \left[\left(\frac{1+\pi_{t-1}}{1+\overline{\pi}}\right)^{\varphi_\pi}\left(\frac{Y_t}{Y}\right)^{\varphi_y}\right]^{(1-\rho_{i^G})} \exp\left(\xi_t^{i^G}\right)$$

The parameters $\varphi_\pi > 0$, and $\varphi_y > 0$ 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. ρ_{i^G} is the interest rate smoothing term and $\xi_t^{i^G}$ is the policy rate shock.

Our model departs from standard New Keynesian model in an important way. It allows both the policy rate (i_t^G) and the money supply (M_t^B) to be two independent monetary policy tools. While the Central Bank follows a simple money supply rule, and the short term government bond rate (i.e., the policy rate) follows 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 (19) via the stochastic discount factor (since i^R and i^p are constant) and adjustment of the deposit rate via the mark down rule in Equation (15). On the other hand, shocks to the policy rate in Equation (23), 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.[20] We shall see later in the quantitative analysis section that the strength of monetary transmission of a money base shock is sensitive to the parameters of the Taylor rule.

I. Fiscal Policy

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

$$(24)\quad \begin{aligned} P_tG_t &+ \left(1+i_t^G\right)B_{t-1} + \left(1+i^R\right)M_{t-1}^R \\ &+ (1+i^a)D_{t-1}^a = P_tT_t + B_t + M_t^R \\ &+ D_t^a + (1+i^p)E_t\max\left(\widetilde{W}_t - M_t^R, 0\right) \end{aligned}$$

where G_t corresponds to real government purchases, and B_t denotes the stock of public debt. The left hand side of Equation (24) denotes total expenditure by the government (nominal government purchases + interest payments on public debt + interest rates on reserves + interest payments at administered rate on postal deposits).[21] The right hand side of Equation (24) denotes the total resources available to the government (nominal lump sum taxes + new debt + new reserves + administered deposits + interest payments from withdrawal penalties). 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 the government's prediction of penalty income. Given a mandated level of 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 up taxing the household less.[22]

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

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

where ξ_t^G denotes the shock to government spending, and follows an AR(1) process.

Since fiscal policy is not the focus of our paper, we have kept this building block in our model

20. In the standard New Keynesian model (Gali 2008), interest rate is the principal policy tool. The Central Bank exploits an ad-hoc transaction money demand function to accommodate any policy rate shock. In our model, the steady state real bank reserve demand is pinned down by the inflation target ($\overline{\pi}$). The Central Bank has to let bank reserves grow at $\overline{\pi}$ to sustain the steady state equilibrium. The Central Bank can perturb this steady state equilibrium in the short run either by a policy rate shock ($\xi_t^{i^G}$) or a monetary base shock (ξ_t^{μ}). In the case of the former, there is a short run equilibrating change in inflation which keeps the money market in equilibrium. In case of the latter, the policy rate (i_t^G) adjusts via the Taylor rule when inflation responds immediately to a monetary base shock. Thus, both the monetary base and the policy rate can be used as independent controls unlike the standard New Keynesian model.

21. We think of the government as a combined fiscal-monetary entity.

22. Alternatively, we can formulate the government budget constraint by making the penalty revenue state dependent which also means adjustment of lump taxes in the state when the government does not earn penalty revenue. Neither of these two specifications has any effect on the households' first order conditions.

very simple. The government pre-commits to an exogenous path of government spending. The government issues only enough debt to finance the SLR holdings of banks. In this respect, government bonds are endogenously determined by the time paths of deposits. In addition, the government has to finance interest on excess reserves and administered deposits, and the predicted surplus/shortage of penalty revenue predicted in advance. The only instrument for financing all these is a lump sum tax, T_t. Because of the lump-sum nature of the taxes, it has no distortionary effects on the economy.[23]

IV. EXTENDED MODEL: INFORMAL SECTOR WITH RT CONSUMERS

In our baseline model, there is no transaction demand for money. Bank deposits play the role of money in this setting. This could be viewed as an over-simplification while modeling the Indian economy and other EMDEs, 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 and allow for segmented labor markets. We change the risk neutral wholesale producers hiring workers from two groups of households: (a) who supply labor as a credit good and, (b) *RT* unbanked workers who supply labor as cash goods. The proportion of *RT* consumer in the household sector is assumed to be $\phi \in [0, 1]$. Thus, the labor markets are segmented with proportions of ϕ and $(1-\phi)$ types of *RT* and Ricardian consumers, respectively. To pay the first 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 III.E. The dynamic cash flow problem facing the risk neutral producers is as follows:

$$(25)\quad Max \sum_{t=0}^{\infty} \lambda_t^{/} \left[L_t + M_{t-1}^T + (1-\delta_k)P_tQ_tK_{t-1} + P_t^W Y_t^W - M_t^T - W_t^{RT}H_t^{RT} - W_t^F H_t^F - \left(1+i_t^L\right)L_{t-1} - Q_tP_tK_t\right]$$

where all symbols are the same as before, L_t is the new nominal loan and M_t^T is non-interest bearing cash (different from interest bearing bank reserve M_t^R), and Y_t^W is subject to the same production function as in the baseline model. $\lambda_t^{/}$ is an inflation adjusted discount factor which will be specified later. New notations here are H_t^{RT}, H_t^F which are the labor demanded from *RT* and forward looking households, respectively. The production function now is: $Y_t^W = A_tK_{t-1}^{\alpha}(\phi H_t^{RT} + (1-\phi)H_t^F)^{1-\alpha}$. 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.[24] 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:

$$(26)\qquad P_tQ_tK_t \leq L_t$$

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

$$(27)\qquad W_t^{RT}H_t^{RT} \leq M_{t-1}^T$$

In this extended model with *RT* consumers and a cash in advance constraint given by (27), we get two labor demand functions facing the risk neutral wholesaler. These are given as follows for *RT* and *F* workers, respectively,[25]

$$(28)\quad \frac{W_t^{RT}}{P_t} = \left\{\frac{\beta U'\{C_t\}}{U'\{C_{t-1}\}}\right\}\left(\frac{P_{t-1}}{P_t}\right)\left(\frac{P_t^W}{P_t}\right)MPH_t$$

$$(29)\qquad \left(P_t^W/P_t\right)MPH_t^F - \left(W_t^F/P_t\right) = 0$$

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 the marginal product of labor.

23. As in Smets and Wouters (2007), we assume that government spending is exogenous. Endogenizing government spending by bringing an automatic stabilizer could make the real effect of a policy rate stronger but is beyond the scope of this paper.

24. Thus, the usual labor mobility story does not apply here.

25. See Technical Appendix C for derivations of the extended model.

A. *Labor Supply of* RT *and Ricardian Households*

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

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

s.t.

$$P_t C_t^{RT} = W_t H_t^{RT}$$

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

$$U'\left(C_t^{RT}\right)\left(W_t/P_t\right) = \Phi'\left(H_t^{RT}\right) \quad (30)$$

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:

$$H_t^{RT} = 1 \quad (31)$$

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

B. *Labor Market Equilibrium*

Because of segmented labor markets arising due to a payment friction in the RT sector, two real wages will prevail in equilibrium. In Technical Appendix C, we show how this happens in a steady state equilibrium.

C. *Government Budget Constraint*

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

$$\begin{aligned} P_t G_t + \left(1 + i_t^G\right) B_{t-1} + \left(1 + i^R\right) M_{t-1}^R & \\ + (1 + i^a) D_{t-1}^a + M_{t-1}^T & \\ = P_t T_t + B_t + M_t^R + M_t^T + D_t^a & \\ + (1 + i^p) E_t \max\left(\widetilde{W}_t - M_t^R, 0\right) & \end{aligned} \quad (32)$$

D. *Monetary Policy*

Money supply is now augmented to include currency. 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:

$$\frac{M_t^s / M_{t-1}^s}{1 + \bar{\pi}} = \left(\frac{M_{t-1}^s / M_{t-2}^s}{1 + \bar{\pi}}\right)^{\rho_\mu} \exp(\xi_t^\mu). \quad (33)$$

V. QUANTITATIVE ANALYSIS

The objective of our quantitative analysis is to understand why monetary transmission is weak in India using the baseline and extended models. We refer to the baseline model as "Model 1" and its extended version with the presence of an unbanked population and segmented labor markets as "Model 2." As mentioned at the outset, we define monetary transmission as the real effect (particularly, the output effect) of monetary policy. We focus on the conventional 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 is measured using the FEVD results of key macroeconomic variables of the model. In our analysis, we specify the baseline parameterization of the model and calibrate the shock structure to match empirical moments. We then report the variance decomposition results and sensitivity experiments with structural and policy parameters, and explain the impulse response properties of the baseline and extended model.

A. *Calibration*

Following the extant DSGE literature on India and using Indian data for our macroeconomic variables, we calibrate the structural and policy parameters of our models. The share of capital in the production process is set as 0.3 (Banerjee and Basu 2019). 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 (2019). The mark down factor, ζ, 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, Shanaka, and Saxegaard (2010) and indexation of past inflation is set to 58% following Sahu (2013). For the extended model, the proportion of RT consumers in the 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 (2019), where the interest rate smoothing coefficient is 0.66, inflation stabilizing

TABLE 2
Baseline Parameter Values

Parameters	Description	Value	Source
α	Share of capital	0.30	Banerjee and Basu (2019)
β	Discount rate	0.98	Gabriel et al. (2012)
η	Preference for holding bank deposit	0.84	RBI database
δ_k	Depreciation rate of capital	0.025	Banerjee and Basu (2019)
κ	Investment adjustment cost	2	Banerjee and Basu (2019)
ζ	Mark-down factor for deposit rate	0.97	Set to match the savings account rate
ϵ^Y	Price elasticity of demand	7	Gabriel et al. (2012)
ϕ_p	Price adjustment cost	118	Anand, Shanaka, and Saxegaard (2010)
θ_p	Past inflation indexation	0.58	Sahu (2013)
ρ_{i^G}	Interest rate smoothing parameter	0.66	Gabriel et al. (2012)
φ_π	Inflation stabilizing coefficient	1.20	Gabriel et al. (2012)
φ_y	Output stabilizing coefficient	0.50	Banerjee and Basu (2019)
α_q	Statutory Liquidity Ratio	19.25%	RBI Database
π	Long-run inflation target	4%	RBI Patel Committee Report (2014)
i^G	Steady state policy rate	6.875%	RBI Database
i^a	Steady state administered rate	4%	Indian Postal Service Website
i^p	Steady state penalty rate	7.5%	RBI Database

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 RBI (2014). The steady state value of the policy rate is set to 6.875% in line with the time-average over the period of inflation targeting in India. As of March 2019, the statutory liquidity requirement of the commercial banks is 19.25%, and the value of α_q is set accordingly. The government administered interest rate is set to 4% as observed from the savings account rates in the Indian Postal Service. The steady state value of the penalty rate is chosen to be 7.5%, which is the time-average of the marginal standing facility (MSF) rate in the LAF corridor. The steady state value of productivity and policy shocks are normalized to one. Table 2 summarizes the baseline values of the structural and policy parameters.

For the baseline parameterization of the exogenous shock processes, we follow a method of moments approach. In Technical 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.[26] 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, (a) standard deviations of output, inflation and the lending rate, and (b) six cross-correlation targets, namely, correlations of output with consumption, investment, bank deposits, correlation of the lending rate with inflation, and correlations of the administered deposits with the policy interest rate and bank lending rate. For the volatilities, output and CPI inflation are considered to be the primary objectives for inflation targeting Central Banks. The 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 3 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, the 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, Shanaka, and Saxegaard (2010). For the IST shock, the values for the AR(1) coefficient and standard error (0.63 and 0.133, respectively) are in line with the estimates of Banerjee and Basu (2019). In case of the autonomous shock to money base, our calibrated numbers for the persistence coefficient and standard error (0.32 and 0.042, respectively)

26. There are four shock processes with two parameters to calibrate for each. The error term in the interest rate process is however i.i.d., meaning that only one parameter, i.e., the standard deviation of the shock needs to be calibrated for this equation. In sum, we have nine parameters related to the shock structure of the model.

TABLE 3
Baseline Parameterization of Shock Processes

Parameters	Description	Values
ρ_a	Persistence coefficient of TFP shock	0.82
ρ_{Z_x}	Persistence coefficient of IST shock	0.63
ρ_G	Persistence coefficient of Fiscal shock	0.59
ρ_μ	Persistence coefficient of Money base shock	0.32
σ_a	Standard error of TFP shock	0.016
σ_{Z_x}	Standard error of IST shock	0.133
σ_G	Standard error of Fiscal shock	0.026
σ_μ	Standard error of Money base shock	0.042
σ_{i^G}	Standard error of Interest rate shock	0.002

fits fairly well with the estimates of the AR(1) coefficient and standard error of the growth rate of real reserves. The standard error of the policy rate shock is set to 0.002 in line with the estimate of Anand, Shanaka, and Saxegaard (2010).

B. 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 this, we compare the non-targeted moments of the business cycle properties of Indian data and our baseline model. Our model is validated over the sample period of 1996:Q4 to 2016:Q4. Sources and treatments with the data for analysis are provided in the Technical Appendix E of the paper. Tables 4 and 5 report the data and model comparison for Models 1 and 2 with respect to targeted and non-targeted moments.[27]

The output and lending rate volatilities are quite accurately predicted by both models in terms of the respective standard deviations. Inflation volatility is somewhat under-predicted. For the non-targeted moments, the model generated first order persistence coefficients of output, inflation and real loans are in line with their data counterparts. The cross-correlations in both models predict the signs correctly. All model generated non-targeted second moments are in the 95% confidence bands of the data counterparts. A few important observations should be noted. First, the correlation between output and monetary base growth is positive in both the data and our model which is indicative of monetary transmission emanating from changes in the monetary base. Second, the correlation between the policy rate and the lending rate is strongly positive in the data (0.68) and predicted reasonably by the model (0.58). One may be tempted to conclude from this observation that the credit 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 (0.34) and model (0.25) which goes contrary to the conventional Taylor rule based wisdom that a lower policy rate would raise output.[28]

Regarding the interpretation of cross-correlation results, an important caveat is in order. This moment matching exercise essentially gives us a broad guidance of how the model performs in matching India's business cycle statistics. One cannot necessarily infer the degree of monetary transmission or the efficacy of the credit 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 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.

C. Variance Decomposition Results from Baseline Model

Table 6 reports the forecast error variance decomposition results of the key variables with

27. Note that the definition of the monetary base is different between Models 1 and 2. In Model 1, the monetary base just includes the bank reserve while in Model 2 it includes bank reserve and currency in circulation. Thus, 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 the monetary base. For this reason, correlations of $[Y, (x_t/x_{t-1})]$ and $[d, (x_t/x_{t-1})]$ are marginally different between Table 4 and Table 5.

28. We have also computed the same second moments using different filtering procedures such as the Hodrick-Prescott and Christiano-Fitzgerald symmetric filters. We find that the empirical second moments used for the purpose of model calibration are reasonably robust across different filtering procedures since they mostly lie within a 95% confidence interval of the BK-filter based empirical moments. The details of these computations are available from the authors upon request.

TABLE 4
Results of Moment Matching between the Data and Model 1

Targeted Moments			Nontargeted Moments			
Moment	**Data**	**Model**	**Moment**	**Data**	**Confidence Interval**	**Model**
$SD(Y)$	0.02	0.02	correl$[Y, (x_t/x_{t-1})]$	0.40	[0.20, 0.57]	0.28
$SD(\pi)$	0.03	0.01	correl$[Y, i^G]$	0.34	[0.13, 0.52]	0.25
$SD(i^L)$	0.02	0.02	correl$[i^G, i^L]$	0.68	[0.54, 0.78]	0.58
correl$[Y, C]$	0.37	0.36	correl$[l, \pi]$	0.37	[0.17, 0.54]	0.34
correl$[Y, I]$	0.79	0.51	correl$[d, (x_t/x_{t-1})]$	0.39	[0.19, 0.56]	0.25
correl$[i^L, \pi]$	0.59	0.77	correl$[d, I]$	0.49	[0.31, 0.64]	0.38
correl$[Y, d]$	0.70	0.59	AR(1) coefficient of Y	0.89	[0.83, 0.93]	0.81
correl$[d^a, i^G]$	−0.36	−0.95	AR(1) coefficient of π	0.82	[0.73, 0.88]	0.95
correl$[d^a, i^L]$	−0.43	−0.66	AR(1) coefficient of l	0.92	[0.88, 0.95]	0.92

TABLE 5
Results of Moment Matching between the Data and Model 2

Targeted Moments			Nontargeted Moments			
Moment	**Data**	**Model**	**Moment**	**Data**	**Confidence Interval**	**Model**
$SD(Y)$	0.02	0.02	correl$[Y, (x_t/x_{t-1})]$	0.35	[0.14, 0.53]	0.22
$SD(\pi)$	0.03	0.01	correl$[Y, i^G]$	0.34	[0.13, 0.52]	0.22
$SD(i^L)$	0.02	0.02	correl$[i^G, i^L]$	0.68	[0.54, 0.78]	0.57
correl$[Y, C]$	0.37	0.37	correl$[l, \pi]$	0.37	[0.17, 0.54]	0.37
correl$[Y, I]$	0.79	0.50	correl$[d, (x_t/x_{t-1})]$	0.34	[0.13, 0.52]	0.26
correl$[i^L, \pi]$	0.59	0.76	correl$[d, I]$	0.49	[0.31, 0.64]	0.40
correl$[Y, d]$	0.70	0.54	AR(1) coefficient of Y	0.89	[0.83, 0.93]	0.77
correl$[d^a, i^G]$	−0.36	−0.96	AR(1) coefficient of π	0.82	[0.73, 0.88]	0.94
correl$[d^a, i^L]$	−0.43	−0.65	AR(1) coefficient of l	0.92	[0.88, 0.95]	0.91

respect to five fundamental shocks for both models. For Model 1, it is found that monetary policy shocks (adding both autonomous money base shocks and shocks to the short term policy rate) explain approximately 21% of output fluctuations in which the monetary base accounts for 20%. The lion's share (45.11%) of output fluctuations is explained by the shock to TFP as argued in the literature (Banerjee and Basu 2019). In addition, government spending shocks make a significant contribution to cyclical variations (31.49%) in output. Inflation (50.80%), and the bank lending rate (49.20%) are also largely driven by the shocks to TFP.

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 in output fluctuations declines to around 16% while the fiscal policy shock (35.91%) 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. Since non-Ricardian households are present, the impact of a fiscal spending shock on output fluctuations is amplified.

D. Sensitivity Experiments for Monetary Transmission

In Table 7, 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.

A few observations are in order. In the banking sector, a change in the preference parameter for commercial bank deposit holding (η), changes in the financial repression parameter, α_q (the SLR requirement) and i^a (the administered interest rate) have a negligible impact on monetary transmission. On the nominal front, lower price adjustment costs (ϕ_p) and a higher degree of inflation indexation (θ_p) in the retail sector make monetary transmission weaker. Not surprisingly, a lower nominal friction and the lack of forward looking price setting behavior limits the real effects of a monetary policy shock.

TABLE 6
Variance Decomposition Results for Major Macroeconomic Variables

List of	ξ^a		ξ^{Z_x}		ξ^G		ξ^μ		ξ^{i^G}	
Variables	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Y	45.11	45.62	2.40	2.13	31.49	35.91	20.01	15.59	1.00	0.76
C	38.61	46.27	29.38	30.36	10.19	8.83	20.32	13.46	1.50	1.08
I	27.44	25.14	58.24	58.76	3.09	3.16	10.98	12.69	0.25	0.25
π	50.80	48.35	0.15	0.13	0.16	0.15	48.82	51.31	0.07	0.07
i^L	49.20	47.30	1.08	0.93	6.43	6.31	40.59	42.91	2.70	2.55
i^G	21.76	20.64	0.41	0.40	2.51	2.82	73.20	73.90	2.11	2.23
$(i^L - i^D)$	45.78	44.99	1.40	1.09	12.00	12.02	31.87	33.39	8.94	8.51
l	26.02	24.28	51.16	51.05	4.63	4.74	17.29	19.03	0.90	0.90
d	19.80	19.79	0.13	0.13	0.04	0.04	80.01	80.03	0.01	0.01
d^a	39.84	37.12	0.56	0.54	3.58	3.80	54.80	57.30	1.22	1.24
x	20.96	21.00	0.13	0.12	0.03	0.03	78.87	78.85	0.01	0.01

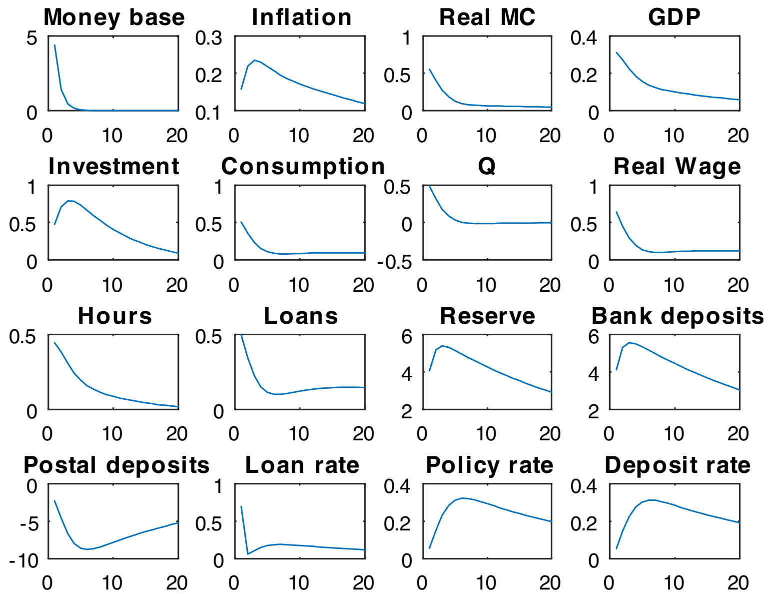
TABLE 7
Sensitivity Experiments for Monetary Transmission to Output

Sensitivity	**Share of ξ^μ in FEVD in Y**		**Share of ξ^{i^G} in FEVD in Y**		**correl$[Y, (x_t/x_{t-1})]$**		**Correl$[Y, i^G]$**	
Experiments	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Baseline	20.01	15.59	1.00	0.76	0.28	0.22	0.25	0.22
$\eta = 0.756$	20.01	15.64	1.00	0.76	0.28	0.23	0.25	0.22
$i^a = 0.036$	20.01	15.59	1.00	0.76	0.28	0.22	0.25	0.22
$\alpha_q = 0.1733$	20.01	15.59	1.00	0.76	0.28	0.22	0.25	0.22
$\phi_p = 106$	17.79	13.59	0.93	0.70	0.27	0.22	0.21	0.18
$\theta_p = 0.522$	21.72	16.97	1.04	0.80	0.28	0.22	0.29	0.26
$\zeta = 0.873$	61.05	58.32	0.19	0.14	0.51	0.43	0.69	0.69
$\rho_i^G = 0.594$	19.14	14.52	0.62	0.45	0.25	0.21	0.27	0.23
$\varphi_\pi = 1.08$	25.92	21.12	1.01	0.78	0.31	0.26	0.34	0.31
$\varphi_y = 0.45$	20.26	15.84	0.98	0.75	0.28	0.23	0.24	0.21

On the monetary policy front, the parameter (ζ) determining the pass-through of the policy rate to deposit rate in (15) has a major implication for monetary transmission driven by the money base. The transmission of the monetary base shock becomes conspicuously higher (61.05%) as seen from the FEVD and money-output correlation while the transmission of the interest rate shock is remarkably diminished. The intuition for this stems from the fact that a lower ζ 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 (19)), banks hold fewer reserves in proportion to deposit and extend more loans which strengthens the credit channel. Thus the propagation of a monetary base shock becomes stronger through the bank lending channel because banks hold less reserves. On the other hand, since a lower ζ widens the spread $(i_t^L - i_t^D)$, and i_t^L is largely determined by inflation, the pass-through from a policy rate shock to the bank lending rate ($i_t{}^L$) becomes weaker which explains why the policy rate accounts for less variation in output.

The interest rate smoothing coefficient (ρ_{i^G}) in Taylor rule has a noteworthy implication for monetary transmission. A lower ρ_{i^G} significantly reduces monetary transmission of the policy rate as evidenced by the variance decomposition of output. The policy rate accounts for 0.62% as opposed to 1% 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 φ_π) and less output stabilization (lower φ_y) raises the pass-through of a monetary base shock to output. The result of the sensitivity experiments remains fairly similar for Model 2.

FIGURE 4
Impulse Responses with Respect to a Positive Monetary Base Shock



E. Impulse Response Analysis of the Monetary Transmission Mechanism

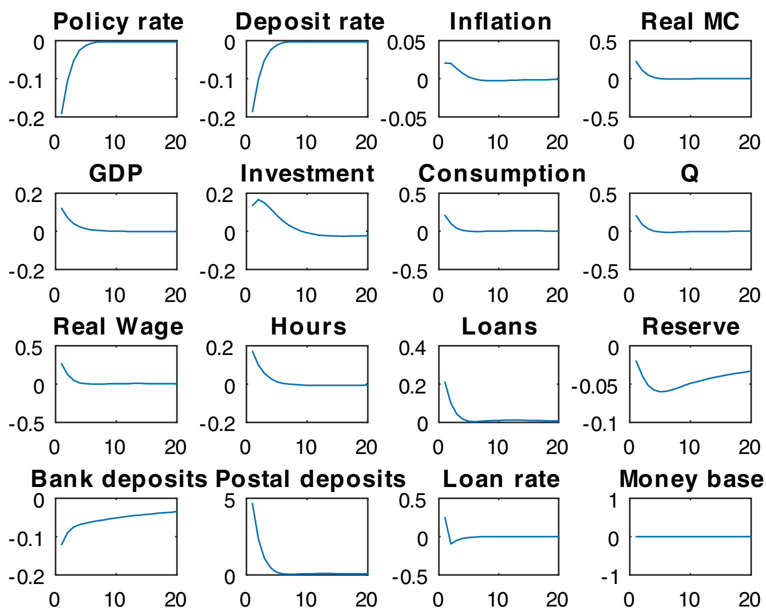
We next study the IRF of the relevant macroeconomic variables with respect to shocks to the monetary base and policy rate. Figures 4 and 5 plot the IRF of a monetary base shock (ξ_t^{μ}) and a policy rate shock ($\xi_t^{i^G}$). All the IRF are measured as percent deviation from the steady state.

Effect of a Shock to Monetary Base. Starting from the steady state with constant real reserves and inflation, a positive shock to ξ_t^{μ} immediately impacts inflation π_t via the monetary base rule in Equation (22). Higher inflation transmits to a higher real marginal cost (P^W/P) following the staggered price adjustment cost Equation (10). This is where the standard New Keynesian staggered price-setting mechanism starts having a real effect on the economy. A higher real marginal cost makes firms expand output and employment because the value of the marginal product of capital and labor schedules shift out which raises the equilibrium real wage. Such an expansion in the economy via a wealth effect raises consumption. The nominal interest rate on deposits rises because the Central Bank adjusts the policy rate upward in response to inflation which passes through to a higher deposit rate via the mark down rule in Equation (15).

On the banking front, several equilibrating adjustments take place. Bank loans rise to accommodate this expansion which also explains higher investment. Tobin's Q rises because of higher investment via Equation (9). Bank reserves also rise following the bank reserve Equation (19) because households increase their holding of bank deposits lured by a higher deposit rate. This also means a substitution of deposits from the administered sector to the banking sector which explains why postal deposits fall. The nominal interest rate on loans rises in equilibrium due to higher inflation via the bank's loan Euler Equation (20). Such a rise in the nominal loan rate resembles a Fisher effect. A positive shock to the monetary base thus has an unambiguously stimulative effect on the economy.

Effect of a Shock to Policy Interest Rate. A negative shock to the policy interest rate, i_t^G directly passes through to a lower deposit rate i_t^D via (15). Households reshuffle their deposits away from commercial bank deposits to administered rate accounts (d_t^a) for a relatively higher return. This explains why real bank deposits fall. Lower bank deposits spillover to lower real bank reserves

FIGURE 5
Impulse Responses with Respect to a Negative Policy Interest Rate Shock

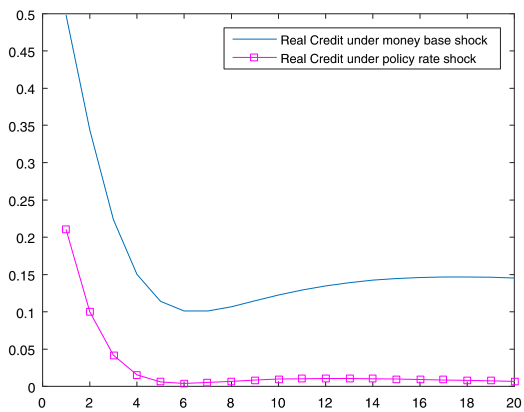


through the bank reserve demand function (19). Since the Central Bank has not changed the stock of reserves, M_t^B is fixed at date t. Thus, lower real bank reserves means a discrete rise in the price level, P_t, which means π_t rises. However, this rise in inflation is considerably lower than the case of a positive shock to monetary base. Following this, the conventional New Keynesian inflation-real mc relationship makes real output rise on impact. The expansionary effect of a lower policy rate is, however, noticeably weaker than a positive base money shock. Bank loans also make equilibrating adjustments to this weaker expansion. Bank deposits go down, which translates to lower bank reserves but the reserve/deposit ratio rises contributing to a weak credit channel. The nominal interest rate on loan rises in impact as in the case of a base money shock reflecting the Fisher effect. Note that by construction the monetary base does not change in this policy experiment (see Equation (21)) and thus does not respond to a shock to the policy rate. The remaining impulses are the same as in the case of a money base shock although the effects are quantitatively smaller.

Strength of the Credit Channel. To get a sense of loan disbursement under both policy instruments, Figure 6 plots the equilibrium real loan, l_t which is equal to Q_tK_t by definition. The real loan rises in response to a positive money shock and a lower policy rate shock. It is noticeable that the rise in loans is at least as twice as high in case of a money base shock compared to a policy rate shock. From the FEVD results of Table 6, it can be observed that the money base shock explains nearly 17% of the fluctuations in real credit while the interest rate shock explains only about 0.9% of the same. Such results show that the money base shock can drive the credit channel with a greater strength compared to an interest rate shock. This happens because inflation rises more in the case of a money base shock, leading to a stronger effect on output via the NK real mc-inflation channel. A lower policy rate raises the reserve-deposit (x_t/d_t) ratio, while it lowers the reserve-deposit ratio in the case of a money shock. This further reinforces the effects of the money shock on real loans.

Implications. Two important observations are noteworthy from these two policy simulations. First, a combination of a credit channel and the standard New Keynesian inflation-real mc channel is at work in characterizing the monetary transmission mechanism of two types of

FIGURE 6
Responsiveness of Real Credit under Monetary Policy Shocks



monetary policy shocks. Both channels complement each other and pin down the pass-through from inflation to output. However, the New Keynesian sticky price channel is quite fundamental. Absent price stickiness, the real effect of monetary policy disappears.[29] Second, the comparison of output impulse responses of the monetary base versus policy rate shocks reveals that the output response is much more pronounced and prolonged for a positive shock to the monetary base as opposed to the interest rate. The IE on 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 output effect lasts more than 20 quarters for a monetary base shock, while for the interest rate shock, it dissipates after 11 quarters. Such differences between the output effects of a monetary base and interest rate shock is partly due to the fact that the money base shock dominates its interest rate counterpart in explaining the variations in real credit.

The punch-line of our exercise is that a shock to the monetary base has a far stronger and persistent effect on output than a shock to the policy interest rate. This agrees well with the empirical SRVAR impulse responses reported in Section II.

F. Robustness Checks for the Size of Monetary Policy Shocks

The upshot of the variance decomposition and impulse response analysis is that the output effect of a shock to the monetary base dominates the same effect of a policy rate change. One may wonder whether the superior output effects of a monetary base shock compared to a policy shock is due to the calibrated size of the shocks of monetary base vis-a-vis the policy rate. To investigate this further, we do a robustness check of the standard error of each shock. We consider the mean squared error (MSE) as a measure of the goodness of fit of our model, and compute the same from the difference between theoretical and empirical impulse responses of output with respect to each type of monetary policy shock. We take the median output IRF reported in Figures 1 and 2 as the empirical benchmarks, and compare them with the relevant model generated output IRF in order to calculate the baseline MSE for the money base and interest rate shocks. For the baseline parameterization, the MSE of money base and interest rate shocks are 4.4E−06 and 3.2E−06, respectively. We find that the MSE of impulse responses rises if the standard deviation of the (a) money base shock falls and (b) policy rate shock rises from their baseline values. Based on this sensitivity analysis, we take the position that the calibrated sizes of the money base and interest rate shocks are optimal in terms of predicting the observed output IRF.[30]

G. Impulse Response Analysis of Extended Model

We now turn to the impulse response analysis of Model 2 which has an important feature, namely, the inclusion of *RT* consumers residing in an unbanked sector. The monetary transmission channel for the extended model is similar to the baseline model except that an inflationary monetary policy has a weaker real

29. It is straightforward to verify that shutting down the staggered pricing (i.e., ϕ_p equals to zero) completely eliminates the real marginal cost channel of inflation. Monetary policy then turns out to be neutral. Details of the flexible price IRF dynamics are available from the authors upon request.

30. We have also performed other robustness checks on the dominance of monetary base shocks. When we shut down both auto-correlations by setting $\rho_{iG} = \rho_{\mu} = 0$, the FEVD of output with respect to an interest rate shock reduces to zero making money shocks unambiguously dominate over the interest rate shock in determining output variation. Money base shock still contributes in the FEVD of output by 9.11%. When we shut off only the auto-correlation coefficient in the money base shock, the role of the interest rate shock improves marginally, but the dominance of the money base shock remains unaltered.

TABLE 8
Monetary Transmission in Model 2

1. A positive monetary base shock
   (a) $\xi_t^{\mu} \uparrow \Rightarrow \pi_t \uparrow$ via money supply rule $\Rightarrow i_t^D \uparrow$ via Taylor rule $\Rightarrow d_t \uparrow$ and $d_t^a \downarrow$
   (b) Higher $\pi_t \Rightarrow$ with price stickiness real mc $\frac{P_t^W}{P_t} \uparrow \Rightarrow VMPL$ shifts out $\Rightarrow Y \uparrow$
   (c) Higher $\pi_t \Rightarrow$ consumption of $RT \downarrow \Rightarrow$ adverse demand side effect $\Rightarrow Y \downarrow$
2. A negative policy rate shock
   (a) $i_t^G \downarrow \Rightarrow i_t^D \downarrow$ via mark down rule $\Rightarrow d_t \downarrow => x_t \downarrow \Rightarrow$ given M_t^B, $P_t \uparrow \Rightarrow \pi_t \uparrow$
   (b) Higher $\pi_t \Rightarrow$ with price stickiness real mc $\frac{P_t^W}{P_t} \uparrow \Rightarrow VMPL$ shifts out $\Rightarrow Y \uparrow$
   (c) Higher $\pi_t \Rightarrow$ consumption of $RT \downarrow \Rightarrow$ adverse demand side effect $\Rightarrow Y \downarrow$

effect than our baseline model.[31] This happens because a positive inflation tax lowers the consumption of the *RT* consumers. The sketch of monetary transmission mechanisms of the two monetary policy shocks is outlined in Table 8.

Notice that for both policy shocks, the transmission channels (a) and (b) shown in Table 8 are the same as in the baseline model. The only new feature is that a higher inflation has an adverse wealth effect on the *RT* consumers because their real wage is subject to the cash-in-advance constraint Equation (27). Such an adverse wealth effect is not suffered by the forward looking (*F*) consumers. Figure 7 demonstrates this further by comparing the consumption responses of *RT* and *F* consumers. 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. The 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 occurs due to a sharp rise in output through the inflation-real mc channel mentioned earlier. This positive output effect explains why *RT* consumers experience a higher consumption in the second period.

The negative consumption effect of *RT* consumers dampens monetary transmission from the demand side as seen by the weak IE of an easy monetary policy. This is demonstrated in Figure 8. Figure 8A compares the output responses of a positive money base shock between Models 1 and 2, and Figure 8B does the same for a negative policy interest rate shock. Regarding the IE, as it is evident from Figure 8A, an expansionary money base shock raises output in both models (0.31% and 0.23% in Models 1 and 2, respectively) but much less in Model 2. From the second period, output rises discretely in Model 2 and then declines. The capital stock is predetermined 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. From the second period, real marginal cost-inflation channel sets in motion. From date 3 onward output starts reverting to the mean. On the whole, computing the accumulated effects of a money base shock over the time horizon of 5 years, we find that the output effect is trimmed down from 2.46% in Model 1 to 2.17% in Model 2.

The response of output to a negative interest rate shock is similar to a money base shock but quantitatively less pronounced as shown in Figure 8B. The accumulated output effect of an interest rate shock over a period of 5 year turns out to be 0.27% in Model 1 and 0.26% in Model 2.

H. Banking Sector Frictions and RT *Consumers: A Comparative Analysis of the Impediments to Monetary Transmission*

Using the lens of the augmented model (Model 2), we find that there are two crucial frictions which could be a challenge for the monetary transmission mechanism. These are banking sector related frictions and the presence of unbanked *RT* consumers. Which one poses a greater obstacle to monetary transmission for an EME like India? We do a comparative analysis among the relevant structural parameters using the baseline parameterization of Model 2. We focus on four parameters, namely, the administered interest rate (i^a), SLR of the commercial bank (α_q), preference for holding commercial bank deposit (η) and proportion of the RT consumers (ϕ) in the labor market. The first three parameters represent banking sector frictions while the last one identifies *RT* consumers, which is a financial friction. We perturb

31. The details of the impulse responses of Model 2 are presented in Technical Appendix D.

FIGURE 7
Consumption Responses to a Positive Monetary Base Shock and Negative Policy Interest Rate Shock in Model 2

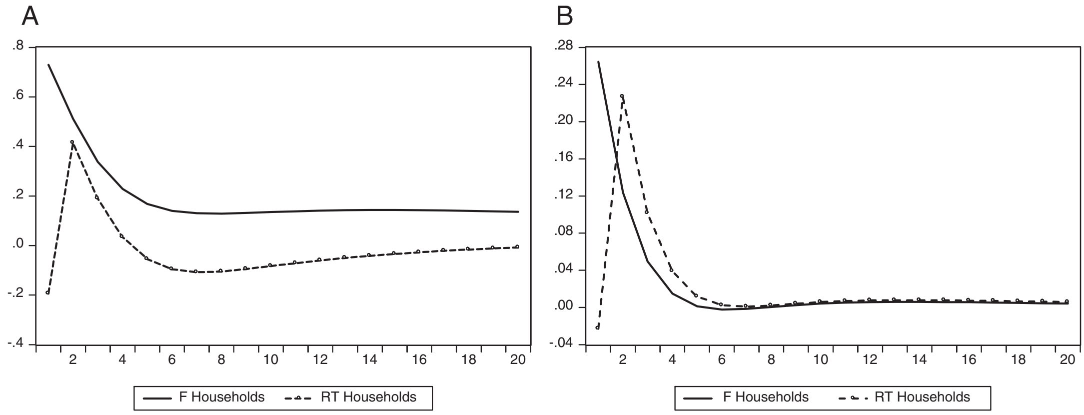
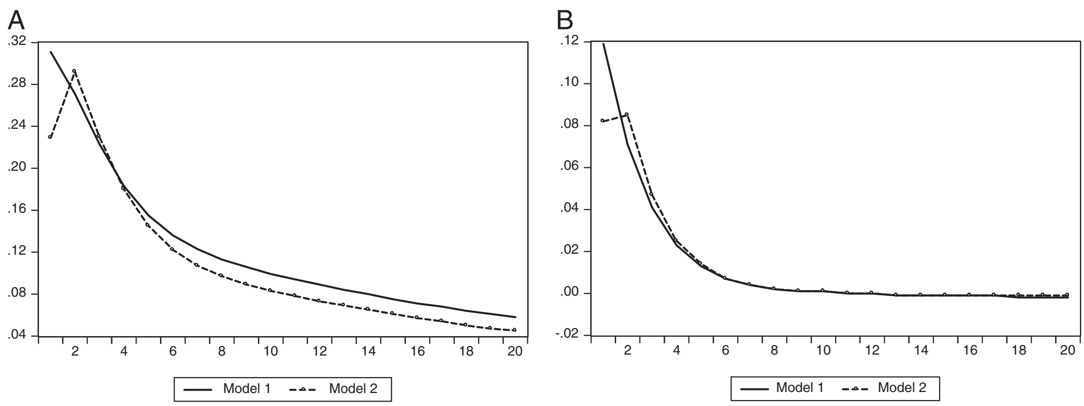


FIGURE 8
Output Responses to a Positive Money Base and Negative Policy Interest Rate Shock in Both Models



the baseline values of the above parameters by 50% and measure the changes in monetary policy transmission from three indicators: (a) changes in share of each type of monetary policy shock in the FEVD of real output (y); (b) IE of real output with respect to each type of monetary policy shocks; and (c) correlation between real output and each type of policy instrument. The results are presented in Tables 9 and 10. It is noteworthy that the banking sector related frictions emerge as negligible factors in explaining weak monetary transmission. In contrast, the increase in the presence of *RT* consumers in the labor market plays a nontrivial role in determining the degree of monetary policy transmission irrespective of the choice of the policy instrument.

To investigate further how much of the difference in strength of monetary transmission is accounted by the presence of *RT* consumers, we consider an extreme case when there is no *RT* consumers ($\phi = 0$), keeping the remaining baseline parameters unchanged. Under this condition, we shock both the policy instruments and measure the changes of transmission indicators. The key prediction of the model regarding the relative importance of money base shock over interest rate shock remains unaltered. However, it is observed that: (a) contributions of the monetary base shock and interest rate shock to aggregate

TABLE 9

Comparing Frictions in the Transmission of a Monetary Base Shock from Model 2

Relevant	Baseline				After Changing Baseline Parameters by 50%			
Parameters	Value	FEVD of Y (%)	IE of Y (%)	Correlation with Y	Value	FEVD of Y (%)	IE of Y (%)	Correlation with Y
i^a	0.040	15.59	0.23	0.22	0.060	15.59	0.23	0.22
α_q	0.1925	15.59	0.23	0.22	0.2888	15.59	0.23	0.22
η	0.840	15.59	0.23	0.22	0.420	16.06	0.23	0.23
ϕ	0.350	15.59	0.23	0.22	0.525	13.41	0.18	0.19

TABLE 10

Comparing Frictions in the Transmission of an Interest Rate Shock from Model 2

Relevant	Baseline				After Changing Baseline Parameters by 50%			
Parameters	Value	FEVD of Y (%)	IE of Y (%)	Correlation with Y	Value	FEVD of Y (%)	IE of Y (%)	Correlation with Y
i^a	0.040	0.76	0.08	0.22	0.060	0.76	0.08	0.22
α_q	0.1925	0.76	0.08	0.22	0.2888	0.76	0.08	0.22
η	0.840	0.76	0.08	0.22	0.420	0.75	0.08	0.23
ϕ	0.350	0.76	0.08	0.22	0.525	0.70	0.06	0.20

output improve almost equally (by 32% and 29%, respectively); (b) improvement in the IE of output with respect to an interest rate shock (46%) exceeds that of the money base shock (39%); and (c) improvement in the correlation between output and the money base, and output and interest rate by 27% and 18%, respectively. In the absence of *RT* consumers, therefore, the transmission mechanism from policy interest rate can be enhanced either by a similar magnitude or even a bigger magnitude compared to the monetary base. Hence, the prevalence of *RT* consumers in the economy play a crucial role in explaining the weak monetary transmission in India.

VI. CONCLUSION

The key research question of this paper is: *what explains weak monetary policy transmission in India?* We construct a closed economy NK-DSGE model with banking and financial frictions and an informal sector calibrated to the Indian economy to address this question. The predominant channel of monetary transmission in our model is a credit channel. Our analysis is general enough to lend itself to the study of monetary transmission in other EMDEs.

In a comparison of output impulse responses of monetary base versus policy rate shocks, the baseline model shows that the output response is much more prolonged for a positive shock to the monetary base as opposed to the interest rate. The IE 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 the monetary base has a far stronger and persistent effect on output than a shock to the policy interest rate. This agrees well with the empirical SRVAR impulse responses reported in Section II.

The baseline model also 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 and segmented labor markets, we show that the contribution of base money shocks and policy rate shocks to output can increase almost by similar magnitudes in the absence of the RT consumers. Transmission is hindered because an inflationary monetary policy reduces real wages of the RT consumers, which reduces their consumption. Our results suggest that the presence of RT consumers weakens monetary transmission in India.

Finally, our paper also addresses a long standing hypothesis in the policy discussion on the impediments to monetary transmission. A prominent hypothesis in India is that the existence of an administered postal 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 instruments, and to changes in the statutory liquidity ratio. Our results therefore suggest that while banking sector frictions do not impact monetary transmission significantly, the presence of an informal sector does.

Our model is able to explain weak monetary transmission which is an endemic feature of the Indian economy as well as other EMDEs. A possible extension of our model would be to incorporate segmentation and linkages between formal and informal finance, a duality that is characteristic of many EMDEs, and frictions in the goods markets (such as barriers to entry and competition) coupled with segmented labor markets to proxy better for the informal sector. We leave these extensions for future research.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1: Supporting Information.