A Monetary Business Cycle Model for India

Shesadri Banerjee\textsuperscript{1}  Parantap Basu\textsuperscript{2}  Chetan Ghate\textsuperscript{3}  Pawan Gopalakrishnan\textsuperscript{4}  Sargam Gupta\textsuperscript{5}

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\textsuperscript{1}Madras Institute of Development Studies
\textsuperscript{2}Durham University
\textsuperscript{3}Indian Statistical Institute - Delhi
\textsuperscript{4}Reserve Bank of India
\textsuperscript{5}Indian Statistical Institute - Delhi
Monetary policy in India has undergone a major overhaul

- Flexible inflation targeting with a clearly defined nominal anchor (de facto adoption in April 2014)
  - Requires the RBI to publicly hit announced inflation targets
  - Monetary policy transmission crucial to the success of this regime
- Clearly defined mandate
- Formation of a monetary policy committee (since September 2016)
- Expert Committee to Revise and the Strengthen the Monetary Policy Committee Framework (January 2014)
Survey based inflation expectations of households
Background

- Real policy rates

Real Policy Rate (Deflated by headline CPI Inflation) and CPI Combined Inflation (Headline and Core)

![Graph showing real policy rates and CPI combined inflation over time.](image-url)
Despite major changes in monetary policy, monetary transmission has been partial, asymmetric, and slow

- See Das (2015), Mishra, Montiel and Sengupta (2016), and Mohanty and Rishab (2016)

- To quote from Mishra, Montiel, and Sengupta (2016, p. 60-61)

"While the pass through from the policy rate to bank lending rates is in the right direction, pass through is incomplete...Unable to uncover evidence for any effect of monetary policy shocks on aggregate demand either in the IIP gap or the inflation rate"

- Expert Committee (January 2014) also lists other factors hindering monetary transmission

  - fiscal dominance; small savings schemes / administered interest rates; presence of large informal sector
Goals

- Key research question: *what explains weak monetary policy transmission mechanism in India?*
- Very few studies use DSGE style frameworks to address this question
  - See Levine et al. (2012), and Banerjee and Basu (2017)
- Build and calibrate/estimate a New Keynesian monetary business cycle model to understand weak monetary transmission in India
  - Embed fiscal dominance in the form of (i) SLR and (ii) administered interest rates
  - "Twin monetary policy specification" in terms of a money supply rule and Taylor Rule
- We focus on the aggregate demand channel/interest rate channel of monetary transmission
  - From policy rates to bank lending and deposit rates
  - From bank lending and deposit rates to real economy outcomes (GDP, inflation)
We identify the intuition behind base money and interest rate shocks.

Relative importance of technological versus non-technological shocks. Horse race between several contenders shows

- Roughly half of the variance in output are explained by TFP shocks
- One-third by fiscal shocks;
- Monetary policy in terms of interest rate shocks and base money shocks only explain a negligible amount.
Preview of main results

- Sensitivity results show that neither administered interest rates or SLR weaken monetary transmission as is widely believed.
- A larger borrowing-lending spread and less aggressive inflation and output targeting makes monetary policy transmission weaker from a policy rate shock.
- Higher long term interest rates on government bonds weakens monetary transmission and raises the importance of fiscal spending shocks.
Two extensions

- Extension 1: Add transaction demand for money (CIA constraint on wage payments). Add impatient households (a la Iacoviello (2005)) instead of entrepreneurs.
  - Impatient households consume, produce wholesale goods, hire workers, pay interest on loans, but do not do administered savings. Labor supply comes from patient households.
  - Horse race on shocks preserved.

- Extension 2: Keep the baseline entrepreneur, but allow for heterogenous consumers (Ricardian, and Rule of Thumb) who both supply labor. Rationale is to allow for an "unbanked" population.
  - Entrepreneurs now have two sources of labor
  - CIA constraint is now on wage payments of RT consumers
  - Role of fiscal policy shocks improves, but base money shocks becomes less important because of the presence of RT consumers.
  - However, horse race on shocks preserved again
Theoretical model

- **Households**
- **Capital producers**
  - Perfectly competitive firms invest to produce new capital and supply capital to wholesale producers
  - Face a cost to adjusting investments.
- **Wholesale producers**
  - Perfectly competitive firms produce intermediate goods for final good producing retailers
  - Hire labor from households and debt-finance (from banks) new capital purchases from capital good firms.
- **Final good retail firms**
  - Monopolistically competitive firms buy intermediate goods and package them into final goods.
  - Retailer prices are sticky and indexed to past and steady state inflation as in Gerali et al. (2010)
Theoretical model

- Banks
  - Perfectly competitive
  - Maximize cash flows. Take household deposit sequence as given. Offer loans.
  - Keep reserves at the central bank
  - Constrained to buy government debt (SLR)
  - Deposits subject to withdrawal uncertainty

- Combined government entity sets monetary and fiscal policy
  - Twin monetary policy
  - Fiscal Policy

- Extension of model
  - Add transaction demand for money
  - Allow for an unbanked population
Theoretical Model
Households

- Household and production side, model is similar to Gerali et al. (2010). Economy populated by households and entrepreneurs, each group has unit mass. Infinitely lived households consume \((C)\), work \((H)\), accumulate savings in i) risk free deposits \((D)\), and ii) postal/administered deposits\((D^a)\). Representative household maximizes

\[
\max_{C_t, H_t, D_t, D^a_t} E_0 \sum_{t=0}^{\infty} \beta^t \left[ U(C_t) - \Phi(H_t) + V\left(\frac{D_t}{P_t}, \frac{D^a_t}{P_t}\right) \right]
\]

subject to

\[
P_t (C_t + T_t) + D_t + D^a_t \leq W_t H_t + (1 + i^D_t) D_{t-1} + (1 + i^a_t) D^a_{t-1} + \Pi^k_t + \Pi^r_t + \Pi^b_t
\]

where \(P_t\) is the aggregate price index.

- \(i^D_t > 0\) fixed deposit rate on one period deposits; \(i^a > 0\) fixed administered rate.
Households

Using $D_t/P_t = d_t$ and $D^a_t/P_t = d^a_t$, and substituting out for $U'(C_t) = \lambda_t P_t$, household’s optimality conditions become:

$$D_t : U'(C_t) = V_1'(d_t, d^a_t) + \beta E_t \left\{ U'(C_{t+1})(1 + i^D_{t+1})(P_t/P_{t+1}) \right\},$$

(2)

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

(3)

and

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

(4)

- Equation (2) is the standard Euler equation for deposits.
- Equation (3) is the Euler equation for postal deposits which attract the administered interest rate, $i^a$.
- Equation (4) is the standard intra-temporal optimality condition for labor supply.
Capital Producers

- Competitive firms buy last period’s undepreciated capital, $(1 - \delta_k)K_{t-1}$, at real price $Q_t$ from wholesale-entrepreneurs, and $I_t$ units of the final good from retailers at price $P_t$.
- Convert $I_t$ units of output into $[1 - S(\cdot)]I_t$ units of new capital.
- Capital goods producing firms maximize

$$
\max_{I_t} E_t \sum_{j=0}^{\infty} \Omega_{t,t+j} P_{t+j} \left[ Q_{t+j} I_{t+j} - \left\{ 1 + S \left( \frac{I_{t+j}}{I_{t+j-1}} \right) \right\} I_{t+j} \right] \quad (5)
$$

subject to

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

$\Rightarrow$ capital good pricing equation

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

- In the steady state $Q = 1$
Wholesale Producers

- Risk neutral firms produce intermediate goods for final good producing retailers
- Hire labor from households, and purchase new capital from capital good producing firms, at $Q_t$
- Purchase of new capital debt-financed by $L_t > 0$ loans from banks
- Balance sheet of firms

$$Q_t K_t = \left( \frac{L_t}{P_t} \right).$$  \hspace{1cm} (6)

- Production function

$$Y_t^W = \xi_t^a K_{t-1}^\alpha H_t^{1-\alpha}$$  \hspace{1cm} (7)

where with $0 < \alpha < 1$. $\xi_t^a$ denotes stochastic total factor productivity,
Wholesale Producers

- Real wage rate and rate of return to capital given by

\[
\frac{W_t}{P_t} = \left(\frac{P^W_t}{P_t}\right) MPH_t = (1 - \alpha) \frac{\left(\frac{P^W_t}{P_t}\right) Y^W_t}{H_t}
\]  \hspace{1cm} (8)

\[
1 + r^k_{t+1} = \left(\frac{P^W_{t+1}}{P_{t+1}}\right) MPK_{t+1} + (1 - \delta_k) Q_{t+1}
\]  \hspace{1cm} (9)

Gross Return to 1 unit of K respectively.

- Demand for capital given by the following arbitrage condition

\[
1 + r^k_{t+1} = \left(1 + i^L_{t+1}\right) \frac{P_t}{P_{t+1}}
\]

\[
1 + i^L_{t+1} = \left[\left(\frac{P^W_{t+1}}{P_{t+1}}\right) \frac{MPK_{t+1}}{Q_{t+1}} + 1 - \delta_k\right] \left[\frac{P_{t+1} Q_{t+1}}{P_t Q_t}\right].
\]
Final good retail firms

- Buy intermediate goods at $P^W_t$ and package them into final goods.
- Retail prices are sticky and indexed to combination of past and steady state inflation. If retailers want to change their prices beyond what indexation allows, they face a quadratic adjustment cost.
- Choose $\{P_{t+j} (i)\}_{j=0}^{\infty}$ to the maximize present value of their expected profit.

$$\max_{P_t(i)} E_t \sum_{j=0}^{\infty} \Omega_{t,t+j} \left\{ \Pi^r_{t+j|t} \right\}$$

subject to demand constraint

$$y_{t+j|t} (i) = \left( \frac{P_{t+j} (i)}{P_{t+j}} \right)^{-\varepsilon^Y} y_{t+j}$$
Final good retail firms

- Profit function of the \( i^{th} \) retailer

\[
\Pi'_t(i) = P_t(i)y_t(i) - P^W_t(i)y^W_t(i) - \frac{\phi_p}{2} \left\{ \frac{P_{t+j}(i)}{P_{t+j-1}(i)} - (1 + \pi_{t-1})^{\theta_p} (1 + \bar{\pi})^{1-\theta_p} \right\}^2 P_t y_t
\]
Final good retail firms

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

$$y_t = \left[ \int_0^1 y_t(i) \frac{\varepsilon_Y}{\varepsilon_Y - 1} \, di \right]^{\frac{\varepsilon_Y}{\varepsilon_Y - 1}}; \quad \varepsilon_Y > 1.$$  

$\theta_p$ is an indexation parameter.

- FOC

$$1 - \varepsilon_Y + \varepsilon_Y \left( \frac{P_t}{P_W^t} \right)^{-1} - \phi_p \left\{ 1 + \pi_t - (1 + \pi_{t-1})^{\theta_p} (1 + \pi)^{1-\theta_p} \right\} = 0. \tag{11}$$

As $\pi_t \uparrow \Rightarrow \frac{P_W^t}{P_t} \uparrow$ (real MC $\uparrow$). When $\pi_{t+1} = \pi_t = \pi$, steady state mark-up is,

$$\frac{P}{P_W^t} = \frac{\varepsilon_Y}{\varepsilon_Y - 1}. \tag{12}$$
Banks

- Maximize cash flows by taking deposits and making loans. Take \( \{D_t\}_{t=0}^{\infty} \) as given.
- Keep reserves at the central bank (CB), and constrained to buy public debt (SLR) against deposit inflows.
- Following Chang et al. (2014), banks face a stochastic withdrawal of deposits: if withdrawals exceed bank reserves, banks borrow from the central bank at the penalty rate, \( i^P \).
- Banks pay back the emergency borrowing to the central bank (CB) at the end of the period. Withdrawal uncertainty \( \rightarrow \) banks desire excess reserves.
- Let \( i^L_t \) to be interest rate on loans, \( L_{t-1} \)
- \( i^R \) the interest rate on reserves, \( M^R_t \), mandated by the central bank,
- \( \tilde{W}_t \) is the stochastic withdrawal (Uniform dist.)
- Assume government bonds and deposits are perfect substitutes \( \rightarrow i^D_t = i^G_t = i^S_t \) (say)
Banks

Bank’s cash flow at $t$

\[
CF_t^b = (1 + i_t^L)L_{t-1} + (1 + i^R)M_{t-1}^R + \underline{\alpha_s(1 + i_t^G)D_{t-1}} \quad \text{SLR on last period’s deposits}
\]

\[- (1 + i_t^D)D_{t-1} \quad \text{Cost of Funds of Last period’s Deposits}
\]

\[- (1 + i^p)E \max(W_{t-1} - M_{t-1}^R, 0) + D_t \quad \text{Current Deposits}
\]

\[- \underline{\alpha_s D_t} - L_t - M_t^R \quad \text{SLR this period}
\]
Banks maximizes discounted cash flows in two stages. Banks first solve for optimal reserves, $M^R_t$. Next, choose the loan amount, $L_t$. Given \( \{i_t^D\}_{t=0}^\infty, \{i_t^L\}_{t=0}^\infty, \{D_t\}_{t=0}^\infty \), banks solve

$$\begin{align*}
\text{Max} & \quad E_t \sum_{s=0}^\infty \Omega_{t,t+s} CF_{t+s}^b \\
\text{subject to the statutory reserve requirement:} & \quad M^R_t \geq \alpha_r D_t
\end{align*}$$

subject to the statutory reserve requirement:

$$M^R_t \geq \alpha_r D_t \quad (13)$$

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

We assume (13) never binds (banks always hold excess reserves)
Banks

- FOC for reserves

$$E_t \Omega_{t,t+1} + \left( (1 + i^R) \Omega_{t,t+1} + \lambda_t = 1 \right)$$

Since reserve requirement not binding, KT condition $\Rightarrow \lambda_t = 0$.

Assume $\tilde{W}_t \sim U[0, D_t]$. Equation (14)$\Rightarrow$

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

(15)

where $x_t = M_t^R / P_t$ and $d_t = D_t / P_t$. 

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Banks

- FOC for loans

\[ L_t : 1 = E_t \Omega_{t,t+1}(1 + i_{t+1}^L) \]  

(16)

- In the steady state, equations (16) and (2) yield the spread

\[ i^L - i^D = \frac{(1 + \pi) V'_1(d, d^P)}{\beta} \frac{U'(c)}{U'(c)} > 0 \]

- Spread appears even though banks are not monopolistic because deposits provide a liquidity service (convenience utility) to households. Credit rationing \( \Rightarrow \) positive spread in the steady state.
CB follows a money supply growth rule: It lets the monetary base ($M_t^B$), or the supply of reserves, $M_t^R$ (since currency is zero), increase by the following rule:

$$\frac{M_t^B / M_{t-1}^B}{1 + \pi} = \left( \frac{M_{t-1}^B / M_{t-2}^B}{1 + \pi} \right)^{\rho_{\mu}} \exp(\zeta_{t}^{\mu}) \tag{17}$$

where $\rho_{\mu}$ is the policy smoothing coefficient and $\zeta_{t}^{\mu}$ is the money supply shock, which follows an AR (1) process.

$$M_t^B = M_t^R$$
The short term interest rate on government bonds ($i^G_t$) is the policy rate given by an inflation targeting Taylor rule as follows:

$$\frac{1 + i^G_t}{1 + i^G} = \left( \frac{1 + i^G_{t-1}}{1 + i^G} \right)^{\rho_{iG}} \left[ \left( \frac{1 + \pi_{t-1}}{1 + \pi} \right)^{\varphi_{\pi}} \left( \frac{Y_t}{Y} \right)^{\varphi_Y} \right]^{(1 - \rho_{iG})} \exp \left( \zeta^G_t \right)$$

(18)

The parameters $\varphi_p > 0$, 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. $\rho_{iG}$ is the interest rate smoothing term and $\zeta^G_t$ is the policy rate shock.
Fiscal Policy

- **GBC**

\[ P_t G_t + \left( 1 + i_t^G \right) B_{t-1} + (1 + i^R) M_{t-1}^R + (1 + i^a) D_{t-1}^a \]

\[ = P_t T_t + B_t + M_t^R + D_t^a + (1 + i^p) E \max(\tilde{W}_t - M_t^R, 0) \]

- Government spending (government purchases) evolves stochastically:

\[ G_t - \bar{G} = \rho_G \left( G_{t-1} - \bar{G} \right) + \zeta_t^G. \]

\( \zeta_t^G \) denotes the shock to government spending.

- Goods, loans, and money markets clear.
Steady State
Recursive Steady State

Short run system has 19 endogenous variables. These can be written as a recursive system

1. \((1 + i^L) = (1 + \pi)/\beta\)
2. \((1 + i^L) = \left(\left(\frac{\varepsilon_Y - 1}{\varepsilon_Y}\right) \alpha \left(\frac{K}{H}\right)^{\alpha-1} + 1 - \delta_K\right) (1 + \pi)\)
3. \(W/P = (1 - \alpha) \left(\frac{\varepsilon_Y - 1}{\varepsilon_Y}\right) (\Lambda)^{\alpha} \text{ where } \Lambda = K/H \text{ solved from the preceding equation}\)
4. \(C = W/P\)
5. \(G = \bar{G}\)
6. Using \(C + G = \left[\Lambda^{-(1-\alpha)} - \delta_K\right] K\), and steady state \(G\), Solve \(K\)
7. Using \(K/H = \Lambda\), solve \(H\)
8. Using \(d \left[1 + \pi - \beta \left(1 + i^D\right)\right] = \eta C (1 + \pi)\), and (5) above solve for \(d\).
9. \(d^a \left[1 + \pi - \beta \left(1 + i^a\right)\right] = (1 - \eta) C (1 + \pi)\), solve for \(d^a\)
Recursive Steady State

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

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

12. \( I = \delta K \)

13. \( \pi = \text{long run inflation target} (\bar{\pi}) \) (Note that this is pinned down by the money supply rule (17))

14. \( T \) solved from the steady state government budget constraint

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

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

17. \( A = \bar{A} \)

18. \( i^G = \bar{i^G} \)

19. \( 1 + i^D = \zeta(1 + i^G) \)
Quantitative Analysis
Model validation

- We first calibrate the model on Indian macroeconomic data
  - After baseline model validation, we explain the IRFs and variance decompositions
- Focus on standard instruments of monetary policy in an inflation targeting central bank
  - Money base
  - Short term interest rate
- Also look at the magnitude of cross correlations between policy instruments and policy targets as indicators of pass through of policy shocks.
Model validation: Table 1: Baseline Parametrization

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>Share of capital</td>
<td>0.3</td>
<td>Banerjee &amp; Basu, 2017</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Discount rate</td>
<td>0.98</td>
<td>Gabriel et al., 2011</td>
</tr>
<tr>
<td>$\eta$</td>
<td>Preference for holding bank deposit</td>
<td>0.84</td>
<td>RBI database</td>
</tr>
<tr>
<td>$\delta_k$</td>
<td>Depreciation rate of capital</td>
<td>0.025</td>
<td>Banerjee &amp; Basu, 2017</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Investment adjustment cost</td>
<td>2</td>
<td>Banerjee &amp; Basu, 2017</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>Mark-down factor for Deposit rate</td>
<td>0.97</td>
<td>Set to match savings A/C rate</td>
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<tr>
<td>$\varepsilon^Y$</td>
<td>Price elasticity of demand</td>
<td>7</td>
<td>Gabriel et al., 2011</td>
</tr>
<tr>
<td>$\phi_p$</td>
<td>Price adjustment cost</td>
<td>118</td>
<td>Anand et al., 2010</td>
</tr>
<tr>
<td>$\theta_p$</td>
<td>Past inflation indexation</td>
<td>0.58</td>
<td>Shahu J. P., 2013</td>
</tr>
<tr>
<td>$\rho_{iG}$</td>
<td>Interest rate smoothing parameter</td>
<td>0.81</td>
<td>Banerjee &amp; Basu, 2017</td>
</tr>
<tr>
<td>$\varphi_{\pi}$</td>
<td>Inflation Stabilizing Coefficient</td>
<td>1.64</td>
<td>Banerjee &amp; Basu, 2017</td>
</tr>
<tr>
<td>$\varphi_y$</td>
<td>Output Stabilizing Coefficient</td>
<td>0.50</td>
<td>Banerjee &amp; Basu, 2017</td>
</tr>
</tbody>
</table>
### Model validation: Table 1: Baseline Parametrization

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_s$</td>
<td>Statutory Liquidity Ratio</td>
<td>21.5%</td>
<td>RBI Website</td>
</tr>
<tr>
<td>$\pi$</td>
<td>Long-run inflation target</td>
<td>4%</td>
<td>Urjit Patel Committee Report, 2013</td>
</tr>
<tr>
<td>$i^G$</td>
<td>Steady state policy rate</td>
<td>7%</td>
<td>RBI Database</td>
</tr>
<tr>
<td>$i^a$</td>
<td>Steady state administered rate</td>
<td>4%</td>
<td>Indian Postal Service Website</td>
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<tr>
<td>$i^p$</td>
<td>Steady state penalty rate</td>
<td>6.5%</td>
<td>RBI Database</td>
</tr>
<tr>
<td>$\rho_a$</td>
<td>Persistence coefficient of TFP shock</td>
<td>0.82</td>
<td>Anand et al., 2010</td>
</tr>
<tr>
<td>$\rho_{Zx}$</td>
<td>Persistence coefficient of IST shock</td>
<td>0.59</td>
<td>Banerjee &amp; Basu, 2017</td>
</tr>
<tr>
<td>$\rho_G$</td>
<td>Persistence coefficient of Fiscal shock</td>
<td>0.64</td>
<td>Anand et al., 2010</td>
</tr>
<tr>
<td>$\rho_\mu$</td>
<td>Persistence coefficient of Money base shock</td>
<td>0.27</td>
<td>Estimated from Real reserve data (RBI)</td>
</tr>
<tr>
<td>$\sigma_a$</td>
<td>Standard error of TFP shock</td>
<td>0.06</td>
<td>Set by targeting output volatility</td>
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<tr>
<td>$\sigma_{Zx}$</td>
<td>Standard error of IST shock</td>
<td>0.699</td>
<td>Banerjee &amp; Basu, 2017</td>
</tr>
<tr>
<td>$\sigma_G$</td>
<td>Standard error of Fiscal shock</td>
<td>0.068</td>
<td>Anand et al., 2010</td>
</tr>
<tr>
<td>$\sigma_\mu$</td>
<td>Standard error of Money base shock</td>
<td>0.065</td>
<td>Estimated from Real reserve data (RBI)</td>
</tr>
<tr>
<td>$\sigma_{iG}$</td>
<td>Standard error of Interest rate shock</td>
<td>0.008</td>
<td>Anand et al., 2010</td>
</tr>
</tbody>
</table>
Model validation

Moment comparison is with data from 2011Q2 to 2017Q1.

### Table 2: Second Moments & Cross-correlations: Data and Model

<table>
<thead>
<tr>
<th>List of Variables</th>
<th>Std. Dev Data</th>
<th>Std. Dev Model</th>
<th>Correlation with y Data</th>
<th>Correlation with y Model</th>
<th>Correlation with $x_t/x_{t-1}$ Data</th>
<th>Correlation with $x_t/x_{t-1}$ Model</th>
<th>Correlation with $i^G$ Data</th>
<th>Correlation with $i^G$ Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y$</td>
<td>0.029</td>
<td>0.033</td>
<td>1</td>
<td>1</td>
<td>0.170</td>
<td>0.124</td>
<td>-0.059</td>
<td>-0.550</td>
</tr>
<tr>
<td>$c$</td>
<td>0.044</td>
<td>0.038</td>
<td>0.749***</td>
<td>0.360</td>
<td>0.268</td>
<td>0.191</td>
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<td>-0.756</td>
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<tr>
<td>$i$</td>
<td>0.034</td>
<td>0.126</td>
<td>0.729***</td>
<td>0.550</td>
<td>-0.210</td>
<td>0.035</td>
<td>-0.015</td>
<td>-0.544</td>
</tr>
<tr>
<td>$\pi$</td>
<td>2.067</td>
<td>0.019</td>
<td>-0.462**</td>
<td>-0.254</td>
<td>0.316</td>
<td>0.056</td>
<td>0.172</td>
<td>0.352</td>
</tr>
<tr>
<td>$i^L$</td>
<td>0.417</td>
<td>0.038</td>
<td>0.049</td>
<td>-0.072</td>
<td>-0.222</td>
<td>0.219</td>
<td>0.420*</td>
<td>-0.080</td>
</tr>
<tr>
<td>$i^G$</td>
<td>1.056</td>
<td>0.015</td>
<td>-0.059</td>
<td>-0.550</td>
<td>-0.029</td>
<td>-0.061</td>
<td>1</td>
<td>1</td>
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<tr>
<td>$x$</td>
<td>0.067</td>
<td>0.119</td>
<td>0.050</td>
<td>0.399</td>
<td>0.245</td>
<td>0.295</td>
<td>-0.289</td>
<td>-0.071</td>
</tr>
<tr>
<td>$d$</td>
<td>0.038</td>
<td>0.117</td>
<td>0.183</td>
<td>0.349</td>
<td>0.388*</td>
<td>0.292</td>
<td>-0.348*</td>
<td>0.028</td>
</tr>
<tr>
<td>$d^a$</td>
<td>0.072</td>
<td>0.608</td>
<td>0.139</td>
<td>0.501</td>
<td>0.156</td>
<td>0.063</td>
<td>-0.419**</td>
<td>-0.927</td>
</tr>
<tr>
<td>$TD$</td>
<td>0.040</td>
<td>0.147</td>
<td>0.187</td>
<td>0.588</td>
<td>0.377*</td>
<td>0.237</td>
<td>-0.365*</td>
<td>-0.644</td>
</tr>
</tbody>
</table>
Impulse response analysis of monetary transmission

Figure: Effects of Shock to Money Base
Impulse response analysis of monetary transmission

Figure: Effects of Shock to Money Base
Intuition

- Money Base $\uparrow \Rightarrow \pi \uparrow \Rightarrow$ Real MC ($\frac{P^W}{P}$) $\uparrow$
- Real MC $\uparrow \Rightarrow VMP_K \uparrow, VMP_L \uparrow \Rightarrow K, L \uparrow \Rightarrow$ Firms increase their supply of output
- Nominal markup falls ($\frac{P}{P^W}$) $\downarrow$
- Higher inflation promotes investment (Tobin effect)
- $i^L \uparrow$ because of the Fisher effect
- Higher $\frac{W}{P} \Rightarrow C \uparrow$
- Higher $\pi \Rightarrow i^G \uparrow$ (acts like a built in stabilizer for the MB shock)
- Since $i^G = i^D \Rightarrow d \uparrow \Rightarrow x \uparrow$, but $\frac{x}{d} \downarrow$
- $\frac{x}{d} \downarrow \Rightarrow$ Bank Lending $\uparrow \Rightarrow Inv \uparrow$
- When $i^D \uparrow \Rightarrow d \uparrow \Rightarrow d^a \downarrow$, but total deposits $d + d^a \uparrow$
- Spread $= (i^L - i^D) \uparrow$
Impulse response analysis of monetary transmission

Figure: Effects of Shock to Policy Interest Rate
Impulse response analysis of monetary transmission

Figure: Effects of Shock to Policy Interest Rate
Intuition

- When $i^G \downarrow$ output $\uparrow$ and inflation $\uparrow$ and real marginal costs $\uparrow \Rightarrow$ Investment $\uparrow$ (via the Tobin Effect)
- But $i^G = i^D \downarrow \Rightarrow d \downarrow$ and $d^a \uparrow$. Households also consume more.
- Shortage of loanable funds raises $i^L$ (but also $\pi$ has increased)
- Rise of $i^L$ does not last long. $i^G$ also falls over time $\Rightarrow i^D$ falls over time. Bank deposits fall over time, and administered deposits $\uparrow$
- Since $d \downarrow \Rightarrow x$ (real reserves) also fall.
Variance decomposition results

Table 3: Variance Decomposition Results for Major Macroeconomic Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>$\xi^a$</th>
<th>$\xi^{Z_x}$</th>
<th>$\xi^G$</th>
<th>$\xi^\mu$</th>
<th>$\xi^{iG}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y$</td>
<td>50.13</td>
<td>2.38</td>
<td>36.26</td>
<td>2.80</td>
<td>8.43</td>
</tr>
<tr>
<td>$c$</td>
<td>42.19</td>
<td>24.36</td>
<td>12.81</td>
<td>4.61</td>
<td>16.03</td>
</tr>
<tr>
<td>$i$</td>
<td>50.27</td>
<td>41.11</td>
<td>3.99</td>
<td>1.56</td>
<td>3.06</td>
</tr>
<tr>
<td>$\pi$</td>
<td>95.12</td>
<td>0.28</td>
<td>0.61</td>
<td>2.13</td>
<td>1.86</td>
</tr>
<tr>
<td>$i_L$</td>
<td>60.23</td>
<td>5.07</td>
<td>6.44</td>
<td>5.59</td>
<td>22.66</td>
</tr>
<tr>
<td>$i_G$</td>
<td>56.33</td>
<td>1.03</td>
<td>4.66</td>
<td>5.61</td>
<td>32.37</td>
</tr>
<tr>
<td>$(i_L - i_D)$</td>
<td>47.42</td>
<td>5.07</td>
<td>5.87</td>
<td>10.31</td>
<td>31.34</td>
</tr>
<tr>
<td>$d$</td>
<td>21.32</td>
<td>0.03</td>
<td>0.21</td>
<td>77.9</td>
<td>0.53</td>
</tr>
<tr>
<td>$d^a$</td>
<td>76.20</td>
<td>1.22</td>
<td>4.93</td>
<td>1.74</td>
<td>15.9</td>
</tr>
<tr>
<td>$TD$</td>
<td>61.53</td>
<td>0.54</td>
<td>2.09</td>
<td>29.12</td>
<td>6.72</td>
</tr>
<tr>
<td>$x$</td>
<td>24.67</td>
<td>0.03</td>
<td>0.14</td>
<td>74.82</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Lion’s share of fluctuations in $y$, $\pi$, and $i^L$ explained by shock to TFP
Sensitivity analysis

Table 4: Sensitivity Experiments for Monetary Transmission to Output

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Share of $\xi^\mu$ in FEVD in $y$</th>
<th>Share of $\xi^G$ in FEVD in $y$</th>
<th>Correlation between $y$ and $(x_t/x_{t-1})$</th>
<th>Correlation between $y$ and $i^G$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2.80</td>
<td>8.43</td>
<td>0.124</td>
<td>-0.550</td>
</tr>
<tr>
<td>$\eta = 0.756$</td>
<td>2.80</td>
<td>8.43</td>
<td>0.124</td>
<td>-0.550</td>
</tr>
<tr>
<td>$i^a = 0.036$</td>
<td>2.80</td>
<td>8.43</td>
<td>0.124</td>
<td>-0.550</td>
</tr>
<tr>
<td>$\alpha_s = 0.194$</td>
<td>2.80</td>
<td>8.43</td>
<td>0.124</td>
<td>-0.550</td>
</tr>
<tr>
<td>$\zeta = 0.873$</td>
<td>26.51</td>
<td>3.11</td>
<td>0.364</td>
<td>-0.010</td>
</tr>
<tr>
<td>$\phi_p = 106$</td>
<td>2.58</td>
<td>7.76</td>
<td>0.121</td>
<td>-0.573</td>
</tr>
<tr>
<td>$\theta_p = 0.522$</td>
<td>2.84</td>
<td>8.83</td>
<td>0.124</td>
<td>-0.529</td>
</tr>
<tr>
<td>$\varphi = 1.476$</td>
<td>3.51</td>
<td>9.22</td>
<td>0.137</td>
<td>-0.524</td>
</tr>
<tr>
<td>$\varphi_y = 0.45$</td>
<td>2.90</td>
<td>8.47</td>
<td>0.126</td>
<td>-0.557</td>
</tr>
</tbody>
</table>
Main Takeaways

- Sensitivity experiment with respect to the preference parameter for administered deposits versus regular deposits, suggests no change in the baseline values of the monetary transmission indicators.
- Fiscal dominance parameters $\alpha_s$ (the SLR requirement) and $i^a$ (the administered interest rate) have no effect on monetary transmission indicators.
- With low price adjustment costs (low $\phi_p$) and higher degree of past inflation indexation (high $\theta_p$) in the retail sector, monetary transmission becomes weaker. Lower values of the nominal friction and forward looking price setting behavior limits the real effects of a monetary policy shock via the expectation channel.
Main Takeaways

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

- In terms of the mark-down factor (\( \zeta \)), the transmission of monetary base shock becomes *higher* as seen by the error variance decomposition and money-output correlation while the transmission of interest rate shock is *diminished*.

  - Intuition: Lower \( \zeta \Rightarrow \) deposit rates ↓ ⇒ households deposit less ⇒ Reserve demand ↓ ⇒ Loans ↑ ⇒ Contribution to money growth shock ↑
  
  - If \( \zeta \downarrow \Rightarrow (i^L - i^D) \downarrow \Rightarrow \) pass through from a policy rate shock to \( i^L \) weakens ⇒ policy rate has a lower correlation with output.
Fiscal Dominance

- Counterfactual experiment reveals that fiscal policy receives more importance when the long run value of policy interest rate is elevated.
- Given an exogenous stream government spending, a higher interest rate on government bonds necessitates higher tax liability on the private sector which makes fiscal policy more important.

Table 5: Sensitivity Experiment on Fiscal Dominance

<table>
<thead>
<tr>
<th>Output</th>
<th>$i^G$</th>
<th>$\xi^a$</th>
<th>$\xi^{Zx}$</th>
<th>$\xi^G$</th>
<th>$\xi^\mu$</th>
<th>$\xi^{i^G}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.08</td>
<td>50.33</td>
<td>2.62</td>
<td>36.71</td>
<td>1.11</td>
<td>9.24</td>
<td></td>
</tr>
<tr>
<td>0.07</td>
<td>50.13</td>
<td>2.38</td>
<td>36.26</td>
<td>2.80</td>
<td>8.43</td>
<td></td>
</tr>
<tr>
<td>0.06</td>
<td>49.65</td>
<td>2.19</td>
<td>35.58</td>
<td>4.90</td>
<td>7.67</td>
<td></td>
</tr>
<tr>
<td>0.05</td>
<td>49.00</td>
<td>2.04</td>
<td>34.77</td>
<td>7.23</td>
<td>6.96</td>
<td></td>
</tr>
</tbody>
</table>
Model Extension 1

- So far banks are assumed to provide liquidity services to households. Now we add a transaction demand for money.
- Add impatient households (a la Iacoviello (2005)) instead of entrepreneurs
- Impatient households consume, produce wholesale goods, hire workers, pay interest on loans, but do not do administered savings. Labor supply comes from patient households.
- Flow budget constraint of impatient household given by

$$P_t C_t' + M_t^T + W_t H_t + (1 + i_t^L)L_{t-1} + Q_t P_t K_t$$

$$= L_t + M_{t-1}^T + (1 - \delta_k) P_t Q_t K_{t-1} + P_t^w Y_t^w$$

(19)

$C_t'$ is the consumption of the impatient wholesale producer, $L_t$ is new nominal loan, $M_t^T$ is in interest bearing cash (different from interest bearing bank reserve $M_t^R$), $Y_t^w$ is the production function (7))
Model Extension 1

- Impatient households subject to a borrowing constraint, which we assume binds

\[ P_t Q_t K_t \leq L_t \]  \hspace{1cm} (20)

- Assume also that the impatient household has to pay a wage bill in cash which necessitates a transaction demand for money (CIA) which also binds

\[ W_t H_t \leq M^T_{t-1} \]  \hspace{1cm} (21)

The impatient household maximizes

\[ \max_{C'_t, H'_t, M^T'_t} E_0 \sum_{t=0}^{\infty} \beta'^t U(C'_t) \]

(with \( \beta' < \beta \)) subject to (25), (20), and (21).
Model Extension 1

- Basic return equation

\[ 1 + i_{t+1}^L = \left[ \left( \frac{P^w_{t+1}}{P_{t+1}} \right) \frac{MPK'_{t+1}}{Q_{t+1}} + 1 - \delta_k \right] \left[ \frac{P_{t+1}Q_{t+1}}{P_tQ_t} \right]. \] (22)

- New labour demand equation for the impatient wholesale producer.

\[ \frac{W_t}{P_t} = \frac{\beta' U'(C'_t)}{U'(C'_{t-1})} \cdot \left( \frac{P_{t-1}}{P_t} \right) \cdot \left( \frac{P^w_t}{P_t} \right) MPH_t \] (23)

- Implication

The wage bill is subject to last period cash constraint, so real wage is subject to an inflation tax. Hiring a worker today also entails use of cash today which means less cash available for wage disbursement tomorrow, hence the discounting of marginal product of labour.
Model Extension 1

- GBC
  \[ P_t G_t + (1 + i_t^G) B_{t-1} + (1 + i^R) M^R_{t-1} + (1 + i^a) D^a_{t-1} + M^{T}_{t-1} \]

  \[ = P_t T_t + B_t + M^R_t + M^T_t + D^a_t + (1 + i^p) E \max(\widehat{W}_t - M^R_t, 0) \]

- Monetary Policy: Stochastic process for \( M^s_t \):

  \[
  \frac{M^s_t / M^s_{t-1}}{1 + \pi} = \left( \frac{M^s_{t-1} / M^s_{t-2}}{1 + \pi} \right)^{\rho_\mu} \exp(\zeta_t^\mu) \tag{24}
  \]

Money supply \( (M^s_t) \) is given by

\[ M^s_t = M^T_t + M^R_t \]
New steady state system changes to 21 eqns (two extra variables $m^T$ and $C'$).

1. \((1 + i^L) = (1 + \pi) / \beta\)
2. \((1 + i^L) = \left[ \left( \frac{\varepsilon_Y - 1}{\varepsilon_Y} \right) \alpha \left( \frac{K}{H} \right)^{\alpha - 1} + 1 - \delta_K \right] \)
3. \(W / P = \frac{\beta'}{1 + \pi} (1 - \alpha) \left( \frac{\varepsilon_Y - 1}{\varepsilon_Y} \right) (\Lambda)^\alpha\) where \(\Lambda = K / H\) solved from the preceding equation (Modified)
4. \(C = W / P\)
5. \(C' = \Theta K (New)\)
6. \(m^T = \Lambda^* K (New)\)
7. \(G = \bar{G}\)
8. Using \(C + C' + G = \left[ \Lambda^{-(1-\alpha)} - \delta_K \right] K\), and steady state \(G\), Solve \(K\) (Modified)
9. Using \(K / H = \Lambda\), solve \(H\)
10. Using \( d \left[ 1 + \pi - \beta (1 + i^D) \right] = \eta C(1 + \pi) \), and (5) above solve for \( d \).
11. \( d^p \left[ 1 + \pi - \beta (1 + i^a) \right] = (1 - \eta) C(1 + \pi) \), solve for \( d^a \)
12. \( \frac{x}{d} = 1 - \frac{1-(1+i^R)\Omega}{(1+i^p)\Omega} \)
13. \( \frac{P_t}{P_t^{W}} = \frac{\varepsilon^Y}{\varepsilon^Y - 1} \).
14. \( I = \delta K \)
15. \( \pi = \text{long run inflation target} (\bar{\pi}) \) (Note that this is pinned down by the money supply rule (17))
16. \( T \) solved from the steady state government budget constraint (\textbf{Modified})
17. (Stochastic Discount Factor) \( \Omega = \beta/(1 + \pi) \)
18. \( Y = AK^{\alpha}H^{1-\alpha} \)
19. \( A = \bar{A} \)
20. \( i^G = \bar{i}^G \)
21. \( 1 + i^D = \zeta (1 + i^G) \)
So far banks are assumed to provide liquidity services to households. Now we add a transaction demand for money.

Add impatient households (a la Iacoviello (2005)) instead of entrepreneurs

Impatient households consume, produce wholesale goods, hire workers, pay interest on loans, but do not do administered savings. Labor supply comes from patient households.

Flow budget constraint of impatient household given by

\[ P_t c_t' + M^T_t + W_t H_t + (1 + i^L_t) L_{t-1} + Q_t P_t K_t \]

\[ = L_t + M^T_{t-1} + (1 - \delta_k) P_t Q_t K_{t-1} + P^w_t Y^w_t \]  \( (25) \)

\( c_t' \) is the consumption of the impatient wholesale producer, \( L_t \) is new nominal loan, \( M^T_t \) is in interest bearing cash (different from interest bearing bank reserve \( M^R_t \)), \( Y^w_t \) is the production function \((7)\)
Table 6: Variance Decomposition for Extended Model 1

<table>
<thead>
<tr>
<th>Variables</th>
<th>$\zeta^a$</th>
<th>$\zeta^{Z_x}$</th>
<th>$\zeta^G$</th>
<th>$\zeta^\mu$</th>
<th>$\zeta^{i^G}$</th>
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</thead>
<tbody>
<tr>
<td>$y$</td>
<td>79.29</td>
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<td>17.26</td>
<td>10.59</td>
<td>2.88</td>
<td>10.49</td>
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<tr>
<td>$i$</td>
<td>61.23</td>
<td>32.91</td>
<td>3.20</td>
<td>.96</td>
<td>1.70</td>
</tr>
<tr>
<td>$\pi$</td>
<td>95.22</td>
<td>.86</td>
<td>.52</td>
<td>1.99</td>
<td>1.41</td>
</tr>
<tr>
<td>$i^L$</td>
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<td>6.12</td>
<td>5.16</td>
<td>17.92</td>
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<tr>
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<td>1.72</td>
<td>3.99</td>
<td>23.05</td>
</tr>
<tr>
<td>$(i^L - i^D)$</td>
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<td>2.39</td>
<td>4.13</td>
<td>5.04</td>
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<td>$d$</td>
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<td>27.45</td>
<td>.22</td>
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<td>.47</td>
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<td>$d^a$</td>
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<td>2.54</td>
<td>1.63</td>
<td>8.93</td>
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<tr>
<td>$TD$</td>
<td>84.86</td>
<td>3.08</td>
<td>2.07</td>
<td>2.43</td>
<td>7.56</td>
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<tr>
<td>$x$</td>
<td>31.91</td>
<td>.17</td>
<td>.12</td>
<td>67.53</td>
<td>.27</td>
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<tr>
<td>$m^T$</td>
<td>82.77</td>
<td>4.64</td>
<td>.48</td>
<td>2.62</td>
<td>9.48</td>
</tr>
</tbody>
</table>
Risk neutral entrepreneurs now hire from two groups of workers: households who supply labor as a credit good (F) and households who supply labor as a cash good (RT).

Production function is given by

$$ Y_t^W = \zeta_t K_{t-1}^{\alpha} [H_t^{RT} + H_t^F]^{1-\alpha} $$

Entrepreneurs are subject to a borrowing constraint

$$ P_t Q_t K_t \leq L_t $$  \hspace{1cm} (26)

which we assume binds.

RT consumers have to be paid in cash. Assume a CIA constraint

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

Because of the payment friction, wages of the two groups is not the same.
Model Extension 2

- Basic return equation continues to hold

\[ 1 + i_{t+1}^L = \left[ \left( \frac{P_{t+1}^w}{P_{t+1}} \right) \frac{MPK_{t+1}'}{Q_{t+1}} + 1 - \delta_k \right] \frac{P_{t+1}Q_{t+1}}{P_tQ_t}. \]  

(28)

- New labour demand equation for the RT consumer

\[ \frac{W_{t}^{RT}}{P_t} = \beta U'(C_t) \left( \frac{P_{t-1}}{P_t} \right) \left( \frac{P_{t}^w}{P_t} \right) MPH_t \]  

(29)

- Labour demand equation for the F consumer

\[ \left( \frac{P_{t}^w}{P_t} \right) MPH_t^F - \frac{W_{t}^F}{P_t} = 0 \]  

(30)

- In the steady state, higher inflation depresses the RT wage and creates more wage inequality.
Table 7: Variance Decomposition for Extended Model 2

<table>
<thead>
<tr>
<th>Variables</th>
<th>ξ^a</th>
<th>ξ^Zx</th>
<th>ξ^G</th>
<th>ξ^μ</th>
<th>ξ^i^G</th>
</tr>
</thead>
<tbody>
<tr>
<td>y</td>
<td>49.33</td>
<td>1.54</td>
<td>41.03</td>
<td>1.02</td>
<td>7.07</td>
</tr>
<tr>
<td>c</td>
<td>50.21</td>
<td>24.61</td>
<td>11.31</td>
<td>1.54</td>
<td>12.33</td>
</tr>
<tr>
<td>i</td>
<td>48.57</td>
<td>42.51</td>
<td>4.64</td>
<td>0.74</td>
<td>3.54</td>
</tr>
<tr>
<td>π</td>
<td>96.17</td>
<td>0.34</td>
<td>0.65</td>
<td>0.99</td>
<td>1.86</td>
</tr>
<tr>
<td>i^L</td>
<td>64.06</td>
<td>3.73</td>
<td>6.93</td>
<td>2.45</td>
<td>22.83</td>
</tr>
<tr>
<td>i^G</td>
<td>58.71</td>
<td>0.80</td>
<td>4.96</td>
<td>2.51</td>
<td>33.02</td>
</tr>
<tr>
<td>(i^L − i^D)</td>
<td>54.94</td>
<td>3.04</td>
<td>6.88</td>
<td>2.50</td>
<td>32.64</td>
</tr>
<tr>
<td>d</td>
<td>22.47</td>
<td>0.05</td>
<td>0.23</td>
<td>76.69</td>
<td>0.56</td>
</tr>
<tr>
<td>d^a</td>
<td>76.99</td>
<td>1.02</td>
<td>5.07</td>
<td>0.90</td>
<td>16.03</td>
</tr>
<tr>
<td>TD</td>
<td>75.07</td>
<td>0.76</td>
<td>3.71</td>
<td>8.71</td>
<td>11.75</td>
</tr>
<tr>
<td>x</td>
<td>25.79</td>
<td>0.05</td>
<td>0.15</td>
<td>73.66</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Importance of fiscal shocks increase; base money shocks become less important.
Conclusion

- We started by asking: *what explains weak monetary policy transmission mechanism in India?*

- One of the first DSGE models to focus on monetary transmission in the Indian context.

- We find that
  - Fiscal dominance does not weaken monetary transmission
  - Large borrowing lending spread, more aggressive inflation and output targeting reduces transmission from the policy rate to output.
  - Preference for administered deposits versus regular deposits doesn’t matter for transmission.

- We consider two extensions of the baseline model which add a transaction demand for money
  - In both, the horse race on shocks is preserved.
Thank you