A Monetary Business Cycle Model for India

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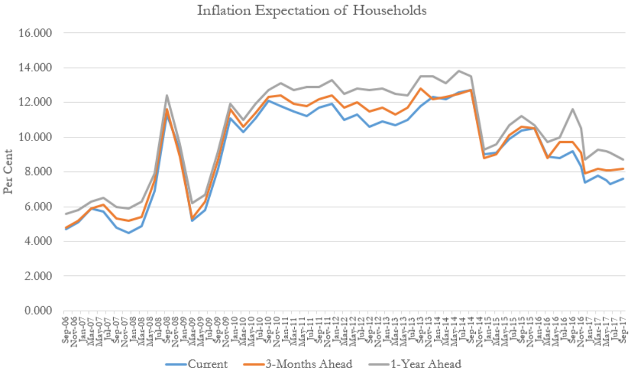
Introduction

- 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)

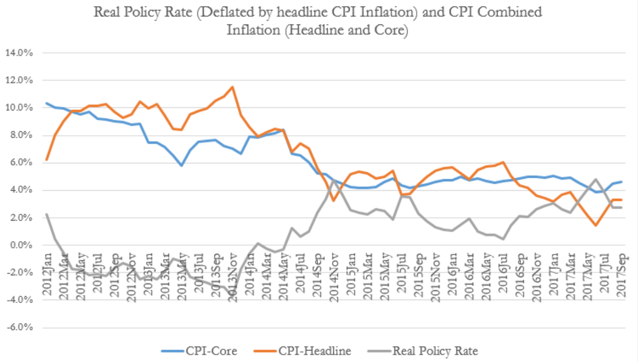
Background

- Survey based inflation expectations of households



Background

- Real policy rates



Introduction

- 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

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- 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)

Preview of main results

- 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

$$\max_{C_t, H_t, D_t, D_t^a} E_0 \sum_{t=0}^{\infty} \beta^t \left[U(C_t) - \Phi(H_t) + \underbrace{V(D_t/P_t, D_t^a/P_t)}_{\text{Convenience Utility}} \right] \qquad (1)$$

subject to

$$\underbrace{P_t\left(C_t + T_t\right) + D_t + D_t^a}_{\text{Flow of Expenses}} \leq \underbrace{\begin{array}{c} W_t H_t + (1 + i_t^D) D_{t-1} + \\ (1 + i^a)\, D_{t-1}^a + \Pi_t^k + \Pi_t^r + \Pi_t^b \end{array}}_{\text{Resources}}$$

where P_t is the aggregate price index.

- $i_t^D > 0$ fixed deposit rate on one period deposits; $i^a > 0$ fixed administered rate.

Households

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

$$D_t: \; U'(C_t) = V_1'(d_t, d_t^a) + \beta E_t \left\{ U'(C_{t+1})(1 + i_{t+1}^D)(P_t / P_{t+1}) \right\}, \tag{2}$$

$$D_t^a: \; U'(C_t) = V_2'(d_t, d_t^a) + \beta E_t \left\{ U'(C_{t+1})(1 + i^a)(P_t / P_{t+1}) \right\} \tag{3}$$

and

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

  - 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

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

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

$\Rightarrow$ 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

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

- Production function

$$Y_t^W = \zeta_t^a K_{t-1}^{\alpha} H_t^{1-\alpha} \tag{7}$$

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

Wholesale Producers

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

$$W_t/P_t = \underbrace{(P_t^W/P_t)}_{\text{Real MC}} MPH_t = (1-\alpha)\frac{(P_t^W/P_t)Y_t^W}{H_t} \tag{8}$$

$$\underbrace{1+r_{t+1}^k}_{\text{Gross Return to 1 unit of K}} = \frac{(P_{t+1}^W/P_{t+1})MPK_{t+1} + (1-\delta_k)Q_{t+1}}{Q_t} \tag{9}$$

respectively.

- Demand for capital given by the following arbitrage condition

$$\begin{aligned} 1+r_{t+1}^k &= \left(1+i_{t+1}^L\right)\frac{P_t}{P_{t+1}} \\ 1+i_{t+1}^L &= \left[\left(\frac{P_{t+1}^w}{P_{t+1}}\right)\frac{MPK_{t+1}}{Q_{t+1}} + 1 - \delta_k\right]\left[\frac{P_{t+1}Q_{t+1}}{P_tQ_t}\right]. \end{aligned}$$

Final good retail firms

- Buy intermediate goods at P_t^W 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.

$$\max_{P_t(i)} E_t \sum_{j=0}^{\infty} \Omega_{t,t+j} \left\{ \Pi^r_{t+j|t} \right\} \tag{10}$$

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

$$
\begin{aligned}
\Pi_t^r(i) &= P_t(i)\, y_t(i) - P_t^W(i)\, y_t^W(i) - \\
&\frac{\phi_p}{2}\left[\left\{\frac{P_{t+j}(i)}{P_{t+j-1}(i)} - \underbrace{(1+\pi_{t-1})^{\theta_p}(1+\bar{\pi})^{1-\theta_p}}_{\text{Costly Price Adjustment in Goods Markets}}\right\}^2 P_t y_t\right]
\end{aligned}
$$

Final good retail firms

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

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

θ_p is an indexation parameter.

- FOC

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

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

$$\frac{P}{P^W} = \frac{\varepsilon^Y}{\varepsilon^Y - 1}. \tag{12}$$

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_t^L to be interest rate on loans, L_{t-1}
- i^R the interest rate on reserves, M_t^R, mandated by the central bank,
- $\widetilde{W}_t$ is the stochastic withdrawal (Uniform dist.)
- Assume government bonds and deposits are perfects substitutes $\rightarrow i_t^D = i_t^G = i_t^S$ (say)

Banks

- Bank's cash flow at t

$$
\begin{aligned}
CF_t^b = {} & (1+i_t^L)L_{t-1} + (1+i^R)M_{t-1}^R + \underbrace{\alpha_s(1+i_t^G)D_{t-1}}_{SLR \text{ on last period's deposits}} \\
& - \underbrace{(1+i_t^D)D_{t-1}}_{\text{Cost of Funds of Last period's Deposits}} \\
& - (1+i^p)E\max(\widetilde{W_{t-1}} - M_{t-1}^R, 0) + \underbrace{D_t}_{\text{Current Deposits}} \\
& - \underbrace{\alpha_s D_t}_{SLR \text{ this period}} - L_t - M_t^R
\end{aligned}
$$

Banks

- Banks maximizes discounted cash flows in two stages. Banks first solve for optimal reserves, M_t^R. Next, choose the loan amount, L_t. Given $\left\{i_t^D\right\}_{t=0}^{\infty}$, $\left\{i_t^L\right\}_{t=0}^{\infty}$, $\left\{D_t\right\}_{t=0}^{\infty}$, banks solve

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

subject to the statutory reserve requirement:

$$M_t^R \geqq \alpha_r D_t \tag{13}$$

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

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

Banks

- FOC for reserves

$$E_t\Omega_{t,t+1}\left[\begin{array}{c}\underbrace{(1+i^R)}_{\text{Banks Interest Income from Reserves}} \qquad + \\ \underbrace{(1+i^p)\int_{M_t^R}^{D_t} f(\widetilde{W}_t)\,d\widetilde{W}_t}_{\text{Expected saving of penalty because of the holding of more reserves}}\end{array}\right] + \lambda_t = 1 \tag{14}$$

- Since reserve requirement not binding, KT condition $\Rightarrow \lambda_t = 0$. Assume $\widetilde{W}_t \sim U[0, D_t]$. Equation (14)$\Rightarrow$

$$\frac{x_t}{d_t} = 1 - \frac{1-(1+i^R)E_t\Omega_{t,t+1}}{(1+i^p)E_t\Omega_{t,t+1}} \tag{15}$$

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

Banks

- FOC for loans

$$L_t : \; 1 = E_t \Omega_{t,t+1}(1 + i^L_{t+1}) \tag{16}$$

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

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

- 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.

Monetary Policy

- 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:

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

where ρ_μ is the policy smoothing coefficient and ξ_t^μ is the money supply shock, which follows an AR (1) process.

$$M_t^B = M_t^R$$

Monetary Policy

- The short term interest rate on government bonds (i_t^G) is the policy rate given by an inflation targeting Taylor rule as follows:

$$\frac{(1+i_t^G)}{(1+\bar{i}^G)} = \left(\frac{(1+i_{t-1}^G)}{(1+\bar{i}^G)}\right)^{\rho_{i^G}} \left[\left(\frac{1+\pi_{t-1}}{1+\pi}\right)^{\varphi_\pi}\left(\frac{Y_t}{Y}\right)^{\varphi_Y}\right]^{(1-\rho_{i^G})} \exp\left(\xi_t^G\right) \tag{18}$$

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

Fiscal Policy

- GBC

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

- Government spending (government purchases) evolves stochastically:

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

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

Recursive Steady State

10. $\frac{x}{d} = 1 - \frac{1-(1+i^R)\ \Omega}{(1+i^p)\Omega}$
11. $\frac{P_t}{P_t^W} = \frac{\varepsilon^Y}{\varepsilon^Y - 1}$.
12. $I = \delta K$
13. $\pi =$ *long run* inflation target $(\bar{\pi})$ (Note that this is pinned down by the money supply rule (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. $i^G = \overline{i^G}$
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

Parameters	Description	Value	Source
α	Share of capital	0.3	Banerjee & Basu, 2017
β	Discount rate	0.98	Gabriel et al., 2011
η	Preference for holding bank deposit	0.84	RBI database
δ_k	Depreciation rate of capital	0.025	Banerjee & Basu, 2017
κ	Investment adjustment cost	2	Banerjee & Basu, 2017
ζ	Mark-down factor for Deposit rate	0.97	Set to match savings A/C rate
ε^Y	Price elasticity of demand	7	Gabriel et al., 2011
ϕ_p	Price adjustment cost	118	Anand et al., 2010
θ_p	Past inflation indexation	0.58	Shahu J. P., 2013
ρ_{iG}	Interest rate smoothing parameter	0.81	Banerjee & Basu, 2017
φ_π	Inflation Stabilizing Coefficient	1.64	Banerjee & Basu, 2017
φ_y	Output Stabilizing Coefficient	0.50	Banerjee & Basu, 2017

Model validation: Table 1: Baseline Parametrization

α_s	Statutory Liquidity Ratio	21.5%	RBI Website
π	Long-run inflation target	4%	Urjit Patel Committee Report, 2013
i^G	Steady state policy rate	7%	RBI Database
i^a	Steady state administered rate	4%	Indian Postal Service Website
i^p	Steady state penalty rate	6.5%	RBI Database
ρ_a	Persistence coefficient of TFP shock	0.82	Anand et al., 2010
ρ_{Z_x}	Persistence coefficient of IST shock	0.59	Banerjee & Basu, 2017
ρ_G	Persistence coefficient of Fiscal shock	0.64	Anand et al., 2010
ρ_μ	Persistence coefficient of Money base shock	0.27	Estimated from Real reserve data (RBI)
σ_a	Standard error of TFP shock	0.06	Set by targeting output volatility
σ_{Z_x}	Standard error of IST shock	0.699	Banerjee & Basu, 2017
σ_G	Standard error of Fiscal shock	0.068	Anand et al., 2010
σ_μ	Standard error of Money base shock	0.065	Estimated from Real reserve data (RBI)
σ_{i^G}	Standard error of Interest rate shock	0.008	Anand et al., 2010

Model validation

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

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

List of	Std. Dev		Correlation with y		Correlation with (x_t/x_{t-1})		Correlation with i^G	
Variables	Data	Model	Data	Model	Data	Model	Data	Model
y	0.029	0.033	1	1	0.170	0.124	-0.059	-0.550
c	0.044	0.038	0.749***	0.360	0.268	0.191	-0.115	-0.756
i	0.034	0.126	0.729***	0.550	-0.210	0.035	-0.015	-0.544
π	2.067	0.019	-0.462**	-0.254	0.316	0.056	0.172	0.352
i^L	0.417	0.038	0.049	-0.072	-0.222	0.219	0.420*	-0.080
i^G	1.056	0.015	-0.059	-0.550	-0.029	-0.061	1	1
x	0.067	0.119	0.050	0.399	0.245	0.295	-0.289	-0.071
d	0.038	0.117	0.183	0.349	0.388*	0.292	-0.348*	0.028
d^a	0.072	0.608	0.139	0.501	0.156	0.063	-0.419**	-0.927
TD	0.040	0.147	0.187	0.588	0.377*	0.237	-0.365*	-0.644

Impulse response analysis of monetary transmission

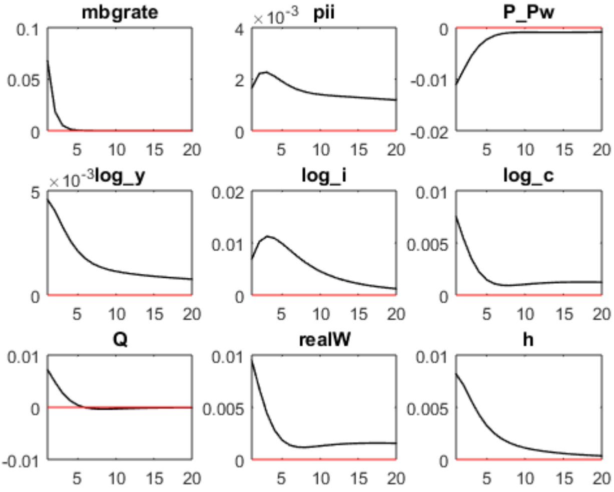

Figure : Effects of Shock to Money Base

Impulse response analysis of monetary transmission

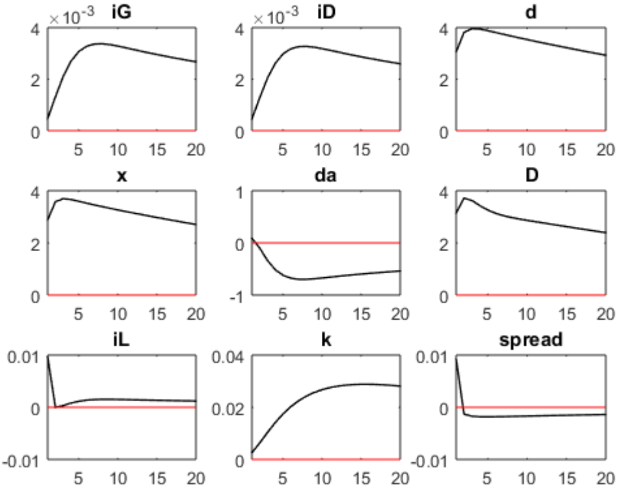

Figure: Figure : Effects of Shock to Money Base

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

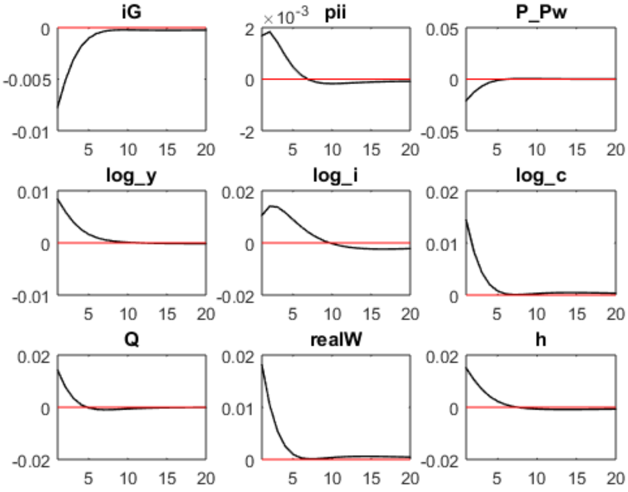

Figure : Effects of Shock to Policy Interest Rate

Impulse response analysis of monetary transmission

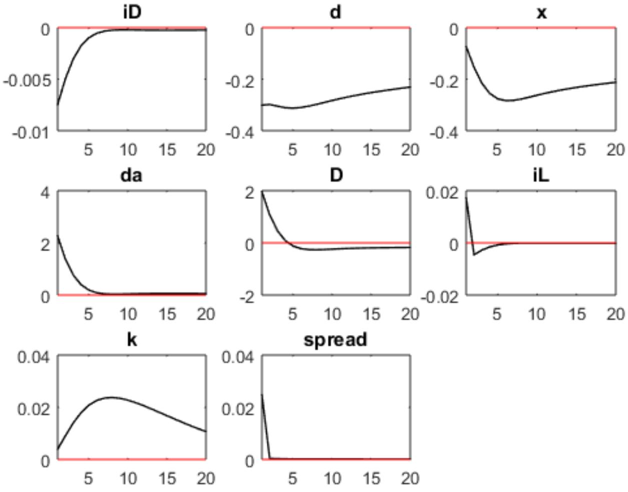

Figure : Effects of Shock to Policy Interest Rate

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 π 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

Variables	ξ^a	ξ^{Z_x}	ξ^G	ξ^μ	ξ^{i^G}
y	50.13	2.38	36.26	2.80	8.43
c	42.19	24.36	12.81	4.61	16.03
i	50.27	41.11	3.99	1.56	3.06
π	95.12	0.28	0.61	2.13	1.86
i^L	60.23	5.07	6.44	5.59	22.66
i^G	56.33	1.03	4.66	5.61	32.37
$(i^L - i^D)$	47.42	5.07	5.87	10.31	31.34
d	21.32	0.03	0.21	77.9	0.53
d^a	76.20	1.22	4.93	1.74	15.9
TD	61.53	0.54	2.09	29.12	6.72
x	24.67	0.03	0.14	74.82	0.34

Lion's share of fluctuations in y, π, and i^L explained by shock to TFP

Sensitivity analysis

Table 4: Sensitivity Experiments for Monetary Transmission to Output

Sensitivity Experiments	Share of ξ^{μ} in FEVD in y	Share of ξ^{i^G} in FEVD in y	Correlation between y and (x_t/x_{t-1})	Correlation between y and i^G
Baseline	2.80	8.43	0.124	-0.550
$\eta = 0.756$	2.80	8.43	0.124	-0.550
$i^a = 0.036$	2.80	8.43	0.124	-0.550
$\alpha_s = 0.194$	2.80	8.43	0.124	-0.550
$\zeta = 0.873$	26.51	3.11	0.364	-0.010
$\phi_p = 106$	2.58	7.76	0.121	-0.573
$\theta_p = 0.522$	2.84	8.83	0.124	-0.529
$\varphi_\pi = 1.476$	3.51	9.22	0.137	-0.524
$\varphi_y = 0.45$	2.90	8.47	0.126	-0.557

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 α_s (the SLR requirement) and i^a (the administered interest rate) have no effect on monetary transmission indicators.
- With low price adjustment costs (low ϕ_p) and higher degree of past inflation indexation (high θ_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 φ_π) and less output stabilization (lower φ_y) raises the pass through of monetary base shock to output, inflation and the nominal loan rate.
- In terms of the mark-down factor (ζ), 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 $\downarrow \Rightarrow$ households deposit less $\Rightarrow$ Reserve demand $\downarrow \Rightarrow$ Loans $\uparrow \Rightarrow$ Contribution to money growth shock $\uparrow$
  - If $\zeta \downarrow \Rightarrow (i^L - i^D) \downarrow \Rightarrow$ pass through from a policy rate shock to i^L weakens $\Rightarrow$ 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

Output					
i^G	ξ^a	ξ^{Z_x}	ξ^G	ξ^μ	ξ^{i^G}
0.08	50.33	2.62	36.71	1.11	9.24
0.07	50.13	2.38	36.26	2.80	8.43
0.06	49.65	2.19	35.58	4.90	7.67
0.05	49.00	2.04	34.77	7.23	6.96

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

$$\begin{aligned} & P_t C_t^{\prime} + M_t^T + W_t H_t + (1+i_t^L) L_{t-1} + Q_t P_t K_t \\ = \; & L_t + M_{t-1}^T + (1-\delta_k) P_t Q_t K_{t-1} + P_t^w Y_t^w \end{aligned} \tag{19}$$

$C_t^{\prime}$ 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

$$P_t Q_t K_t \;\leq\; L_t \tag{20}$$

- 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

$$W_t H_t \leq M_{t-1}^{T} \tag{21}$$

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

$$1 + i^L_{t+1} = \left[\left(\frac{P^w_{t+1}}{P_{t+1}} \right) \frac{MPK^{'}_{t+1}}{Q_{t+1}} + 1 - \delta_k \right] \left[\frac{P_{t+1} Q_{t+1}}{P_t Q_t} \right]. \qquad (22)$$

- New labour demand equation for the impatient wholesale producer.

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

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

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

- Monetary Policy: Stochastic process for M_t^s :

$$\frac{M_t^s / M_{t-1}^s}{1 + \bar{\pi}} = \left(\frac{M_{t-1}^s / M_{t-2}^s}{1 + \bar{\pi}} \right)^{\rho_\mu} \exp(\xi_t^\mu) \tag{24}$$

Money supply (M_t^s) is given by

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

Model Extension 1

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

Model Extension 1

10. Using $d\left[1+\pi-\beta\left(1+i^{D}\right)\right]=\eta C(1+\pi)$, and (5) above solve for d.
11. $d^{p}\left[1+\pi-\beta\left(1+i^{a}\right)\right]=(1-\eta)\,C(1+\pi)$, solve for d^{a}
12. $\frac{x}{d}=1-\frac{1-\left(1+i^{R}\right)\ \Omega}{\left(1+i^{p}\right)\Omega}$
13. $\frac{P_t}{P_t^W}=\frac{\varepsilon^Y}{\varepsilon^Y-1}$.
14. $I=\delta K$
15. $\pi=$ *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 (**Modified**)
17. (Stochastic Discount Factor) $\Omega=\beta/(1+\pi)$
18. $Y=AK^{\alpha}H^{1-\alpha}$
19. $A=\bar{A}$
20. $i^G=\overline{i^G}$
21. $1+i^D=\zeta(1+i^G)$

Model Extension 1

- So far banks are assumed to provide liquidity services to households. Now we add a transaction demand for money.
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- Flow budget constraint of impatient household given by

$$\begin{aligned} & P_t C_t^{'} + M_t^T + W_t H_t + (1 + i_t^L) L_{t-1} + Q_t P_t K_t \\ = \quad & L_t + M_{t-1}^T + (1 - \delta_k) P_t Q_t K_{t-1} + P_t^w Y_t^w \end{aligned} \tag{25}$$

$C_t^{\prime}$ 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

Table 6: Variance Decomposition for Extended Model 1

Variables	ξ^{a}	ξ^{Z_x}	ξ^{G}	ξ^{μ}	ξ^{i^G}
y	79.29	5.35	3.41	2.35	9.60
c	58.78	17.26	10.59	2.88	10.49
i	61.23	32.91	3.20	.96	1.70
π	95.22	.86	.52	1.99	1.41
i^L	65.60	5.20	6.12	5.16	17.92
i^G	68.84	2.40	1.72	3.99	23.05
$\left(i^L - i^D\right)$	63.21	2.39	4.13	5.04	25.24
d	27.45	27.45	.22	71.65	.47
d^a	83.82	3.59	2.54	1.63	8.93
TD	84.86	3.08	2.07	2.43	7.56
x	31.91	.17	.12	67.53	.27
m^T	82.77	4.64	.48	2.62	9.48

Model Extension 2

- 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

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

- Entrepreneurs are subject to a borrowing constraint

$$P_t Q_t K_t \leq L_t \tag{26}$$

which we assume binds.

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

$$W_t^{RT} H_t^{RT} \leq M_{t-1}^T \tag{27}$$

- Because of the payment friction, wages of the two groups is not the same.

Model Extension 2

- Basic return equation continues to hold

$$1 + i^L_{t+1} = \left[\left(\frac{P^w_{t+1}}{P_{t+1}} \right) \frac{MPK'_{t+1}}{Q_{t+1}} + 1 - \delta_k \right] \left[\frac{P_{t+1} Q_{t+1}}{P_t Q_t} \right]. \qquad (28)$$

- New labour demand equation for the RT consumer

$$\frac{W^{RT}_t}{P_t} = \frac{\beta U'(C_t)}{U'(C_{t-1})} \left(\frac{P_{t-1}}{P_t} \right) \left(\frac{P^w_t}{P_t} \right) MPH_t \qquad (29)$$

- Labour demand equation for the F consumer

$$\left(\frac{P^w_t}{P_t} \right) MPH^F_t - \frac{W^F_t}{P_t} = 0 \qquad (30)$$

- In the steady state, higher inflation depresses the RT wage and creates more wage inequality.

Model Extension 2

Table 7: Variance Decomposition for Extended Model 2

Variables	ξ^a	ξ^{Z_x}	ξ^G	ξ^μ	ξ^{i^G}
y	49.33	1.54	41.03	1.02	7.07
c	50.21	24.61	11.31	1.54	12.33
i	48.57	42.51	4.64	0.74	3.54
π	96.17	0.34	0.65	0.99	1.86
i^L	64.06	3.73	6.93	2.45	22.83
i^G	58.71	0.80	4.96	2.51	33.02
$\left(i^L - i^D\right)$	54.94	3.04	6.88	2.50	32.64
d	22.47	0.05	0.23	76.69	0.56
d^a	76.99	1.02	5.07	0.90	16.03
TD	75.07	0.76	3.71	8.71	11.75
x	25.79	0.05	0.15	73.66	0.35

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