Financial Frictions, Bank Intermediation and Transmission Mechanism of Monetary Policy: Evidence from Indian Economy*

Shesadri Banerjee† Harendra Behera‡

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Abstract

How do the frictions in financial market determine the transmission of monetary policy in the emerging market economies? We investigate this question using India as the country for analysis. We adopt a New Keynesian business cycle model with bank intermediation (Gerali et al. 2010, Anand et al. 2014), extend it by Indian economy-specific features of liquidity-constrained population, competitive labour market and statutory requirements of the bank, and validate the model with the data. The baseline model explains the comovements of interest rates, incomplete pass-through and adjustment mechanism of the real, nominal and financial variables for a positive interest rate shock. It identifies the critical role and quantitative significance of liquidity-constrained and collateral-constrained households, and interest rate rigidity in the transmission process. Further, it predicts that targeting financial stability through monetary policy rule may not serve the purpose of economic stabilisation.

Keywords : Monetary Policy, Financial Frictions, Tranmission Mechanism, Indian Economy

JEL Codes : [E12, E31, E32, E44, E52, E58]

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†*Corresponding Author:* Madras Institute of Development Studies (MIDS), Chennai 600020, India. Tel: 91-44-2441-2589. Fax: 91-44-2491-0872. E-mail: shesadri.banerjee@mids.ac.in.

‡Reserve Bank of India, Central Office Building, Shahid Bhagat Singh Marg, Mumbai 400001, India. E-mail:hbehera@rbi.org.in

1 Introduction

How do the frictions in financial market determine the transmission of monetary policy in the emerging market economies (EMEs)? We investigate this question using India as the country for analysis. Our research question is motivated by three research gaps in the relevant literature. First, there is a consensus on the fact that financial sector is an *interface* between the policies of central bank and the real economy, and it plays a pivotal role in shaping the monetary policy transmission (MPT) mechanism (Ma and Lin, 2016).[1] While examining the cross-country evidence on MPT, researchers have found that the MPT is much weaker in the EMEs compared to the advanced countries due to weak and underdeveloped financial sector (Mohanty and Turner, 2008; Kletzer, 2012).[2] More specifically, the presence of information asymmetries, limited enforceability of contracts and heterogeneity among the economic agents give rise to frictions in the financial market transactions and can influence the pass-through and speed of adjustments in the transmission mechanism.[3] This strand of literature identifies financial frictions as the potential determinants of MPT, but does not shed light on the relative importance of different forms of frictions in the propagation of monetary policy shock. Second, in the mainstream literature on macroeconomic modelling, financial friction is incorporated either in the form of external finance premium which affects the price of credit (Bernanke and Gertler, 1989; Carlstrom and Fuerst, 1997; and Bernanke et al. 1999) or by collateralised debt affects the quantity of credit availability (Kiyotaki and Moore, 1997; and Iacoviello, 2005, 2015). Later, this modelling strategy is enriched with inclusion of financial intermediaries into the analytical framework (Goodfriend and McCullam, 2007; Gertler and Kiyotaki, 2009; Dib, 2010; Gertler and Karadi, 2011; Agenor et al. 2013; Curdia and Woodford, 2016). Although, these studies have investigated the effects of financial frictions on the transmission of monetary policy shock, but the context of their analysis remains confined within advanced countries and the experience of EMEs

[1] Using a cross-country analysis, Cecchetti and Krause (2001) have shown that the transmission of monetary policy to the interest rate movements, domestic output and prices depends significantly on the structure of the country's banking system and financial markets.

[2] In a survey of empirical evidence on MPT in low income countries, Mishra and Montiel (2014) documented that poor institutional environment in the financial sector increases the cost of bank lending and restricts the lending activities of banks in a manner that weakens the effects of monetary policy actions.

[3] The literature on financial market frictions started to evolve since late 1970s. Theoretical justifications for the sources of frictions at the micro-level are provided in Townsend (1979), Stiglitz and Weiss (1981), Hart and Moore (1994), and Kiyotaki (2011). Besides, macroeconomic implications of the same are examined by Bernanke and Gertler (1989) Carlstrom and Fuerst (1997), Kiyotaki and Moore (1997), Cooley et al. (2004), Kiyotaki and Moore (2008), Gertler and Kiyotaki (2010), Mendoza (2010), Jermann and Quadrini (2012), Brzoza-Brzezina and Kolasa (2013), Merola (2015), Copaciu et al. (2015) Galvaoa et al. (2016), and Guerrieri and Iacoviello (2017). In the post global financial crisis era, the lending view based explanation of MPT emphasising the role of financial market frictions has expanded substantially.

are overlooked. Dearth of studies on the developing countries examining the role of financial market frictions in MPT is quite apparent in the current state of literature. Finally, it is highly debated in the policy circles whether monetary authorities should respond to the financial sector developments for macroeconomic stabilisation. The associated literature, which defines the contours of monetary and macroprudential policy interventions, shows a strong disagreement in opinions on this issue (Malovana, 2017; Angelina, Neri and Panetta, 2012, Mishkin, 2012, 2009) and lacks evidence from the EMEs.

In the above research gaps, our contributions are as follows. Considering an EME like India as the testbed, first, we show the propagation mechanism of a monetary policy shock in presence of frictions in the financial market with banking sector intermediation based on a New Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) model. Second, we provide a quantitative assessment of the relative importance of different friction components and structural rigidities in MPT mechanism. Third, we examine the alternative forms of monetary policy rules by augmenting with financial variables in order to check if such policy rules can produce a better outcome for overall stabilization.

We choose Indian economy to study as it provides an interesting case for analysis. It is the sixth largest economy in the world with a promise to move up in the ladder further by 2030.[4] So, performances of the demand management tools are under scrutiny to ensure a stable environment for economic prosperity. Under the current policy regime of flexible inflation targeting, an inflation rate of 4 per cent (with a band of +/- 2 per cent) is set as the target to achieve for the Reserve Bank of India (RBI). Failure to achieve the same for three consecutive quarters needs to be explained in the Parliament with the reasons for the failure and the timeline to return to the targeted inflation rate with remedies. Such institutional mandate reflects the need for faster and efficient transmission mechanism in the economy (RBI, 2014). To this end, understanding the role of financial frictions would contribute towards better decision making and policy formulation for the monetary authority. In addition to this country-specific reason, India also stands out as it represents it's peer group in many ways. It shares common traits with respect to heterogeneity in population, behavioural pattern of households, production process, market arrangements, institutional bottlenecks, and policy regulations. Similar to other EMEs, Indian economy features weak transmission of monetary policy. Besides, the economy is characterised by various forms of financial frictions due to less deepened and fragmented financial market, costly financial intermediation and policy-driven market distortions alike other developing countries (RBI,

[4] *Source: Hindusthan Times, June 17, 2018*
https://www.hindustantimes.com/business-news/india-is-world-s-sixth-largest-economy-at-2-6-trillion-says-imf/story-7wXZPXSWlvvImlAvpLKeNL.html

2014). Such structural resemblance with other EMEs makes India a representative economy of the EME group for the purpose of exploration and experimentation.

In India, the financial sector is largely dominated by the public sector commercial banks, which lead the formal credit market activities. These scheduled commercial banks play central role in transmitting the policy-induced monetary impulses across different sectors of the Indian economy. In the bulk of literature on MPT in India, the bank lending channel is found as the most prominent one for transmission. This channel is essentially a sub-conduit of credit channel, operates in combination with the interest rate channel, and impacts the macroeconomic and financial variables with a lag of two to three quarters. Pandit and Vashisht (2011) examined the transmission of policy interest rate from the perspective of demand for bank credit using monthly data from January 2001 to August 2010 in a panel framework of seven emerging market economies including India. They found that the channel of MPT is a hybrid of the traditional interest rate channel and credit channel in India as in other EMEs.[5]

Theoretically, the bank lending channel of transmission occurs in two steps. First, change in the policy rate affects deposit and lending interest rates of the commercial banks, which in turn affects the borrower's and lender's balance sheet positions. Second, the movements of retail interest rates of the banks impact the demand for credit, consumption/savings and investment decisions of the households and firms, which finally translates to aggregate demand and inflation. However, in reality, the expected outcome of policy intervention gets choked off between the steps due to several factors associated with the bank-led formal credit market. Such factors include the presence of financially excluded population, credit constrained borrowers, statutory liquidity ratio (SLR), rigidity in the deposit interest rates due to administered interest rates of small savings schemes of the government, rigidity in the lending interest rates as maximum share of total liabilities are set at a fixed interest rate and low quality of assets with unexpected loan losses in the credit portfolio (Acharya, 2017). All these factors, in sum, lead to frictions in the form of rigidities in the interest rate determination and cause impediments in the pass-through of monetary transmission to policy objectives.

In view of the evidence from the literature on MPT in India, we develop a medium-scale NK-DSGE model using the collateralised debt approach as proposed in Gerali et al. (2010) and Anand et al. (2014). The key features of the model are as follows: (i) household sector comprises of heterogeneous agents due to difference in their participation at the financial market and time preference, (ii) imperfectly competitive formal credit market with

[5] More evidence can be found in Pandit et al. (2006), Aleem (2010), Bhaumik et al. (2010), Khundrakpam (2011), Sen Gupta and Sengupta (2014) and Das (2015).

intermediation of the banking sector, (iii) financial frictions are modelled by the financially excluded population, collateral constraints, quadratic adjustment costs for interest rate setting and maintaining the capital adequacy and reserve requirements of the bank, and (iv) eight exogenous shocks explaining the dynamics of macroeconomic aggregates. Such modelling framework installs the (broad) credit channel via bank lending as the principal route for MPT as observed in India.

Baseline parameterisation of the model is configured by combining the methods of calibration and estimation. The well known deep parameters and steady-state shares are calibrated while the economy-specific friction parameters and shock structure are estimated with quarterly data (1999:Q1 to 2015:Q3) using Bayesian methodology. The baseline model is validated with the second order moments of the data based on volatility and cross-correlations of the key macroeconomic and financial variables. Simulation results of the baseline model replicates the comovement of the credit market interest rates with incomplete pass-through. In response to a positive interest rate shock, the spectrum of interest rates shifts up and squeezes the demand for credit. In consequence, the contractionary effects set in from the demand side of the economy via reduction of consumption and investment demand, and supply side via cost of capital. The two-pronged effect leads to a sharp decline in the demand for factors of production, in particular for the labour market, which drives down the aggregate output and inflation subsequently. The variance decomposition results show that the transmission of an interest rate shock to aggregate demand and inflation is paltry and subject to the structural attributes and degree of financial market frictions.

Focusing on the credit market friction parameters, further, we undertake the counterfactual experiments and evaluate the responsiveness of MPT using the accumulated effects over a time horizon of eight quarters. In general, it is observed that MPT improves as the friction in the financial system diminishes. It is found that the presence of liquidity-constrained and collateral-constrained households pose major obstacles for the transmission mechanism. The results based on the elasticity measure suggest that easing of the collateral constraint and financial inclusion to a greater extent can enhance the degree of transmission more than proportionately. Elimination of the interest rate rigidity on the lending side and composition of saver and borrower in the credit market also have some implications for the transmission mechanism. However, friction related to deposit interest rate does not appear to be a significant one for the weak MPT in the economy.

Further, our policy experiments using central bank loss function with respect to a set of monetary policy rules with financial variables show that the standard form of the Taylor rule with forecast-based inflation and contemporaneous output stands out as the optimal one for all policy frameworks under consideration. Housing price augmented Taylor rule performs marginally better than the standard form of the Taylor rule. In contrast, adjusting policy interest rate to smooth out the credit cycle does not seem to be useful. Overall, it appears that targeting financial variables in the monetary policy rule may not be appropriate for the purpose of economic stabilisation.

The rest of the paper is organised as follows. Section 2 lays out the model. Section 3 reports the quantitative analysis with results from the baseline model. Section 4 presents a discussion on the role of financial frictions in MPT in India based on counterfactual experiments and provide a comparative analysis for alternative policy rules augmented with financial variables. Section 5 concludes the paper.

2 The Model

2.1 Description of the Economy

We closely follow Gerali et al. (2010) and Anand et al. (2014) to build up our medium scale DSGE model. The model is essentially an extension of the standard New Keynesian framework with financially excluded population, savers, credit-constrained borrowers and imperfectly competitive banking sector. A variety of frictions are modelled in the forms of collateral constraints and symmetric adjustment costs except external habit formation in consumption and inflation indexation in price-setting. Exogenous shocks are incorporated as appropriate for the business cycle features of a developing economy. The environment of our model is explained below.

The household sector consists of the representatives from the financially excluded, patient, impatient and entrepreneur groups. Financially excluded households are liquidity-constrained and cannot participate in the financial market. In contrast, the representative households from the patient, impatient, and entrepreneur groups are financially included but heterogenous due to the difference in their time preference. Production side of the economy comprises four sectors: (i) intermediate goods producing wholesale firms run by the entrepreneurs, (ii) retailers who convert the intermediate goods into the final goods, (iii) capital goods producing sector which produces new capital using old capital and investment and (iv) housing goods producing sector that operates analogous to capital goods sector.

Operation of the representative commercial bank is managed by its two branches: wholesale branch and retail branch. The bank offers two types of one-period financial instruments: one is deposit contract (for patient households) and the other is loan contract (for impatient households and entrepreneurs). They collect financial resources via selling of deposit contracts to the patient households; issue collateralised loans to the borrowing households and the wholesale firms; meet the reserve requirements in the form of cash reserve ratio and statutory liquidity ratio and macroprudential norm of the central bank in the form of capital adequacy ratio; and accumulate capital from its profit. The balance sheet constraint of the bank establishes the link between the business cycle and credit cycle in the economy through bank capital. The degree of pass-through of the change in policy rate to retail deposit and lending rates critically depends on the credit market imperfections, interest rate stickiness and adjustment cost of bank's capital-to-asset ratio.

There is a government that spends on final consumption goods. This fiscal expenditure is financed by the lump-sum taxes and issuing of government securities that are held by the commercial banks. The central bank follows a Taylor-type interest rate rule by targeting the forecast-based inflation and current business cycle conditions.

2.2 Household Sector

The economy is populated by households and entrepreneurs, each one with a unit mass. Households are segmented into two groups according to their access to the financial market transactions. The first group is the liquidity-constrained households (R) that cannot participate in the financial market. The other group of households actively participates in the financial market operations and features heterogeneity with respect to their degree of time preference. This financially included group consists of patient households (P), impatient households (I), and entrepreneurs (E). Patient households have a discount factor (β_P) which is higher than impatient households (β_I) and entrepreneurs (β_E). Such a difference in the time preference allows the patient households to be lenders and impatient households and entrepreneurs to be borrowers in the model environment.

2.2.1 Liquidity-constrained Household

A representative i^{th} household of the financially excluded segment of population consumes the final goods $C_{R,t}(i)$ and supplies labour $L_{R,t}(i)$ to the packer in the competitive labour market at real wage rate of $w_{R,t}$. They maximise the following utility function:

$$U_{R,t} = \left[\ln C_{R,t}(i) - \frac{L_{R,t}^{1+\sigma_l}(i)}{1+\sigma_l} \right] \tag{1}$$

subject to their budget constraint:

$$C_{R,t}(i) \leq w_{R,t} L_{R,t}(i) \tag{2}$$

Hence, their optimal choice of consumption and labour supply yields:

$$\frac{1}{C_{R,t}(i)} = \lambda_{R,t} \tag{3}$$

$$L_{R,t}^{\sigma_l}(i) = w_{R,t}\lambda_{R,t} \tag{4}$$

where, $\lambda_{R,t}$ is the Lagrangian multiplier implying the shadow price of consumption.

2.2.2 Patient Household

A representative patient household i chooses final consumption goods $C_{P,t}(i)$ subject to habit formation on aggregate consumption, housing goods $H_{P,t}(i)$, labour supply $L_{P,t}(i)$, and deposits $D_t(i)$ in order to maximise the present value of life-time expected utility given the periodical budget constraint. The expected utility function of a patient household is:

$$E_0 \sum_{t=0}^{\infty} \beta_P^t \left[(1-\sigma_h) \ln \left(C_{P,t}(i) - \sigma_h C_{P,t-1} \right) + \varepsilon_{H,t} \ln H_{P,t}(i) - \frac{L_{P,t}^{1+\sigma_l}(i)}{1+\sigma_l} \right] \tag{5}$$

where, σ_h denotes the degree of habit persistence in consumption, σ_l is the inverse of Frisch elasticity of labour supply, and $\varepsilon_{H,t}$ is an exogenous shock to preference for housing services. The flow of funds of the patient households is as follows:

$$\begin{aligned} & C_{P,t}(i) + Q_t^h \left\{ H_{P,t}(i) - (1-\delta_h) H_{P,t-1}(i) \right\} + D_t(i) + TX_{P,t}(i) \\ & \leq w_{P,t} L_{P,t}(i) + \left\{ \frac{\left(1 + i_{t-1}^d\right)}{\pi_t} \right\} D_{t-1}(i) + \Pi_{P,t}^r \end{aligned} \tag{6}$$

where, Q_t^h is real price of housing, δ_h is depreciation rate of housing goods, $w_{P,t}$ is real wage, i_t^d is nominal interest rate on deposits, and π_t is consumer price inflation at date t. On the outflow of funds, expenditures are incurred for current consumption, accumulation of housing goods, purchase of new deposit contracts, and lump-sum tax paid to the government $(TX_{P,t})$. On the inflow of fund, household receives labour income from the entrepreneurs, interest income from the deposit holding of the previous period, and the profit received from the ownership of retail goods producing firms $\left(\Pi_{P,t}^r\right)$.

Patient household makes an optimal choice for $\{C_{P,t}(i), H_{P,t}(i), L_{P,t}(i), D_t(i)\}_{t=0}^{\infty}$ which yields the following optimisation conditions:

$$\frac{(1-\sigma_h)}{(C_{P,t}(i) - \sigma_h C_{P,t-1})} = \lambda_{P,t} \tag{7}$$

$$\left[\frac{\varepsilon_{H,t}}{H_{P,t}(i)}\right] = \lambda_{P,t} Q_t^h - \beta_P \left(1 - \delta_h\right) \lambda_{P,t+1} Q_{t+1}^h \tag{8}$$

$$L_{P,t}^{\sigma_l}\left(i\right) = w_{P,t} \lambda_{P,t} \tag{9}$$

$$\lambda_{P,t} = \beta_P \left(\frac{1 + i_t^d}{\pi_{t+1}}\right) \lambda_{P,t+1} \tag{10}$$

where, $\lambda_{P,t}$ is Lagrangian multiplier for the budget constraint in real terms.

2.2.3 Impatient Household

The representative i^{th} household from the impatient group derives utility from the consumption of final goods $C_{I,t}(i)$ subject to habit formation on aggregate consumption, and housing goods $H_{I,t}(i)$, and disutility from labour supply $L_{I,t}(i)$. It maximises the present value of life-time expected utility:

$$E_0 \sum_{t=0}^{\infty} \beta_I^t \left[\left(1 - \sigma_h\right) \ln\left(C_{I,t}(i) - \sigma_h C_{I,t-1}\right) + \varepsilon_{H,t} \ln H_{I,t}(i) - \frac{L_{I,t}^{1+\sigma_l}\left(i\right)}{1 + \sigma_l} \right] \tag{11}$$

subject to the sequence of budget constraint which is specified as:

$$\begin{aligned} & C_{I,t}(i) + Q_t^h \left\{H_{I,t}(i) - \left(1 - \delta_h\right) H_{I,t-1}(i)\right\} + \left\{\frac{\left(1 + i_{t-1}^{bH}\right)}{\pi_t}\right\} B_{H,t-1}\left(i\right) + TX_{I,t}\left(i\right) \\ & \leq w_{I,t} L_{I,t}\left(i\right) + B_{H,t}\left(i\right) \end{aligned} \tag{12}$$

where, $w_{I,t}$ is real wage and i_t^{bH} is interest rate on borrowing at date t. Expenditures are incurred for consumption, accumulation of housing goods, repayment of previous period loans $B_{H,t-1}(i)$ with interest, and lump-sum tax payment to the government $TX_{I,t}(i)$. Inflow of funds comes in the forms of labour income and current period borrowing.

In addition to the budget constraint, representative impatient household faces a borrowing constraint that needs to be honoured to get loans from the bank. The household can get credit upto the limit of expected nominal value of their collateral. Household uses its accumulated physical assets of housing as the collateral. The borrowing constraint takes the following form:

$$\left(1 + i_t^{bH}\right) B_{H,t}\left(i\right) \leq \varepsilon_{LV,t}^H \left(1 - \delta_h\right) E_t \left\{Q_{t+1}^h \pi_{t+1}\right\} H_{I,t}\left(i\right) \tag{13}$$

where, $\varepsilon^{H}_{LV,t}$ is exogenously time varying LTV ratio for the borrowing households.

Impatient household optimally chooses $\{C_{I,t}(i),\, H_{I,t}(i),\, L_{I,t}(i),\, B_{H,t}(i)\}_{t=0}^{\infty}$ which results into the following optimal conditions:

$$\frac{(1-\sigma_h)}{(C_{I,t}(i)-\sigma_h C_{I,t-1})}=\lambda_{I,t} \tag{14}$$

$$\left[\frac{\varepsilon_{H,t}}{H_{I,t}(i)}\right]=\lambda_{I,t}Q^h_t-\beta_I\left(1-\delta_h\right)\lambda_{I,t+1}Q^h_{t+1}-\varepsilon^{H}_{LV,t}\left(1-\delta_h\right)\mu_{I,t}Q^h_{t+1} \tag{15}$$

$$L^{\sigma_l}_{I,t}\left(i\right)=w_{I,t}\lambda_{I,t} \tag{16}$$

$$\lambda_{I,t}=\beta_I\left(\frac{1+i^{bH}_t}{\pi_{t+1}}\right)\lambda_{I,t+1}+\left(1+i^{bH}_t\right)\mu_{I,t} \tag{17}$$

where, $\lambda_{I,t}$ and $\mu_{I,t}$ are the Lagrangian multipliers on the budget and borrowing constraints, respectively.

2.2.4 Entrepreneur

There exists infinitely large number of entrepreneurs within a unit interval. The representative entrepreneur i derives utility from its final consumption $(C_{E,t})$ subject to habit formation on their aggregate consumption. The intertemporal discount factor of the entrepreneur is denoted by β_E. The present value of life-time expected utility function of the entrepreneur is as follows:

$$E_0\sum_{t=0}^{\infty}\beta^t_E\left[(1-\sigma_h)\ln\left(C_{E,t}(i)-\sigma_h C_{E,t-1}\right)\right] \tag{18}$$

The entrepreneur faces a budget constraint as well as a borrowing constraint which are given below.

$$\begin{aligned}&C_{E,t}(i)+w_{R,t}L_{R,t}\left(i\right)+w_{P,t}L_{P,t}\left(i\right)+w_{I,t}L_{I,t}\left(i\right)\\&+\left\{\frac{\left(1+i^{bE}_{t-1}\right)}{\pi_t}\right\}B_{E,t-1}\left(i\right)+Q^k_tK_t\left(i\right)+\psi_t\left(u_t\right)K_{t-1}\left(i\right)\\&\leq\frac{Y_{E,t}\left(i\right)}{X_t}+B_{E,t}\left(i\right)+Q^k_t\left(1-\delta_k\right)K_{t-1}\left(i\right)\end{aligned} \tag{19}$$

$$\left(1+i^{bE}_t\right)B_{E,t}\left(i\right)=\varepsilon^{E}_{LV,t}\left(1-\delta_k\right)E_t\left\{Q^k_{t+1}\pi_{t+1}\right\}K_t\left(i\right) \tag{20}$$

where,

$$Y_{E,t} = \varepsilon_{A,t} \left\{u_t\left(i\right) K_{t-1}\left(i\right)\right\}^{\alpha} L_t^{1-\alpha}\left(i\right) \tag{21}$$

$$L_t\left(i\right) = L_{R,t}^{\gamma_R}\left(i\right) \left\{L_{P,t}^{\gamma}\left(i\right) L_{I,t}^{1-\gamma}\left(i\right)\right\}^{1-\gamma_R} \tag{22}$$

$$\psi_t\left(u_t\right) = \psi_a\left(u_t - 1\right) + \frac{\psi_b}{2}\left(u_t - 1\right)^2 \tag{23}$$

$$X_t = \frac{P_t}{P_{E,t}} \tag{24}$$

In the above budget and borrowing constraints, i_t^{bE} is interest rate on borrowing from bank for entrepreneurs, $B_{E,t}$ is amount of entrepreneurial borrowing, Q_t^k is real price of physical capital, $\varepsilon_{A,t}$ is the shock to total factor productivity, L_t is aggregate labour (after combining the labour inputs from liquidity-constrained, patient and impatient households) and K_t is physical capital used in wholesale goods production, $\psi_t\left(u_t\right)$ is cost of utilisation of capital, $Y_{E,t}$ is intermediate wholesale goods produced by the entrepreneur, and $\left(\frac{1}{X_t}\right)$ is real marginal cost of wholesale goods production at date t. The share of capital in the production function is α, the shares of labour of liquidity constrained, patient and impatient households in the production are γ_R, $\left\{\gamma\left(1-\gamma_R\right)\right\}$, and $\left\{\left(1-\gamma\right)\left(1-\gamma_R\right)\right\}$, respectively and the curvature parameters of the utilisation cost function are ψ_a and ψ_b.

In the entrepreneurial budget constraint of (19), expenditures are incurred for current consumption, payment of wage bills to liquidity-constrained, patient, and impatient households for their labour supply, repayments of previous period's debt, and utilisation cost of capital. Entrepreneur receives inflow of resources in the form of output produced, borrowing from the bank at current period, and selling of the undepreciated stock of physical capital of the previous period.

The credit availability from the bank is determined by the stock of physical capital, which is offered as collateral by the entrepreneurs. The loan restriction for entrepreneur is given by equation (20). In the borrowing constraint, we have $\varepsilon_{LV,t}^{E}$ which is exogenously time-varying LTV ratio for the entrepreneur.

The sequences of $\{C_{E,t}(i),\ K_t(i),\ u_t,\ L_{R,t}(i),\ L_{P,t}(i),\ L_{I,t}(i),\ B_{E,t}(i)\}_{t=0}^{\infty}$ are optimally chosen by the entrepreneur, and this results into the following optimal conditions:

$$\frac{(1-\sigma_h)}{(C_{E,t}(i) - \sigma_h C_{E,t-1})} = \lambda_{E,t} \tag{25}$$

$$\lambda_{E,t}Q_t^k = \varepsilon_{LV,t}^E\left(1-\delta_k\right)\mu_{E,t}Q_{t+1}^k\pi_{t+1}+$$
$$\beta_E\lambda_{E,t+1}\left[r_{t+1}^k u_{t+1}+\left(1-\delta_k\right)Q_{t+1}^k-\psi_{t+1}\left(u_{t+1}\right)\right] \tag{26}$$

$$r_t^k = \psi_a + \psi_b\left(u_t - 1\right) \tag{27}$$

$$w_{R,t} = \gamma_R\gamma\left(1-\alpha\right)\left\{\frac{Y_{E,t}\left(i\right)}{X_t}\right\}\left\{\frac{1}{L_{R,t}\left(i\right)}\right\} \tag{28}$$

$$w_{P,t} = \left(1-\gamma_R\right)\gamma\left(1-\alpha\right)\left\{\frac{Y_{E,t}\left(i\right)}{X_t}\right\}\left\{\frac{1}{L_{P,t}\left(i\right)}\right\} \tag{29}$$

$$w_{I,t} = \left(1-\gamma_R\right)\left(1-\gamma\right)\left(1-\alpha\right)\left\{\frac{Y_{E,t}\left(i\right)}{X_t}\right\}\left\{\frac{1}{L_{I,t}\left(i\right)}\right\} \tag{30}$$

$$\lambda_{E,t} = \beta_E\left(\frac{1+i_t^{bE}}{\pi_{t+1}}\right)\lambda_{E,t+1}+\left(1+i_t^{bE}\right)\mu_{E,t} \tag{31}$$

where, marginal product of capital is: $r_t^k = \alpha\left\{\frac{Y_{E,t}(i)}{X_t}\right\}\left\{\frac{1}{u_t(i)K_{t-1}(i)}\right\}$; $\lambda_{E,t}$ and $\mu_{E,t}$ are Lagrangian multipliers on the budget and borrowing constraints of the entrepreneurs, respectively.

2.2.5 Competitive Labour Market

Labour market is perfectly competitive where liquidity-constrained household, patient household and impatient household sell their labour to entrepreneur. All types of labour inputs are bundled up via an aggregation technology by the entrepreneur in a costless way to produce homogenous labour input for the wholesale goods production. From the entrepreneur's choice of labour input, given the labour aggregator is in place, one can obtain the following aggregate real wage weighted by share of different types of household's labour in the labour market.

$$w_t = \widetilde{\gamma}w_{R,t}^{\gamma_R}w_{P,t}^{\gamma(1-\gamma_R)}w_{I,t}^{(1-\gamma)(1-\gamma_R)} \tag{32}$$

where, $\widetilde{\gamma} = \left[\gamma_R^{\gamma_R}\left\{\gamma\left(1-\gamma_R\right)\right\}^{\gamma(1-\gamma_R)}\left\{\left(1-\gamma\right)\left(1-\gamma_R\right)\right\}^{(1-\gamma)(1-\gamma_R)}\right]^{-1}$

Since there is no intra-group heterogeneity within the respective household group with respect to their endowments, all individuals within a particular group face the same budget constraint and objective function. Thus, they choose identical time paths for optimisation.

For this reason of symmetry within the group, hereafter we drop the household sector relevant script i.

2.3 Producers

2.3.1 Monopolistically Competitive Retailer

The representative retailer buys homogenous intermediate goods at price $P_{E,t}$ from the entrepreneur, does the packaging with different brands at zero cost and turns them into differentiated final goods. These differentiated final goods are sold at price $P_t(j)$ in the imperfect market that features monopolistic competition and nominal price rigidity. This price is indexed by a weighted combination of last period inflation and steady-state level of inflation. If the retailer adjusts the price of his goods beyond the indexation rule suggests, he will face a quadratic adjustment cost parameterised by ϑ_p. Further, price of final goods is subject to the mark-up shock due to the presence of exogenously time-varying price elasticity of demand $(\varepsilon_{Y,t})$. The retail sector firm maximises:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[P_t(j) Y_t(j) - P_{E,t} Y_t(j) - \frac{\vartheta_p}{2} \left(\frac{P_t(j)}{P_{t-1}(j)} - \pi_{t-1}^{\theta_p} \pi^{1-\theta_p} \right)^2 P_t Y_t \right] \tag{33}$$

subject to the sequence of demand constraints:

$$Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon_{Y,t}} Y_t \tag{34}$$

and finds the following optimal pricing condition for their goods:

$$1 - \varepsilon_{Y,t} + \left(\frac{\varepsilon_{Y,t}}{X_t} \right) - \vartheta_p \left[\pi_t - \pi_{t-1}^{\theta_p} \pi^{1-\theta_p} \right] \pi_t + \beta_P \left[\begin{array}{c} \left(\frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) \vartheta_p \\ \left(\pi_{t+1} - \pi_t^{\theta_p} \pi^{1-\theta_p} \right) \pi_{t+1} \left(\frac{Y_{t+1}}{Y_t} \right) \end{array} \right] = 0 \tag{35}$$

2.3.2 Capital Goods Producing Sector

The capital goods producing sector is incorporated in order to derive the equation of the market price of capital. This helps in determining the value of collateral of entrepreneurs as they demand loans from the bank. In a perfectly competitive environment at the beginning of each period t, these producers buy undepreciated last period's capital stock of the entrepreneurs $(1 - \delta_k) K_{t-1}$ at a price P_t^k. In addition, they purchase an amount of I_t^k units of the final goods from retailers at a price of P_t. The undepreciated capital of the previous period is converted into the new capital at the rate of one-to-one. However, the final good purchased from the retailers have this conversion subject to a quadratic adjustment costs. Thus, the effective capital stock K_t, which is finally sold to entrepreneurs at a price P_t^k, has its law of motion as given below:

$$K_t = (1-\delta_k) K_{t-1} + \left[1 - \frac{\vartheta_k}{2}\left\{\varepsilon_{i^k,t}\left(\frac{I_t^k}{I_{t-1}^k}\right) - 1\right\}^2\right] I_t^k \tag{36}$$

where, ϑ_k represents the adjustment cost of investment, $\varepsilon_{i,t}$ is a shock to the productivity of the investment and $Q_t^k = \left(\frac{P_t^k}{P_t}\right)$ is the price in real terms of the capital. As a result, the capital producer maximises:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}\left[Q_t^k \left\{K_t - (1-\delta_k) K_{t-1}\right\} - I_t^k\right] \tag{37}$$

subject to (36). Hence, the first order condition of optimisation of the capital goods producing firm turns out as:

$$Q_t \left[\begin{array}{c} 1 - \frac{\vartheta_k}{2}\left\{\left(\frac{\varepsilon_{i^k,t} I_t^k}{I_{t-1}^k}\right) - 1\right\}^2 - \vartheta_k \left\{\left(\frac{\varepsilon_{i^k,t} I_t^k}{I_{t-1}^k}\right) - 1\right\}\left(\frac{\varepsilon_{i^k,t} I_t^k}{I_{t-1}^k}\right) \\ +\beta_P \vartheta_k \left\{\left(\frac{\lambda_{P,t+1}}{\lambda_{P,t}}\right) \varepsilon_{i^k,t+1} Q_{t+1} \left\{\left(\frac{\varepsilon_{i^k,t+1} I_{t+1}^k}{I_t^k}\right) - 1\right\}\left(\frac{I_{t+1}^k}{I_t^k}\right)^2\right\} \end{array}\right] = 1 \tag{38}$$

2.3.3 Housing Goods Producing Sector

Similar to capital goods producing sector, we add an explicit sector, which provides the basis for market price of housing goods and subsequently, the valuation of collateral of impatient household for taking loans from the bank. In this sector, firms operate in a competitive environment and produces new housing goods using the previous period undepreciated housing goods from borrowing households $(1-\delta_h) H_{t-1}$ and I_t^h amount of final goods from the retailers. Firms purchase undepreciated housing goods from borrowing households at price of P_t^h and final goods from the retailers at P_t. While the old undepreciated housing goods can be converted to new housing goods one-to-one, the new investment in house producing is subject to quadratic adjustment cost. The law of motion of housing goods accumulation is as follows:

$$H_t = (1-\delta_h) H_{t-1} + \left[1 - \frac{\vartheta_h}{2}\left\{\left(\frac{I_t^h}{I_{t-1}^h}\right) - 1\right\}^2\right] I_t^h \tag{39}$$

where, ϑ_h denotes the adjustment cost of investment in housing. The housing goods producing firms, therefore, maximise the following objective function:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[Q_t^h \left\{ H_t - (1-\delta_h) H_{t-1} \right\} - I_t^h \right] \tag{40}$$

subject to (39). This optimisation exercise yields the following first order condition with real price of housing goods $Q_t^h \left(= \frac{P_t^h}{P_t}\right)$ as:

$$Q_t^h \left[\begin{array}{c} 1 - \frac{\vartheta_h}{2} \left\{ \left(\frac{I_t^h}{I_{t-1}^h} \right) - 1 \right\}^2 - \vartheta_h \left\{ \left(\frac{I_t^h}{I_{t-1}^h} \right) - 1 \right\} \left(\frac{I_t^h}{I_{t-1}^h} \right) \\ + \beta_P \vartheta_h \left\{ \left(\frac{\lambda_{P,t+1}}{\lambda_{P,t}} \right) Q_{t+1}^h \left\{ \left(\frac{I_{t+1}^h}{I_t^h} \right) - 1 \right\} \left(\frac{I_{t+1}^h}{I_t^h} \right)^2 \right\} \end{array} \right] = 1 \tag{41}$$

2.4 Banking Sector

The representative bank $j \in [0,1]$ intermediates all financial transactions among the economic agents in the model and works using two branches: one is the retail branch and the other is the wholesale branch. The retail branch operates in a monopolistically competitive environment through two departments. One department raises differentiated deposits from the patient household, and the other department provides differentiated loans to the impatient household and wholesale goods producing entrepreneurs. The retail level branches hold some market power in conducting their financial intermediation activity, which allows them to set deposit interest rate and lending rates for the borrowing household and entrepreneur. This type of banking structure enables us to examine different degrees of interest rate pass-through from the change of policy rate, which can affect the real and nominal variables through the transmission mechanism. In contrast to the retail branch, the wholesale unit - operating in a competitive market environment - provides wholesale loans and raises wholesale deposits from the retail branches, and takes care of the position of bank capital.

2.4.1 Retail Branch

As in Gerali et al. (2010), we assume that units of deposit and loan contracts are differentiated financial products bought by the households and entrepreneur, and are composed by an aggregator with constant elasticities of substitution (CES). For a representative bank j, the deposit contract to patient household, loan contract to impatient household and loan contract to entrepreneur, elasticities of substitutions are ε^d, ε^{bH}, and ε^{bE}, respectively.

We assume that each patient household purchases a deposit contract from each single bank in order to save one unit of her resource. On the other hand, each borrowing household and entrepreneur purchases the loan contract from each single bank in order to meet their ends. Such assumption goes with the standard Dixit-Stiglitz framework for imperfect market structure which shows that the demand for an individual bank's financial contract, either deposit / loan, depends on the interest rate provided / charged by the bank relative to average rates in the economy. Therefore, the demand functions for deposit and loan contracts for the households and entrepreneur are given by:

$$D_t(j) = \left(\frac{i_t^d(j)}{i_t^d} \right)^{\varepsilon^d} D_t \tag{42}$$

$$B_{H,t}(j) = \left(\frac{i_t^{bH}(j)}{i_t^{bH}} \right)^{-\varepsilon^{bH}} B_{H,t} \tag{43}$$

$$B_{E,t}(j) = \left(\frac{i_t^{bE}(j)}{i_t^{bE}} \right)^{-\varepsilon^{bE}} B_{E,t} \tag{44}$$

where, the average interest rates on deposit $\left(i_t^d\right)$, lending for household $\left(i_t^{bH}\right)$, and lending for entrepreneur $\left(i_t^{bE}\right)$ are defined as follows:

$$i_t^d = \left[\int_0^1 i_t^d(j)^{\varepsilon^d+1} \, dj \right]^{\frac{1}{\varepsilon^d+1}} \tag{45}$$

$$i_t^{bH} = \left[\int_0^1 i_t^{bH}(j)^{1-\varepsilon^{bH}} \, dj \right]^{\frac{1}{1-\varepsilon^{bH}}} \tag{46}$$

$$i_t^{bE} = \left[\int_0^1 i_t^{bE}(j)^{1-\varepsilon^{bE}} \, dj \right]^{\frac{1}{1-\varepsilon^{bE}}} \tag{47}$$

Note that the aforementioned set of demand functions and the average interest rates for the economy are derived from the expenditure minimisation exercise of the retail branches of the representative bank.[6]

Retail Deposit Department: The retail deposit department of bank j collects patient household's deposits, $D_t(j)$, and passes them to the wholesale unit, where deposits are remunerated at rate of i_t^s. The problem of the deposit unit is to maximise its expected present value of profit after taking into account the quadratic adjustment cost parameterised by ϕ_d. The optimisation problem can be written as:

[6] See the appendix of Gerali et al. (2010) for further details.

$$Max_{i_t^d}\ E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[\begin{array}{c} i_t^s D_t(j) - i_t^d D_t(j) - \\ \frac{\phi_d}{2} \left(\frac{i_t^d(j)}{i_{t-1}^d(j)} - 1 \right)^2 D_t \end{array} \right] \quad s.t. \quad D_t(j) = \left(\frac{i_t^d(j)}{i_t^d} \right)^{\varepsilon^d} D_t \tag{48}$$

The first order condition of the above problem produces the following expression for optimal deposit interest rate after imposing the symmetric equilibrium condition:

$$\begin{aligned} i_t^d = & \left(\frac{\varepsilon^d}{\varepsilon^d + 1} \right) i_t^s - \left(\frac{\phi_d}{\varepsilon^d + 1} \right) \left[\left(\frac{i_t^d}{i_{t-1}^d} \right) - 1 \right] \left(\frac{i_t^d}{i_{t-1}^d} \right) + \\ & \beta_P \left(\frac{\phi_d}{\varepsilon^d + 1} \right) \left[\left(\frac{i_{t+1}^d}{i_t^d} \right) - 1 \right] \left(\frac{i_{t+1}^d}{i_t^d} \right) \left(\frac{D_{t+1}}{D_t} \right) \end{aligned} \tag{49}$$

Retail Loan Department: Retail loan department of the bank optimally set the lending rates for impatient household's and entrepreneur's borrowing in order to maximise its expected present value of profit and passes them to the wholesale branch at a uniform competitive loan rate of i_t^b. Similar to the deposit department, loan department also faces quadratic adjustment costs while changing the loan interest rates for household (parameterised by ϕ_{bH}) and entrepreneur (parameterised by ϕ_{bH}). So, the retail loan unit maximises:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[\begin{array}{c} i_t^{bH}(j) B_{H,t}(j) + i_t^{bE}(j) B_{E,t}(j) - i_t^b B_t(j) - \\ \frac{\phi_{bH}}{2} \left(\frac{i_t^{bH}(j)}{i_{t-1}^{bH}(j)} - 1 \right)^2 B_{H,t} - \frac{\phi_{bE}}{2} \left(\frac{i_t^{bE}(j)}{i_{t-1}^{bE}(j)} - 1 \right)^2 B_{E,t} \end{array} \right] \tag{50}$$

subject to (43)and (44), where

$$B_t(j) = B_{H,t}(j) + B_{E,t}(j) \tag{51}$$

After imposing the condition of symmetric equilibrium, the optimal retail loan rates for the household and entrepreneur become as follows:

$$\begin{aligned} i_t^{bH} = & \left(\frac{\varepsilon^{bH}}{\varepsilon^{bH} - 1} \right) i_t^b - \left(\frac{\phi_{bH}}{\varepsilon^{bH} - 1} \right) \left[\left(\frac{i_t^{bH}}{i_{t-1}^{bH}} \right) - 1 \right] \left(\frac{i_t^{bH}}{i_{t-1}^{bH}} \right) + \\ & \beta_P \left(\frac{\phi_{bH}}{\varepsilon^{bH} - 1} \right) \left[\left(\frac{i_{t+1}^{bH}}{i_t^{bH}} \right) - 1 \right] \left(\frac{i_{t+1}^{bH}}{i_t^{bH}} \right) \left(\frac{B_{H,t+1}}{B_{H,t}} \right) \end{aligned} \tag{52}$$

$$i_t^{bE} = \left(\frac{\varepsilon^{bE}}{\varepsilon^{bE}-1}\right) i_t^b - \left(\frac{\phi_{bE}}{\varepsilon^{bE}-1}\right)\left[\left(\frac{i_t^{bE}}{i_{t-1}^{bE}}\right)-1\right]\left(\frac{i_t^{bE}}{i_{t-1}^{bE}}\right) +$$
$$\beta_P \left(\frac{\phi_{bE}}{\varepsilon^{bE}-1}\right)\left[\left(\frac{i_{t+1}^{bE}}{i_t^{bE}}\right)-1\right]\left(\frac{i_{t+1}^{bE}}{i_t^{bE}}\right)\left(\frac{B_{E,t+1}}{B_{E,t}}\right) \tag{53}$$

2.4.2 Wholesale Branch

Wholesale branch collects deposits from the retail deposit department, generates loans from the deposits and passes them to retail loan department. However, before converting the financial resources from deposits into loans, the branch has to meet the reserve requirements as stipulated by the RBI. Two types of reserve requirements are mandated, one is CRR (parameterised by α_c) and the other is SLR (parameterised by α_s). CRR is the portion of deposit that the bank is required to keep with the RBI in the form of cash. SLR is the portion of bank's deposit to be held in the form of liquid government securities. The RBI varies these requirements to control credit supply by changing the availability of resources available with the bank to make loans (Anand et al. 2014). The wholesale branch has access to the interbank market to raise loan B_t^{IB}. Combining net worth of the bank Z_t with the interbank loan and deposit, the wholesale branch generates wholesale loan of B_t. Hence, the balance sheet identity that the wholesale branch has to obey is as follows:

$$B_t(j) = (1-\alpha_c-\alpha_s) D_t(j) + B_t^{IB}(j) + Z_t(j) \tag{54}$$

We assume that capital stock of bank j is accumulated each period by adding up its periodical earnings according to:

$$\pi_t Z_t(j) = (1-\delta_b) Z_{t-1}(j) + \Pi_{t-1}^b(j) \tag{55}$$

where, overall bank profit $\left(\Pi_{t-1}^b\right)$ in the previous period made by the two branches of bank j, and δ_b measures the resources used in managing bank capital and conducting overall banking intermediation activity. Since we assume that bank capital is accumulated out of its periodical earnings, the model has an in-built feedback mechanism between the real and the financial side of the economy on the face of exogenous shocks.[7]

Further, we assume that there is a capital adequacy norm imposed by the central bank, which sets a requirement for the representative commercial bank to maintain their capital

[7] If there is any adverse shock which deteriorates the macroeconomic conditions, banks profits will reduce which will further weaken their ability to create new capital. Depending on the nature and size of the shock, it may result in the reduction of amount of loans supplied by the bank and exacerbate the original contraction.

to asset ratio $\left[\frac{Z_t(j)}{B_t(j)}\right]$ at level of κ_b. The bank is subject to a quadratic adjustment cost for any deviation of its capital to asset ratio from the stipulated level. This modelling strategy helps addressing the role of macroprudential norm in the bank capital channel of monetary transmission.

The problem for wholesale branch is to choose loan $B_t(j)$, deposit $D_t(j)$, and interbank borrowing $B_t^{IB}(j)$, so as to maximise the expected present value of profits subject to the balance sheet constraint given by equation (54) and the law of motion for bank's net worth equation (55). Hence the wholesale branch will maximise:

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[\begin{array}{c} i_t^b B_t(j) + i_t^g \{\alpha_s D_t(j)\} - i_t^s D_t(j) - i_t B_t^{IB}(j) \\ -Z_t(j) - \frac{\phi_z}{2}\left(\frac{Z_t(j)}{B_t(j)} - \kappa_b\right)^2 Z_t(j) \end{array} \right] \tag{56}$$

where, i_t^b, i_t^g, i_t^s, and i_t are wholesale interest rate on loan, interest rate received from holding of government bonds as SLR, wholesale deposit rate and interest rate for interbank loan, respectively. The adjustment cost of bank capital is parameterised by ϕ_z. In a symmetric equilibrium, the first order condition gives the following results:

$$i_t^s = (1 - \alpha_c - \alpha_s) i_t + \alpha_s i_t^g \tag{57}$$

$$i_t^b = i_t - \phi_z \left(\frac{Z_t}{B_t} - \kappa_b\right)\left(\frac{Z_t}{B_t}\right)^2 \tag{58}$$

The above optimal conditions link the wholesale deposit and lending rates to the policy rate i_t, interest rate on government bond, reserve requirements, and the leverage of the banking sector. Finally, the profit of bank j, comes as the sum of earnings from the wholesale and the retail branches and can be written by:

$$\begin{aligned} \Pi_t^b(j) = {} & i_t^{bH}(j) B_{H,t}(j) + i_t^{bE}(j) B_{E,t}(j) - i_t^d D_t(j) - i_t B_t^{IB}(j) - \frac{\phi_d}{2}\left(\frac{i_t^d(j)}{i_{t-1}^d(j)} - 1\right)^2 D_t - \\ & \frac{\phi_{bH}}{2}\left(\frac{i_t^{bH}(j)}{i_{t-1}^{bH}(j)} - 1\right)^2 B_{H,t} - \frac{\phi_{bE}}{2}\left(\frac{i_t^{bE}(j)}{i_{t-1}^{bE}(j)} - 1\right)^2 B_{E,t} - \frac{\phi_z}{2}\left(\frac{Z_t(j)}{B_t(j)} - \kappa_b\right)^2 Z_t(j) \end{aligned} \tag{59}$$

2.5 Fiscal Authority

The government consumes an exogenously specified stream of spending G_t of final consumption goods and finances this by lump-sum taxes of $(TX_{P,t} + TX_{I,t})$ and issuing bonds to the bank through SLR. The government budget constraint is given by:

$$G_t + \left(\frac{1+i^g_{t-1}}{\pi_t}\right)\{\alpha_s D_{t-1}(j)\} = (TX_{P,t} + TX_{I,t}) + \{\alpha_s D_t(j)\} \tag{60}$$

2.6 Central Bank

The central bank sets an interest rate rule (i_t) that follows a standard Taylor rule in the short-run and is specified as given below:

$$\left(\frac{i_t}{i}\right) = \left(\frac{i_{t-1}}{i}\right)^{\phi_i}\left\{\left(\frac{\pi_{t+1}}{\pi}\right)^{\phi_\pi}\left(\frac{Y_t}{Y}\right)^{\phi_y}\right\}^{(1-\phi_i)} \exp\{\varepsilon_{m,t}\} \tag{61}$$

where, ϕ_i is the interest rate smoothing parameter, ϕ_π and ϕ_y are the policy responses to deviation of expected inflation π_{t+1} and output from their respective steady-state level. $\varepsilon_{m,t}$ is the monetary policy shock.

2.7 Resource Constraint and Aggregation

The following resource constraint represents the final goods market equilibrium condition:

$$Y_t = C_t \;+\; I^k_t \;+\; I^h_t \;+\; G_t \;+\; \psi_t(u_t)K_{t-1} + \delta_b\left(\frac{Z_{t-1}}{\pi_t}\right) + Adj_t \tag{62}$$

where, the aggregate consumption is:

$$C_t = C_{R,t} + C_{P,t} + C_{I,t} + C_{E,t} \tag{63}$$

and, Adj_t includes all types of adjustment costs incorporated in the model.

Physical asset in the form of housing good is aggregated as:

$$H_t = H_{P,t} + H_{I,t} \tag{64}$$

Finally, credit (B_t) provided by the bank to the borrowing household and firm is aggregated as:

$$B_t = B_{H,t} + B_{E,t} \tag{65}$$

2.8 Forcing Processes

We have eight exogenous variables in our model and they follow AR(1) process as given below:

$$\left(\frac{\varepsilon_{A,t}}{\varepsilon_A}\right) = \left(\frac{\varepsilon_{A,t-1}}{\varepsilon_A}\right)^{\rho_A} \exp\left\{\xi_{A,t}\right\} \tag{66}$$

$$\left(\frac{\varepsilon_{i^k,t}}{\varepsilon_{i^k}}\right) = \left(\frac{\varepsilon_{i^k,t-1}}{\varepsilon_{i^k}}\right)^{\rho_{i^k}} \exp\left\{\xi_{i^k,t}\right\} \tag{67}$$

$$\left(\frac{G_t}{G}\right) = \left(\frac{G_{t-1}}{G}\right)^{\rho_g} \exp\left\{\xi_{g,t}\right\} \tag{68}$$

$$\left(\frac{\varepsilon_{m,t}}{\varepsilon_m}\right) = \left(\frac{\varepsilon_{m,t-1}}{\varepsilon_m}\right)^{\rho_m} \exp\left\{\xi_{m,t}\right\} \tag{69}$$

$$\left(\frac{\varepsilon_{y,t}}{\varepsilon_y}\right) = \left(\frac{\varepsilon_{y,t-1}}{\varepsilon_y}\right)^{\rho_y} \exp\left\{\xi_{y,t}\right\} \tag{70}$$

$$\left(\frac{\varepsilon_{H,t}}{\varepsilon_H}\right) = \left(\frac{\varepsilon_{H,t-1}}{\varepsilon_H}\right)^{\rho_h} \exp\left\{\xi_{h,t}\right\} \tag{71}$$

$$\left(\frac{\varepsilon^H_{LV,t}}{\varepsilon^H_{LV}}\right) = \left(\frac{\varepsilon^H_{LV,t-1}}{\varepsilon^H_{LV}}\right)^{\rho^H_{LV}} \exp\left\{\xi^H_{LV,t}\right\} \tag{72}$$

$$\left(\frac{\varepsilon^E_{LV,t}}{\varepsilon^E_{LV}}\right) = \left(\frac{\varepsilon^E_{LV,t-1}}{\varepsilon^E_{LV}}\right)^{\rho^E_{LV}} \exp\left\{\xi^E_{LV,t}\right\} \tag{73}$$

The above shock variables drive the aggregate dynamics of our model.

3 Quantitative Analysis

We log-linearise the non-linear structure of decision rules, market clearing conditions and resource constraints around the steady-state and obtain a short-run equation system. Our quantitative analysis is premised on this log-linearised system of equations. In this section, we set up the baseline parameterisation for the model that works as a benchmark for analysis and then, explain the transmission mechanism of monetary policy shock based on the properties of impulse response functions (IRF).

3.1 Baseline Model

We construct the baseline parameterisation of the model by synthesising the methods of calibration and estimation. We calibrate some of the model parameters which are available from the existing studies and macroeconomic time series data. In contrast, the parameters that are more country-specific in nature like the heterogeneity in household sector composition, frictions in the banking sector and persistence coefficients and standard errors of the exogenous shocks, are estimated using the quarterly data of Indian macroeconomic and financial variables over the sample period of 1999:Q4 to 2015:Q3.[8] We deploy the methodology of Bayesian rule as it allows the prior information to identify the parameters and impact of shocks using the cross-equation restrictions given the general equilibrium set-up. We blend the posterior means of the estimated parameters along with the well known calibrated parameters to create a baseline model for the Indian economy. Using this baseline model, we study the impulse response properties of the monetary policy shock, which is the central focus of this paper.

3.1.1 Calibrated Parameters

We fall back on the existing DSGE literature to calibrate some of the structural parameters and time-series data of relevant macroeconomic variables to pin down the steady-state shares. In Table 1, the numerical values for calibration are provided. The proportion of liquidity-constrained households (γ_R) is taken as 40 per cent according to the estimate of Gabriel et al. (2011) for India. The heterogenous discount rates for patient household (β_P), impatient household (β_I) and entrepreneur (β_E) are fixed at 0.96, 0.95 and 0.92, respectively based on the average interest rates on deposits (8 per cent), households' borrowing (9.5 per cent) and firms' borrowing (13 per cent) during the sample period of our study.

[8]Sources and computational details of all the time series data used for our quantitative analysis are as follows. Quarterly data on real sector variables measured at constant prices with base 2011-12, viz. Gross Domestic Products (GDP), Private Final Consumption Expenditure, Government Final Consumption Expenditure and Gross Fixed Capital Formation have been extracted from the Central Statistics Office (CSO), Government of India. As the quarterly data for the new series with base 2011-12 are available from 2011-12: Q1, the back series prior to 2011-12 are derived by splicing. The quarterly data for the price index is derived as the average of the respective monthly price index during the quarter. Data on Consumer Price Index (CPI) with base year at 2012 are collected from the website of Central Statistics Office (CSO), Government of India. As the historical data on CPI are not available prior to the year 2011, the same are spliced using the CPI for Industrial Workers (CPI-IW), published by the Indian Labour Bureau, Government of India. Data on banking and interest rate variables such as bank credit, call money rate, cash reserve ratio, SLR, deposit rates and weighted average lending rates were collected from the website of the RBI. The RBI has been disseminating the monthly Weighted Average Lending Rate (WALR) on outstanding loan from Feb-12. For compilation of lending rates prior to Feb-12, the end quarter interest rate (Term loan interest rate other than export credit) for five scheduled commercial banks has been used. The banks selected for this purpose includes three nationalised banks (State Bank of India, Bank of Baroda and Punjab National Bank), one private bank (ICICI Bank Ltd.) and one foreign bank (Citibank). The simple average of the maximum and minimum lending rate for each of the banks has been considered and the lending rate is obtained as the weighted average of each of these banks interest rate, with weights being proportional to the average outstanding credit amount as on end 2010-11 and 2011-12. As a proxy of investment in housing sector, housing price data are taken from the RBI database. The steady-state share of bank deposit to GDP ratio is obtained from the database of St. Louise FRED.

< Insert Table 1 here >

The degree of external habit formation (σ_h) is set to 0.66 similar to Banerjee and Basu (2017). The Frisch elasticity of labour supply (σ_l) is taken as 0.25 in line with the elastic nature of labour supply in India. The share of capital in production is set at 0.25 following Gerali et al. (2010). The quarterly depreciation rates of physical capital (δ_k) and housing goods (δ_h) are set to 2.5 and 1.25 per cent, respectively. The curvature parameters ($\psi_a,\ \psi_b$) of the utilisation cost of capital are set following Silva et al. (2012).

Nominal friction in the form of price adjustment cost (ϑ_p) is chosen to be 118 following Anand et al. (2010). The degree of inflation indexation is set to 0.55 (Sahu, 2013). Following the Indian experience, capital adequacy requirement (κ_b), statutory liquidity ratio (α_s) and cash reserve ratio (α_c) are set at 10, 21.5 and 5.5 per cent, respectively. The depreciation rate of bank capital (δ_b) is chosen as 3.7 per cent (Anand et al., 2014). The elasticities of demand for borrowing by the impatient household $\left(\varepsilon^{bH}\right)$ and firm $\left(\varepsilon^{bE}\right)$, and for deposit contract by the patient household $\left(\varepsilon^{d}\right)$ are chosen in line with Silva et al. (2012).

The steady-state shares for consumption to GDP $\left(\frac{C}{Y}\right)$, gross capital formation to GDP $\left(\frac{I^k}{Y}\right)$, government spending to GDP $\left(\frac{G}{Y}\right)$, deposit to GDP $\left(\frac{D}{Y}\right)$, entrepreneurial borrowing to total borrowing $\left(\frac{B_E}{B}\right)$ ratio - are chosen based on their average value from quarterly data for the sample period of study. Given the level of inflation target, the steady-state value of inflation is chosen as 4 per cent. The long-run value of policy rate is taken as 7 per cent based on the data of repo rate.

Steady-state values of technology and policy shocks are normalised to one. The steady-state value of preference shock to housing is chosen to be 0.2 as proposed by Silva et al. (2012). Following Gerali et al. (2010), we choose the steady-state values of LTV ratio as 0.55 and 0.25 for the impatient household $\left(\varepsilon^{H}_{LV}\right)$ and wholesale entrepreneur $\left(\varepsilon^{E}_{LV}\right)$, respectively.

3.1.2 Estimated Parameters

There are two constituents for implementing the Bayesian estimation for the unknown set of parameters: one is the historical data for a set of observables and the other is prior distributions. We consider the historical data series of real output (y), real gross capital formation (ik), real fiscal consumption (g), CPI inflation (pi), retail deposit rate (id), retail loan rate (il) and call money rate (i). Except the series for interest rates and inflation, all other series are made stationary by taking the first differences. Next, the prior distributions for the relevant parameters are specified. Following the literature, we propose the priors that would fit with the Indian data. In course of specifying the priors for the estimable parameters, we declare their respective probability density functions. Selection of the probability density functions for the priors are based on the theoretical implications of the relevant parameters in the model and the evidence from extant studies. As example, the beta distribution is used for the fraction parameters, while the inverse gamma distribution is specified for the parameters with non-negativity constraints. Due to lack of the estimated DSGE models with financial market frictions for the EMDEs, and for India in particular, we have less information regarding the standard deviations of the prior distributions. Thus, we select higher standard deviations and allow the data to determine the location of the relevant parameters. The choice of such higher standard deviation for the prior's distribution is in line with Gabriel et al. (2012).

We obtain the joint posterior distribution of the estimated parameters by following the Markov Chain Monte Carlo-Metropolis-Hastings (MCMC-MH) algorithm. This algorithm simulates the smoothed histogram that approximates to the posterior distributions from the prior distributions for the parameters of our interest. Two parallel chains are used in the MCMC-MH algorithm. The univariate and multivariate diagnostic statistics show convergence by comparing the 'between' and 'within' moments of multiple chains (Brooks and Gelman, 1998).

In Table 2, the prior and posterior means of the estimated parameters are presented. The posterior means of estimated parameters are reported with 90 per cent confidence intervals subject to the posterior standard deviation. Figures 1 to 3 plot the prior versus posterior distributions.[9] Our estimation results suggest that all the parameters are well identified and the posteriors are generated based on the information extracted from the observables.[10] The modes of the posterior distributions are significantly different from the prior distributions which suggest that the information is extracted reasonably well from the data to compute the posterior means. Combining the calibrated parameters of Table 1 and estimated parameters of Table 2, we constitute the baseline parameterisation of our model for the sample period under study.

< Insert Table 2 here >

< Insert Figure 1 to 3 here >

[9] All the quantitative simulation and estimation of the model are done by using Dynare version 4.5.1. For details of the computation procedure, see Dynare User Guide, 2013, Ch. 8.

[10] Following the criteria of asymptotic information matrix and collinearity patterns of the parameters, as suggested by Iskrev (2010a, b) and Iskrev and Rotto (2010a, b), identification of the shocks and the structural parameters are examined. The strength of identification is verified by visual inspection of the plots of asymptotic information matrix.

3.1.3 Model Validation

In order to examine the reliability of baseline model, we compare the model generated second order moments with their data counterpart for the major macroeconomic and financial variables.[11] In Table 3, descriptions of these key variables are provided.

< Insert Table 3 here >

The data and model comparison is done in two steps. First, we check the model generated volatility with empirically observed volatility for a set of real and financial variables. Next, we do the same for key cross-correlations among the macroeconomic and financial variables.[12] In Table 4, relative volatilities of four core variables – consumption to output, capital investment to output, housing investment to output and bank credit to output – along with the volatility of interest rate spread are presented based on the data and model. Although the model slightly overpredicts, it comes close to the volatility indicators moderately.

< Insert Table 4 and 5 here >

Further, we examine the model predictions for interrelationship among the major macroeconomic and financial variables in Table 5. It is noticeable that the model is predicting signs of cross-correlations correctly. Quantitatively, though there are some variations, most of the key business cycle relevant correlations like consumption and output, credit and output, consumption and investment, output and inflation, and the financial cycle relevant correlations like credit-to-output ratio and interest rate spread, credit-to-output ratio and inflation, inflation and interest rate spread, comovements of policy rate, deposit and lending interest rates, and countercyclical movements of real variables to interest rates are explained by the baseline parametric configuration of model.

3.1.4 Variance Decomposition Results

In Table 6, the results of the forecast error variance decomposition (FEVD) of the baseline model are reported. Similar to the vast empirical literature on monetary transmission in

[11] Given the property of stationarity of the model, the data series of output growth, consumption growth, investment growth and credit-to-output ratio are stationarised using Christiano-Fitzgerald asymmetric business cycle filter. The market interest rates, policy interest rate and CPI inflation rate are kept unchanged. Due to unavailability of long time series data related to the housing sector, we find a balanced sample starting from 2009: Q4 to 2015: Q3. Our model validation is, therefore, restricted within that time period.

[12] Note that, for the convenience of illustration and analysis, we have defined a new variable i^l as the weighted sum of retail lending rates to household $\left(i^{bH}\right)$ and firm $\left(i^{bE}\right)$. The weights are assigned based on the steady-state shares of credit to household $\left(\frac{B_H}{B}\right)$ and credit to firm $\left(\frac{B_E}{B}\right)$. i^l represents the economy-wide average retail lending rate of the bank.

India, we find that monetary policy shock can account for only a small portion of output fluctuations (8.72 per cent). In contrast, the shock to fiscal spending explains the variations of aggregate output in a greater magnitude (12.27 per cent). More than 50 per cent of the output fluctuations are explained by the technology shocks. Similar to aggregate output, 75 per cent of the variations of CPI inflation is explained by the supply side disturbances. Monetary policy shock explains little variation of the same (5.32 per cent). Mark-up shock and preference shock for housing appear to be negligible for the movements of real and financial variables.

< Insert Table 6 here >

While the above set of FEVD results align with the findings of existing literature, we obtain an interesting observation from the contribution of the shock to LTV ratio as one of the drivers of business cycle variations. Except the policy rate, shock to LTV ratio for household explains considerable variations across the real, nominal and financial variables of the model. It is also modestly complemented by the similar kind of shock for the entrepreneur. This result provides evidence for the significance of financial shocks in the Indian economy.

As a whole, the bulk of aggregate fluctuations is explained by the technology shocks in the forms of total factor productivity and investment specific technology. The policy shocks remain to be secondary drivers of the cyclical fluctuations in India. Transmission of monetary shock is found to be substantially weak.

3.2 Transmission Mechanism of Monetary Policy Shock

In our baseline NK-DSGE model with financial frictions, monetary policy shock affects the economy from the demand side as well as the supply side. While the demand side effect of the policy shock works directly through the credit channel, it exerts the supply side effect indirectly via the cost of capital and the labour market adjustments. In our model, a positive interest rate shock by the monetary authority leads to co-movements in the credit market interest rates, and sets in the contractionary effects on the key macroeconomic and financial variables like credit to household and firm, consumption, investment in physical capital and housing, labour employment, output and inflation. Although the interest rate, asset price and expectation channels of transmission do exist in the model, the dynamics of MPT is predominantly led by the broad credit channel. Such predominance of credit channel of MPT is a consequence of the bank lending and the balance sheet channels. The in-built feedback mechanism between real and financial sectors of the model pins down the transmission process of these channels. The bank lending channel comes into action as soon as the set of interest rates starts responding to change in the policy rate and affects the demand for credit in the economy. Besides, the balance sheet channels become operational primarily from the borrower's side (household and firm) and then from the lender's side (bank) too. Given the borrower's balance sheet constraint, contraction of credit demand impacts the demand for consumption and investment goods, and factors of production in the real side. By a cascading effect, contraction of credit demand also impacts the bank's profitability and net worth position due to presence of its balance sheet constraint. We spell out the details of transmission process and sectoral adjustments using the IRF plots of Figures 10 to 12 based on a positive monetary policy shock in our model.

< Insert Figure 4 to 6 here >

3.2.1 Transmission to Banking Sector

Policy interest rate rises and gears up the entire spectrum of interest rates of the banking sector as an immediate effect of a monetary policy shock. At the outset, it raises the lending and deposit rates of the wholesale branch of the bank subject to SLR, CRR and bank capital adequacy norms. Then, it gradually passes through the deposit and lending rates of the retail branch. The pass-through of the shock remains incomplete at the retail level interest rates as the wholesale and retail branches face different types and degrees of financial frictions in the form of quadratic adjustment costs. Since the interest rate adjustment cost is higher for retail lending to the entrepreneur compared to the household, impact response of the lending rate on firm's borrowing is relatively lower than the household's borrowing interest rate subject to the respective elasticities of credit demand. Subsequently, the demand for credit by the impatient household declines sharply as compared to the credit demanded by the firm. Parallel to this, interest rate on deposits rises but in a modest way due to presence of statutory norms, reserve requirements and interest rate adjustment cost.

On the whole, frictions in the bank-based credit market leads to sluggish upward movements of the market interest rates and shifts the demand schedules for deposit and loan contracts. Due to elastic nature of market demand, rising loan interest rate reduces the bank's earning from credit, affects its profit adversely and thus, drives down the net worth. As apparent from the impulse response plots, interest rates on deposits show faster mean reversion compared to the interest rates on loan contracts. Credit to household and firm shrinks substantially, interbank borrowing by the bank decreases and banks' profitability goes through a deep negative swing. Following these banking sector adjustments, real segment of our model economy starts responding to the monetary policy shock.

3.2.2 Transmission to Real Sector

Response from Demand Side: Demand side channel operates via the standard consumption Euler relations, optimal conditions for the capital investment and the investment in housing goods. As the retail deposit rate and borrowing rates rise, the opportunity cost of current consumption and housing accumulation increase. Further, with the rising retail borrowing rate, the borrowing constraint becomes tighter for the impatient household and reduces their access to loanable fund. So, both the savers and borrowing households will cut down their demand for final goods consumption and investment in housing. Entrepreneurial consumption also follows the similar pattern. Hence, we observe a negative impact effect on aggregate consumption. However, it is reversed in the subsequent periods and dies down later as the impatient household enjoys a positive wealth effect for a while due to their rising real wage from the labour market adjustments.[13]

In contrast to the declining demand for consumption and investment in housing, demand for capital investment from the wholesale firms does not fall at the impact of the shock as it is fixed by the last period's choice of capital. For this reason, there is no change in the stock of physical capital at the period of impact. Nevertheless, in the forthcoming quarters, investment in capital goods starts decelerating due to increased lending rate for firm's borrowing and tightening of their collateral constraint. Therefore, impulse of the interest rate shock goes through the contraction of credit demand from the borrowing household and firm to contraction of the aggregate demand in the economy.

The real price of investment in housing drops following the decline in the demand for housing accumulation as an impact effect. However, the same for physical capital remains positive and exhibits a sharp rise at the impact due to positive investment demand. It is pacified in the later periods with the downturn in capital investment.

Response from Supply Side: With rising loan interest rate for firms, the wholesale entrepreneur curtails the purchase of new capital from the capital goods producer as their demand for capital is fully backed by the borrowing from the bank subject to the periodical LTV ratio. Since, the demand for capital is optimally set one period ahead, at the impact of policy shock physical capital does not show any movement and stay close to zero. But in the subsequent periods, the entrepreneur reduces the demand for borrowing subject to the collateral constraint, and we observe a steady decline in the capital goods production. Similar to capital goods production, housing goods producing sector also faces significant contraction with a large swing. As the cost of capital rises, demand for capital and its

[13] Markovic (2006) documented similar type of IRF pattern for consumption while investigating on the bank capital channel of transmission for the UK economy.

utilisation descend in the intermediate goods production. Parallel to this, employment level falls as a general equilibrium response to the contraction of derived demand for labour in production and it drives down the aggregate output. It can be observed from the IRF plots that impulse response of aggregate output reflects similar pattern of the impulse response of labour employment.

3.2.3 Transmission to Inflation

In order to understand the MPT to inflation, we have to consider the internal adjustment process in the competitive labour market as it influences the responsiveness of real wage and real marginal cost. The role of expectation formation also comes in, which together with the real marginal cost determines the response of inflation.

In the set-up of competitive labour market, slack in employment affects the impatient household more adversely than the patient ones due to higher share of the first group in the production process.[14] Since the labour market is heavily populated by the borrowing households, cut down in their employment pushes up their real wage significantly high which raises the average real wage of the economy. Consequently, the real marginal cost of production rises. So, we observe the IRF plot of real marginal cost to mimic the pattern of average economy-wide real wage.[15]

However, this acceleration in real marginal cost does not translate into inflation as the standard new Keynesian forward-looking expectation channel comes into action. Given the calibrated parameters, forward-looking component occupies dominant share (nearly 65 per cent) in expectation formation in the price-setting behaviour of the final goods producing firm. Therefore, the price-setting retail firm adjusts its inflation expectation downward, which takes over the momentum of real marginal cost and brings down inflation. This adjustment in inflation dynamics takes a couple of quarters and generates a feeble positive response at the impact level. Nevertheless, the positive effect dies down quickly and inflation starts to decline sharply.

To summarise the MPT results of our model, a positive interest rate shock leads to output contraction and restrains inflation by raising the market interest rates, squeezing the supply of credit, and shrinking the derived demand for factors of production.

[14] National Accounts Statistics (NAS) of Ministry of Statistics and Programme Implementation (MOSPI) on household savings suggests that the proportion of households with financial saving is 23 per cent on an average over the period of 2011-12 to 2015-16. This estimate lies in the confidence interval of our model estimated result of saver's proportion (i.e., 21 to 45 per cent). This observation closely supports the fact that proportion of saver is much lesser than the proportion of borrower in the economy.

[15] In a cross-country study, Normandin (2006) observed positive response of real wage with respect to a positive interest rate shock. He found this result to be consistent with the models of nominal and financial frictions.

4 Discussion

In this section, given the baseline model in place, we conduct the sensitivity experiments with respect to different financial friction and structural parameters of the credit market to evaluate their relative importance in the MPT mechanism. Next, using central bank's loss fuction, we examine the alternative forms of monetary policy rules augmented by financial variables for macroeconomic stabilisation to illustrate the policy implications of our model.

4.1 Financial Frictions and Monetary Transmission: Evidence from Counterfactual Experiments

Our baseline model is characterised by the real, nominal and financial frictions which can potentially determine the pass-through of a monetary policy shock. Given the objective of this paper, we focus on the role of frictions that are directly or indirectly related to the financial sector. Since the commercial banking led credit market depicts the financial sector in our model, we examine different forms of frictions associated with the credit market activities. These frictions are pertaining to either the price of financial resources or availability of the same. Nevertheless, they have distinguishing implications for the transmission mechanism of a monetary policy shock. As these frictions are captured by a set of parameters, we conduct few counterfactual experiments with respect to baseline values of those parameters and investigate their resultant effects on the transmission mechanism.

We examine the change of accumulated effects of a positive monetary policy shock for different counterfactual experiments and draw our inference accordingly. The accumulated effects of monetary policy shock are taken over the period of eight quarters. In the sensitivity experiment, we reduce the friction parameters one at a time and document the corresponding accumulated effects of monetary policy shock on output, inflation and credit. By comparing these new accumulated effects with the baseline ones, as presented in Table 7, we identify the changes in the magnitude of monetary transmission. In order to understand the policy relevance of these financial market frictions more comprehensively, we evaluate the elasticity of monetary transmission in terms of accumulated effects on output and inflation with respect to each parameter and reported in Table 8. This exercise provides a quantitative assessment for the respective role of different friction components for the transmission mechanism in India.

< Insert Table 7 here >

We start with the set of friction parameters that are related to price-setting actions of the financial products like deposit and loan contracts. In our model, there are three adjustment cost parameters associated with the optimal choice of interest rates on the deposits of patient household (ϕ_d) and loans for the borrowing household (ϕ_{bh}) and firm (ϕ_{be}). In case of interest rate adjustment cost for deposits, the result suggests that the frictionless state ($\phi_d = 0$) has negligible impact on the pass-through of policy shock. This may be attributed to the low base of depositors, which is found to be 19.8 per cent of the labour market population.[16] However, in case of the lending rates for household and firm, reductions in interest rate adjustment cost improve the transmission process except for credit. From Table 7, it is apparent that contractionary effect of a positive interest rate shock becomes moderated for output and turns out to be more intensive for inflation in absence of the adjustment costs. In absence of the adjustment costs, flexible retail lending rates lead to faster mobilisation of financial resources and better allocation of the factors of production, and generates stronger effect on inflation reduction with weaker effect for output contraction.

Next, we examine the frictions related to availability of credit. There are two items in the checklist: one is adjustment cost parameter related to maintaining of bank capital adequacy norm and the other is steady-state LTV ratio for collateral constraints. We do the sensitivity experiments for (i) zero adjustment cost for maintaining the bank capital adequacy requirement ($\phi_z = 0$) and (ii) relaxing the collateral constraint for borrowing household by raising the steady-state LTV $\left(\xi^h_{LV} = 0.65\right)$.

From the change of accumulated effects, it can be noticed that the transmission of monetary policy shock becomes more pronounced for both cases though in different directions and different magnitudes. In absence of adjustment cost for maintaining bank capital adequacy requirement, contractionary effect on output and credit deepen substantially compared to the other types of friction components. Besides, it creates inflationary pressure to some extent. This counter-intuitive result appears due to presence of the large segment of credit-constrained borrowers. In absence of the adjustment cost for restoring capital adequacy requirement, net worth of the bank improves, which subsequently strengthens the bank capital channel of monetary transmission. However, such improvement of transmission process is nullified due to presence of the large section of borrowing households in the labour market. The predominance of borrowing households augments the contraction of aggregate demand via demand for credit and leads to pervasive response of real wage in the labour market. In combination of these two actions simultaneously, the improvement of transmission under frictionless state for bank capital adequacy does not show up in the counterfactual results.[17]

[16] To cross-examine this counterfactual result, we look at the accumulated effects of a monetary policy shock for $\phi_d = 0$ with $\gamma = 0.83$. We find that credit (-44.78 per cent) and output (-1.2 per cent) fall substantially lesser while the inflation declines in a large extent (-1.12 per cent) as compared to the baseline results.

[17] For the validation of our argument regarding this counterfactual result, we look at the accumulated effects

The easing of collateral constraint for borrowing household clearly produces a favourable impact for the monetary transmission to output and credit with a significant fall in inflation. The reason is relatively straight forward. Higher long-run LTV provides borrowing household greater access to credit and strengthens the credit channel of transmission. This improves the transmission process of policy shock in the economy.

Looking into the household structure of the underlying economy, it is notable that presence of liquidity-constrained household and large proportion of borrowing household in the labour market create serious bottleneck for the pass-through of monetary policy shock. Typically, the proportions of liquidity-constrained household ($\gamma_R = 0.40$) and impatient / borrowing household ($\gamma(1-\gamma_R) = 0.402$) are inversely related to the MPT mechanism.[18] With declining share of liquidity-constrained household, the transmission of monetary policy improves in the economy. This result supports the fact that greater financial inclusion leads to better transmission process of the policy shock. Along with the proportion of liquidity-constrained household, the share of patient household or saver (19.8 per cent) vis-à-vis impatient household plays an important role for the monetary transmission. As it is evident from our estimation results, the proportion of borrowers is higher than savers in the Indian economy compared to the other economies. This has two implications. First, it limits the scope of the bank to mobilise deposits for loanable fund. Second, there exists relatively larger proportion of credit-constrained borrowers in the competitive labour market, who play a critical role for determining the response of the overall employment, real wage (thereby, real marginal cost and inflation) and finally, aggregate output with respect to a monetary policy shock. Given that a positive policy shock is in place, the contractionary impact on aggregate demand subsequently leads to reduction in the derived demand for labour employment in the labour market. Since, the credit-constrained borrowers occupy the greater share in the production process, they face the fierce hit of the employment cut, which is pivotal for output contraction. Hence, in our counterfactual experiment with $\gamma = 0.83$, we observe little contraction of credit and output and significant reduction of inflation.

< Insert Table 8 here >

To summarise our observations on the role of different frictions related to financial activities, we compute the elasticity of monetary transmission to output and inflation based on

of a monetary policy shock for $\phi_z = 0$ with $\gamma = 0.83$. Although the inflationary response in transmission does not revert to be negative (0.22 per cent), we find that transmission to credit (-58.32 per cent) and output (-2.79 per cent) improves.

[18] Note that low value of γ indicates greater proportion of borrowers compared to savers in the population and vice versa.

the accumulated effect of the shock.[19] The tabulated numbers in Table 11 reveal how the degree of contractionary effect of a monetary policy shock alters with respect to one unit change in the value of respective friction parameter. The value of elasticity also suggests the quantitative importance of the corresponding friction. It is noticeable that except the frictions for deposit rate adjustment and bank capital adjustment, elimination of the financial frictions from the economy reduces the contractionary effects of monetary policy shock on the real output and stabilises inflation to a larger extent. Given the size of the elasticities, it appears that collateral constraint, financially excluded population and low base of depositors play a major role in hindering the transmission process and need more attention from the policymakers. Frictions related to price of financial resources, albeit quantitatively less significant, play a moderate role to improve the pass-through of the transmission mechanism.

4.2 Policy Experiments

Our model is instrumental to examine a variety of policy rules in order to ensure the best possible outcome for macroeconomic stabilisation. With reference to the baseline model, we explore the alternative forms of monetary policy rules by augmenting the Taylor rule specification with financial variables. In Table 9, we list the different forms of asset price and credit augmented monetary policy rules, which are experimented with the baseline model one at a time. The motivation is to check whether the financial variable augmented policy rule can produce a better outcome in terms of economic stabilisation given the choice of policy frameworks. For this purpose, we consider the central bank loss function ($\mathcal{L}_C$) based on variances of inflation and output as given below:

$$\mathcal{L}_C = \sigma_\pi^2 + \alpha_w \sigma_y^2 \tag{74}$$

where, $\alpha_w > 0$ determines the choice of policy framework according to the relative weightage attached with the policy objectives. When $0 < \alpha_w < 1$; it implies that the policy authority is inclined to minimise its welfare loss incurred due to variability of inflation more rather than the variability of output and hence, attaching higher weightage to inflation stabilisation relative to output stabilisation (IT framework). The situation will be reversed when $\alpha_w > 1$, which implies that output stabilisation is relatively more desirable to the policy authority instead of stabilising inflation (YT framework). Finally, for $\alpha_w = 1$, the policy authority remains indifferent or in a neutral position with respect to stabilising its policy objectives (Neutral framework).

[19] The IRF plots of our counterfactual experiments are not reported for brevity. These plots are available from the authors upon request.

< Insert Table 9 here >

For the policy experiment, first, we set up three cases: $\alpha_w = 0.5$, $\alpha_w = 1$ and $\alpha_w = 1.5$ denoting three different frameworks in terms of policy objectives. Then, we simulate the baseline model with policy rules 1 to 6 one at a time, record the model generated volatilities of inflation and output, and compute the hypothetical welfare loss of the central bank subject to the choice of α_w. Rule 1 is the baseline policy rule of standard form with interest rate smoothing, inflation and output. Following Table 2, we use the estimates of policy coefficients (i.e., φ_i, φ_π, and φ_y). In Rules 2 and 3, we extend the baseline policy rule by adding the asset prices, i.e., real prices of housing ($\hat{Q}_t^h$) and physical capital ($\hat{Q}_t^k$), respectively. In Rule 4, we consider the case when policy rate responds to the movements of credit cycle ($\hat{B}_t$). Rule 5 depicts the scenario when the central bank responds to the deviation of credit-to-output ratio from its steady-state level instead of output only. Modifying Rule 5 with output targeting component along with the credit-to-output ratio, we present Rule 6 as suggested by Badarau and Popescu (2012). Following Castelnuovo (2013), we calibrate the value of φ_f as 1.15 except for Rule 6. In case of Rule 6, we set φ_f at 0.1 as suggested in Badarau and Popescu (2014).

< Insert Table 10 here >

The results of model simulation with alternative monetary policy rules are presented in Table 10. Except the case of housing price augmented Taylor rule, it is found that the standard form of Taylor rule with forecast-based inflation and contemporaneous output stands out as the optimal one across all the policy frameworks. Housing price augmented Taylor rule (i.e., Rule 2) performs marginally better than the conventional Taylor rule as it reduces the volatility of output mildly. In contrast, adjusting policy interest rate to smoothen the credit cycle (Rules 4 to 6) does not seem to be useful. In fact, it exacerbates the volatilities of inflation and output. Moreover, comparing three different policy frameworks we find that inflation stabilisation is the most desirable policy option for the central bank as it leads to minimum welfare loss irrespective of the policy rules. Overall, it appears that targeting financial variables in the monetary policy rule may not be appropriate for the purpose of economic stabilisation.

5 Conclusion

In this paper, we have studied the role of financial frictions emerging from different structural bottlenecks and institutional impediments of the bank-led credit market in the transmission channels of monetary policy in India. Examining the friction of financial sector is important as this type of frictions debilitate the pass-through of monetary policy both from the policy instrument to intermediate targets and intermediate targets to the policy objectives. We have addressed this issue using an NK-DSGE model with a banking sector. The model is augmented with the Indian economy-specific features, estimated with the quarterly data (1999:Q4 to 2015:Q3) and validated with the business cycle facts of the key macroeconomic and financial variables. The baseline model replicates a set of stylised facts like: (i) co-movements of the interest rates with incomplete pass-through, (ii) countercyclical movement of interest rate spread, (iii) presence of the bank lending channel along with the interest rate, credit and bank capital channels, and (iv) weak pass-through of MPT to output and inflation. In addition, it identifies a pervasive response of real wage in the labour market adjustment and underscores the role of forward-looking expectation for stabilising inflation. Considering the degree of MPT in terms of accumulated effects obtained from the 'baseline model' as the *benchmark*, we undertake the counterfactual experiments on the elements of financial frictions. Our experiment provides a comparative analysis on the different credit market frictions which helps evaluating their respective role and quantitative significance. It is found that the collateral constraints and financially excluded segment of the economy cause major obstacles in the MPT while interest rate rigidity on the lending rates is of secondary importance.

There are a few caveats to be mentioned regarding our study. In the modelling framework, structure and implications of the interbank market and soveriegn bond market are not addressed explicitly. Oligopolistic competition of the banking sector and increasing role of the non-bank financial corporations are missing, which would provide more appropriate depiction of the Indian financial sector instead of the monopolistically competitive commercial banking sector. Also, the model does not take into account any labour market frictions. In the side of quantitative analysis, the baseline parameterisation of the model is done using Bayesian methodology, which is sensitive to the choice of prior distributions and the historical data series of the observables. Hence, results of the study critically depend on the microfoundation and parametric configuration of the model.

The study can be enriched if the asymmetric pass-through of the monetary policy shock to the retail interest rates of the commercial bank, subject to the market liquidity, is explained. Besides, the role of informal credit market can be examined as it is quite relevant for India. One can also extend the baseline model to the open economy set-up. All these potential extensions may improve the fitness of the model and provide useful insights for the transmission mechanism of monetary policy in the economy.

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7 List of Tables

Table 1: Calibrated Parameters of Baseline Model

α	β_P	β_I	β_E	δ_h	δ_k	σ_l	ε^y	ε_{LV}^H	ε_{LV}^E	γ_R
0.25	0.96	0.95	0.92	1.25%	2.5%	0.25	7	0.55	0.25	0.4

π	ϑ_p	θ_p	ε^d	ε^{bH}	ε^{bE}	α_c	α_s	κ_b	C/Y	G/Y	I^k/Y	D/Y	B_E/B
4%	118	0.55	13	2.5	5.4	5.5%	21.5%	0.1	0.54	0.1	0.21	0.52	0.65

Table 2: Prior Densities and Posterior Estimates of Baseline Model

Estimated	Priors		Posteriors		Estimated	Priors		Posteriors	
Parameters	Mean	Distribution	Mean	90% C.I.	Parameters	Mean	Distribution	Mean	90% C.I.
γ	0.50	Beta	0.33	[0.21, 0.45]	ρ_g	0.50	Beta	0.35	[0.26, 0.43]
ϑ_h	4	Gamma	4.09	[3.57, 4.57]	ρ_y	0.50	Beta	0.49	[0.34, 0.65]
ϑ_k	4	Gamma	3.70	[3.23, 4.19]	ρ_h	0.50	Beta	0.52	[0.27, 0.78]
ϕ_d	10	Gamma	13.45	[6.88, 19.53]	ρ_{LV}^H	0.50	Beta	0.92	[0.88, 0.96]
ϕ_{bH}	10	Gamma	13.06	[6.98, 18.49]	ρ_{LV}^E	0.50	Beta	0.85	[0.76, 0.94]
ϕ_{bE}	10	Gamma	21.12	[13.04, 28.58]	σ_a	0.10	Inv. Gamma	0.022	[0.019, 0.026]
ϕ_z	5	Gamma	4.85	[4.07, 5.62]	σ_{ik}	0.10	Inv. Gamma	1.616	[1.238, 1.960]
φ_i	0.80	Beta	0.86	[0.82, 0.91]	σ_m	0.10	Inv. Gamma	0.014	[0.012, 0.016]
φ_π	1.50	Normal	1.47	[1.41, 1.52]	σ_g	0.10	Inv. Gamma	0.319	[0.269, 0.366]
φ_y	0.25	Normal	0.24	[0.18, 0.31]	σ_y	0.10	Inv. Gamma	0.512	[0.359, 0.666]
ρ_a	0.50	Beta	0.91	[0.87, 0.94]	σ_h	0.10	Inv. Gamma	0.113	[0.023, 0.278]
ρ_{ik}	0.50	Beta	0.61	[0.52, 0.69]	σ_{LV}^H	0.10	Inv. Gamma	0.316	[0.261, 0.371]
ρ_m	0.50	Beta	0.33	[0.15, 0.51]	σ_{LV}^E	0.10	Inv. Gamma	0.081	[0.068, 0.094]

Table 3: Description of Key Variables

Variable	Description	Variable	Description	Variable	Description
y	Output	qh	Real price of housing	u	Capital utilization
c	Consumption	mc	Real marginal cost	lp	Labour Suply of Patient HH
ik	Capital investment	pi	CPI inflation	lip	Labour Suply of Impatient HH
ih	Housing investment	i	Policy interest rate	bh	Household's borrowing
b	Borrowing	is	Wholesale deposit rate	be	Entrepreneur's borrowing
h	Housing	ib	Wholesale lending rate	bib	Interbank borrowing
k	Capital	id	Retail deposit rate	rw	Aggregate real wage
l	Labour	il	Aggregate Retail lending rate	ibh	Retail lending rate for bh
qk	Real price of capital	pi_b	Bank's profit	ibe	Retail lending rate for be

Table 4: Comparing Volatilities between Data and Model

Target	Data	Model
$\left(\frac{\sigma_c}{\sigma_y}\right)$	1.27	1.15
$\left(\frac{\sigma_{i^k}}{\sigma_y}\right)$	3.03	3.26
$\left(\frac{\sigma_{i^h}}{\sigma_y}\right)$	1.55	2.46
$\left(\frac{\sigma_b}{\sigma_y}\right)$	1.64	1.99
$\sigma_{\left(i^l/i^d\right)}$	0.21	0.24

Table 5: Comparing Cross-correlations between Data and Model

Correlations	Data	Model	Correlations	Data	Model
(y, c)	0.30	0.43	$\left(i^k, \pi\right)$	0.28	0.19
(y, b)	0.20	0.12	$\left(i^k, i\right)$	-0.56	-0.14
$\left(y, i^h\right)$	0.46	0.50	$\left(i^h, i\right)$	-0.37	-0.59
(y, π)	-0.29	-0.34	$\left(i^h, i^d\right)$	-0.31	-0.70
(y, i)	-0.64	-0.25	$\left(i^h, i^l\right)$	-0.52	-0.61
$\left(b/y, i^l/i^d\right)$	-0.52	-0.54	$\left(i, i^d\right)$	0.90	0.60
$(b/y, \pi)$	-0.27	-0.38	$\left(i, i^l\right)$	0.80	0.93
$\left(c, i^k\right)$	-0.39	-0.60	$\left(i^d, i^l\right)$	0.84	0.74
$\left(i^k, b\right)$	0.20	0.12	$\left(i^l/i^d, \pi\right)$	0.40	0.30

Table 6: Baseline Result of Variance Decomposition of Key Aggregates (in per cent)

Variables	ξ_A	ξ_{i^k}	ξ_m	G	ξ_y	ξ_{LV}^H	ξ_{LV}^E	ξ_h
y	48.95	5.58	8.72	12.27	0.25	21.59	2.64	0.00
π	37.32	38.13	5.32	0.25	3.00	14.21	1.77	0.00
b	21.49	24.20	20.09	0.53	0.66	29.95	3.09	0.00
c	37.00	34.11	4.59	2.19	0.23	20.09	1.78	0.00
l	7.62	8.59	20.26	24.32	0.58	33.16	5.46	0.00
i^k	22.59	57.97	3.32	0.95	0.37	10.23	4.57	0.00
i^h	19.07	16.26	30.16	5.83	1.03	22.07	5.58	0.00
i	24.68	30.64	32.61	0.06	0.66	9.91	1.44	0.00
i^d	28.36	32.57	4.95	12.69	1.88	12.17	7.36	0.02
i^l	33.81	37.70	11.40	0.21	0.82	14.03	2.03	0.00

Table 7: Sensitivity Experiments on Accumulated Effects of Monetary Policy Shock (in per cent)

Variables	y	π	b
Baseline	-6.78	-0.88	-67.91
$\phi_d = 0$	-6.80	-0.87	-67.88
$\phi_{bh} = 0$	-6.73	-0.91	-68.89
$\phi_{be} = 0$	-6.47	-1.06	-68.66
$\phi_z = 0$	-11.37	0.49	-107.07
$\xi_{LV}^h = 0.65$	-4.28	-1.22	-64.21
$\gamma_R = 0.10$	-8.44	-0.92	-74.06
$\gamma = 0.83$	-1.20	-1.13	-44.78

Table 8: Financial Frictions and Responsiveness of Monetary Policy Transmission

Friction Parameters	Elasticity of Output Effect	Elasticity of Inflationary Effect
ϕ_d	0	0.01
ϕ_{bh}	0.01	-0.03
ϕ_{be}	0.05	-0.21
ϕ_z	-0.68	1.56
ξ_{LV}^h	-2.03	2.09
γ_R	1.15	-0.05
γ	-0.54	0.18

Table 9: Monetary Policy Rules Augmented by Financial Variables

Policies	Taylor Rule Specifications	Parameters
Rule 1	$\hat{\imath}_t = \varphi_i \hat{\imath}_{t-1} + (1-\varphi_i)\left[\varphi_\pi E_t\{\hat{\pi}_{t+1}\} + \varphi_y \hat{Y}_t\right] + \varepsilon_{m,t}$	$Baseline\ Values$
Rule 2	$\hat{\imath}_t = \varphi_i \hat{\imath}_{t-1} + (1-\varphi_i)\left[\varphi_\pi E_t\{\hat{\pi}_{t+1}\} + \varphi_y \hat{Y}_t + \varphi_f \hat{Q}^h_t\right] + \varepsilon_{m,t}$	$\varphi_f = 1.15$
Rule 3	$\hat{\imath}_t = \varphi_i \hat{\imath}_{t-1} + (1-\varphi_i)\left[\varphi_\pi E_t\{\hat{\pi}_{t+1}\} + \varphi_y \hat{Y}_t + \varphi_f \hat{Q}^k_t\right] + \varepsilon_{m,t}$	$\varphi_f = 1.15$
Rule 4	$\hat{\imath}_t = \varphi_i \hat{\imath}_{t-1} + (1-\varphi_i)\left[\varphi_\pi E_t\{\hat{\pi}_{t+1}\} + \varphi_y \hat{Y}_t + \varphi_f \hat{B}_t\right] + \varepsilon_{m,t}$	$\varphi_f = 1.15$
Rule 5	$\hat{\imath}_t = \varphi_i \hat{\imath}_{t-1} + (1-\varphi_i)\left[\varphi_\pi E_t\{\hat{\pi}_{t+1}\} + \varphi_y \left(\hat{B}_t - \hat{Y}_t\right)\right] + \varepsilon_{m,t}$	$\varphi_y = 0.25$
Rule 6	$\hat{\imath}_t = \varphi_i \hat{\imath}_{t-1} + (1-\varphi_i)\left[\varphi_\pi E_t\{\hat{\pi}_{t+1}\} + \varphi_y \hat{Y}_t + \varphi_f \left(\hat{B}_t - \hat{Y}_t\right)\right] + \varepsilon_{m,t}$	$\varphi_y = 0.25$; $\varphi_f = 0.1$

Table 10: Alternative Policy Rules and Central Bank Welfare Loss

Different Policy Rules	σ^2_π (in %)	σ^2_y (in %)	CB Loss (in %) IT ($\alpha_w = 0.5$)	Neutral ($\alpha_w = 1$)	YT ($\alpha_w = 1.5$)
1	0.39	1.10	0.94	1.49	2.04
2	0.39	1.08	0.93	1.47	2.01
3	0.60	1.17	1.19	1.77	2.36
4	1.87	1.39	2.57	3.26	3.96
5	0.53	1.24	1.15	1.77	2.39
6	0.56	1.12	1.12	1.68	2.24

8 List of Figures

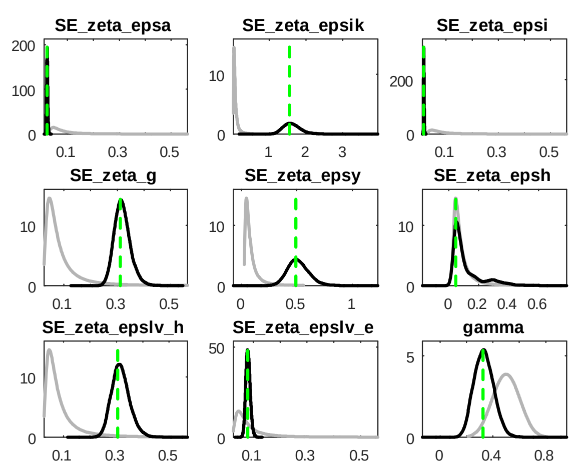

Figure 1: Priors and Posteriors

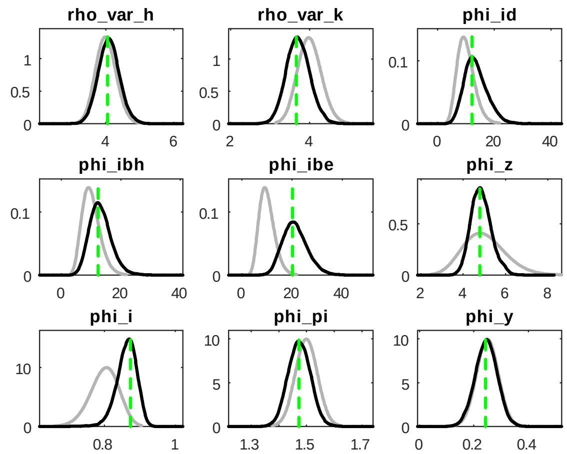

Figure 2: Priors and Posteriors

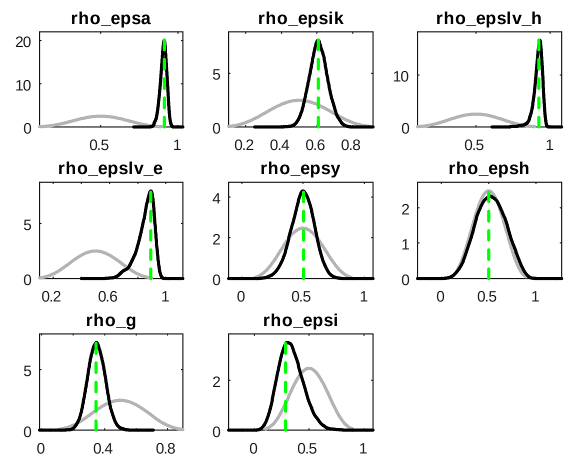

Figure 3: Priors and Posteriors

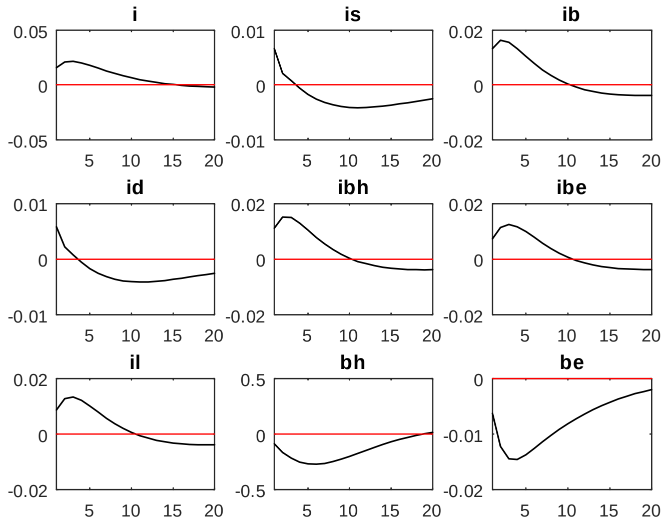

Figure 4: Effects of Monetary Policy Shock

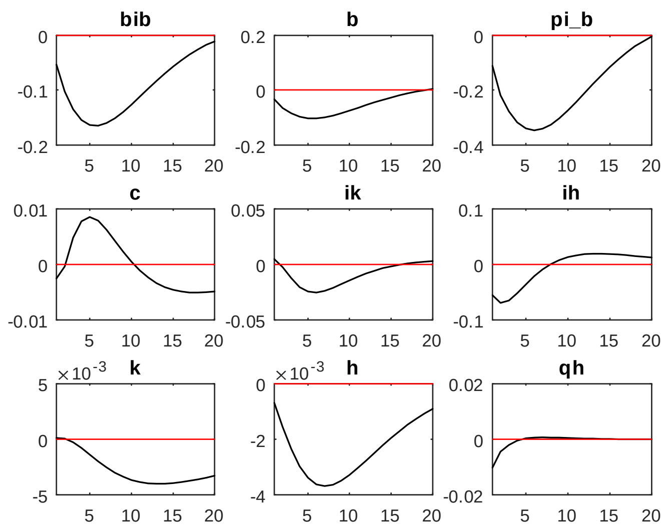

Figure 5: Effects of Monetary Policy Shock

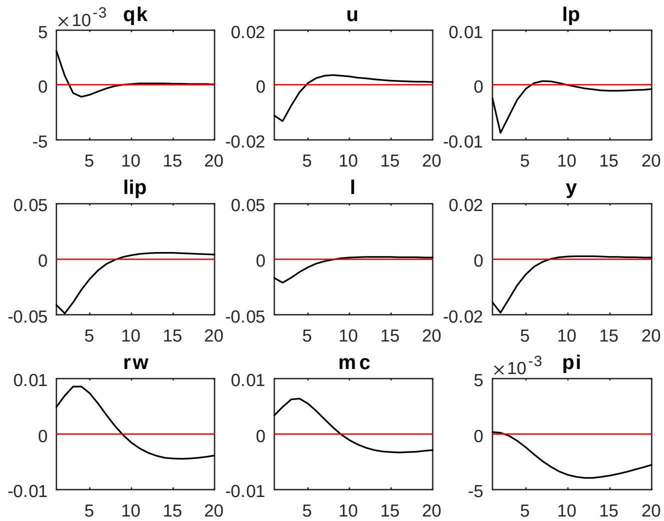

Figure 6: Effects of Monetary Policy Shock