Policy Errors and Business Cycle Fluctuations: Evidence from an Emerging Economy*

Abhishek Kumar[†]
Sushanta Mallick[‡]
Apra Sinha[§]

November 9, 2021

Abstract

In the immediate aftermath of the global financial crisis, the monetary policy in India became accommodative as in other major economies, but the policy subsequently turned highly contractionary despite falling inflation, which we characterize as policy errors. Government expenditure also had similar pattern. This paper therefore estimates a medium scale New Keynesian model (with earnings and assets based collateral constraint) to explore the impact of such policy errors on Indian business cycles, capturing the prevailing narrative on both monetary and fiscal policies along with the actual inflation scenario. Our smoothed estimates of mark-up, productivity, interest rate and government expenditure shocks mimic the actual transition of the economy, with both policy shocks moving together in

*Acknowledgement: The authors would like to thank the editor and three anonymous reviewers of this journal for their constructive comments that contributed to the improvement of this paper. We are solely responsible for any error that might yet remain. An earlier version of this paper was presented at the Allied Social Science Associations (ASSA) Annual Virtual Meeting, 3-5 Jan 2021, and the authors are thankful to the participants for their comments.

[†]Indira Gandhi Institute of Development Research, Mumbai, India. E-mail: abhishek@igidr.ac.in
[‡]Queen Mary University of London, London, UK. E-mail: s.k.mallick@qmul.ac.uk
[§]University of Delhi, Delhi, India. E-mail: asinha@arsd.du.ac.in

a similar pattern in the post crisis period. We find that the interest rate policy was highly contractionary during 2013-16 which led to significantly lower output. We rationalize that if supply side shocks (adverse productivity or mark-up) dominate, such policy errors tend to occur, suggesting that policy makers need to pay attention to the sources of inflation in a developing economy while setting demand-management policies. Given the current pandemic being more of a adverse supply shock, similar policy errors are likely to occur if interest rate responds to this type of inflationary shocks.

JEL classification: E31; E32; E52; E57

Keywords: DSGE; India; Output Gap; Inflation; Monetary Policy; Supply Shock; Government Expenditure Shock; Crowding Out

1 Introduction

Understanding the macroeconomic dynamics of India as a key small emerging market economy has become important, given the high-speed growth over the last two decades. However, in the recent years during the current decade, the deceleration in growth has raised questions about the sources of the business cycle fluctuations. In the third quarter of 2019, the growth rate was registered at 4.5 percent per annum. Figures 1 and 2 show the nine quarter moving average growth rates of a few important macro variables, including the nine quarter moving average of 15-91 days treasury bills rate. We use moving averages to depict the broad trend in macro variables for several reasons. First, quarter on quarter growth rates of macro variables are volatile and thus it becomes difficult to see the underlying pattern in the data. Second, moving averages are also a measure of trend and is widely used in time series and macro literature. The peak of 9 quarter moving average growth of GDP [1] in our sample occurs in 2010:Q1 and the vertical red line in each graph represents that peak.

[1] In the case of India, continuous series of GDP at factor cost is not available, although we use it in this paper. In the data section, we explain the methodology behind the construction of continuous GDP.

As we can see from Figure 1, the moving average of growth of GDP started declining after 2010:Q1, then picked up slightly in 2014:Q1 and again started decreasing. Overall the 9 quarter moving average of quarterly growth rate declined from a peak of 2.43% in 2010:Q1 to 1.80% by end of 2014:Q4. Broadly similar pattern is observed for investment growth (growth of gross fixed capital formation), consumption growth (growth of private final consumption expenditure) and growth of government final consumption expenditure. Even the moving average of inflation was declining after 2010:Q1. Between 2010:Q1 to 2014:Q4, the 9 quarter moving average of quarterly inflation declined from 3.03% to 1.42%. But the interest rate was increasing and remained at elevated levels for long. Between 2010:Q1 to 2014:Q4, the 9 quarter moving average of annual interest rate increased from from 4.61% to 8.01%. In later years higher interest rate was partly done in light of newly instituted inflation targeting framework. Moving average growth of real credit (nominal credit deflated by consumer price index) and deposit started decreasing slightly later but show similar patterns as moving average of GDP growth. In this paper, our objective is to build a new Keynesian model to understand these patterns and identify the plausible reasons for growth and investment slowdown. Reduced form estimates would be of little use because of serious endogeneity concerns among these variables.

This paper is related to two strands of literature on new Keynesian models. First, our new Keynesian model includes investment and borrowing and is related to a large literature on firm financing and borrowing constraints. A significant portion of firm investment is financed by borrowing funds. These borrowing constraints are mainly of two types. In Townsend (1979), Stiglitz and Weiss (1981) and Holmstrom and Tirole (1997), firm's borrowing depends on cash flows from operations and investment, i.e., their earning. Also the firm may be constrained to borrow based on the collateral they can offer (liquidation value of assets). Assets based collateral constraint appear in (Hart and Moore (1994); Shleifer and Vishny (1992); Kiyotaki and Moore (1997); Bernanke, Gertler, and Gilchrist (1999); and Brunnermeier and Sannikov (2014)). Dreschel (2018) brings these two types of borrowing constraints and concludes that these two types of borrowing constraint give rise to different transmission mechanisms of macroeconomic shocks such as investment

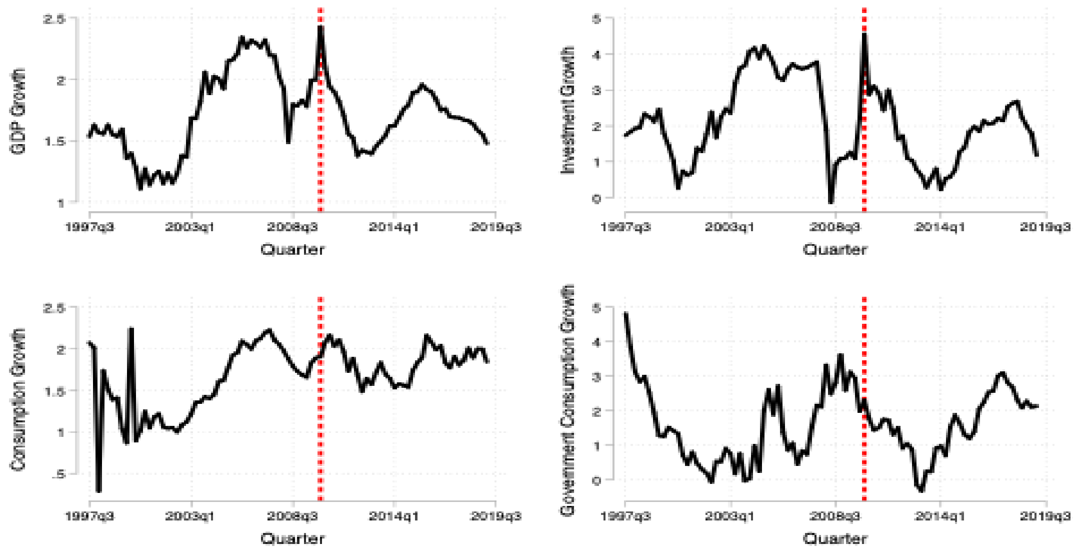


Figure 1: Nine Quarter Moving Average Growth Rates

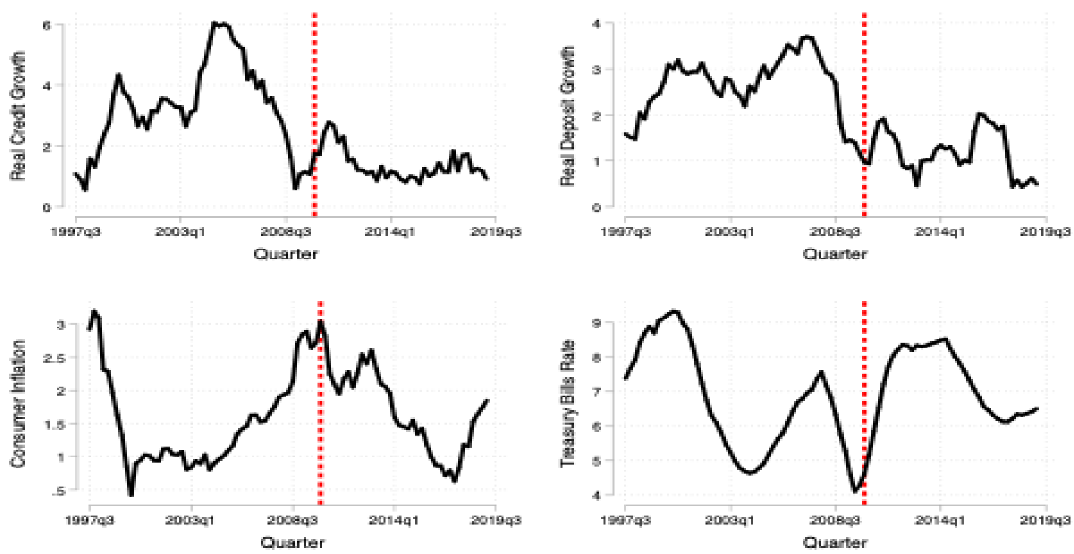


Figure 2: Nine Quarter Moving Average Growth Rates

specific technology shock. We show in the model section that the impact of investment specific technology shock can be very different depending upon the type of borrowing constraints faced by the firm. A positive shock to marginal efficiency of capital lowers the relative price of capital, and therefore the value of the collateral goes down leading to reduced borrowing in the case of assets based collateral constraint. At the same time, this shock leads to higher earnings that may allow to borrow more in the case of earning-based borrowing constraints. Lian and Ma (2018) suggest that 20 percent of corporate debt is collateralized by assets while 80 percent is earning based lending in the case of the US.

Second, our paper is related to the new Keynesian models estimated for emerging economies including India. In the recent years, new Keynesian models have been used to study frictions in the context of emerging economies. While Barrail (2020) show that productivity shocks are a more relevant source of business cycle fluctuations in Mexico, Ghate et al. (2018) explore the role of agricultural terms of trade in India, and Gabriel et al. (2012) suggest financial frictions are important in the Indian economy. Goyal and Kumar (2020) find that supply shocks dominate in determining inflation using these models [2]. Related empirical VAR literature by Mallick and Sousa (2013) and Holtemoller and Mallick (2016) show that inflationary supply shocks lead to an aggressive behaviour from central banks towards inflation stabilization following shocks to global commodity prices, while making inflation mostly as an adverse supply shock in India unlike in advanced economies where inflation is predominantly a demand side issue (see Kumar et al., 2021).

On the other hand, in terms of monetary transmission, Banerjee et al. (2019) argue that interest rate transmission is weaker in India and the shock to base money has more persistent effect on output than interest rate shock. Goyal and Kumar (2021) suggest that interest rate shocks are important, and out of the total variance of output explained by interest rate shock, almost one third is explained by anticipated interest rate shock.

[2]Goyal and Kumar (2018) use a non-separable money in utility to explore the role of money in Indian business cycles and conclude that it plays a significant role, which is different from the role of money in the US and Euro-zone as in Ireland (2001) and Andres et al. (2006) respectively.

We thus relate this paper to the recent literature on agnostic identification in structural vector auto-regression (SVAR), by identifying interest rate shock as a shock that explains maximum forecast error variance of interest rate over 40 quarters. Uhlig (2004), Barsky and Sims (2011), Kurmann and Otrok (2013), Francis et al. (2014) and Cascaldi-Garcia and Galvao (2018) use similar methodology to identify a structural shock of interest. This method is agnostic as it does not require the commonly-used zero restrictions as in Cholesky decomposition.

The model used in this paper is a medium scale new Keynesian model with borrowing constraints (see Wieland et al., 2012) for a large number of new Keynesian models used in the literature). The final good producer is a competitive aggregator as it is standard in new Keynesian models. The intermediate good producers operate in a monopolistic product market with nominal rigidity. The labour market is competitive[3]. Intermediate goods firms are owned by households and they give dividend to a household. These firms accumulate capital and borrow. They face both types of borrowing constraint (a linear combination of earnings-based and assets-based collateral constraint). Interest paid by firms on their borrowing is less than the interest required by households because interest paid by firms is tax deductible. This effective lower interest rate faced by firms ensures that they borrow from the household up to their borrowing constraint and that is why it becomes binding at the steady state. This interest rate differential is the subsidy to the firm and is paid by the government. Households pay lump-sum taxes to the government. Central bank implements monetary policy using a modified Taylor rule.

We use this model to extract smoothed estimates of shocks. Specifically we are interested in three shocks: a mark-up shock, interest rate shock and government expenditure shock. Interest rate and government expenditure shocks are the two main policy instruments for macro stabilization. These estimated shocks depict the transition of the economy in the last decade.

[3]In the case of India, hardly any reliable long term employment data is available and therefore, we refrain from modelling the labour market.

With the onset of the financial crisis, India implemented massive cut in interest rate and implemented huge fiscal stimulus. Our interest rate and government expenditure shocks capture these movement in macro policies. Already rising inflation started increasing at faster rate and remained high for sometime. Between 2007:Q1 to 2010:Q1, the 9 quarter moving average of quarterly inflation increased from 1.54% to 3.03%. Inflation started slowing down after 2010Q1 and as global oil prices started decreasing in 2014, inflation started decreasing sharply too. During 2014-16, crude oil price decreased by more than 50%. Estimated mark-up shock captures these movements in inflation. During this period, India also moved towards inflation targeting framework. Interest rate was kept high despite decreasing inflation during 2013-2016 which led to significant output cost. The model based interest rate shock closely resembles the interest rate shock identified from SVAR which gives us further confidence about the robustness of our result. Government expenditure led to crowding out of private investment but supported output through fiscal multiplier channel. Interest rate does not have strong effect on investment as on output. This is partly due to the fact that high interest rate episodes in our sample are also associated with fiscal consolidation and vice versa. This co-movement of these two main stabilization policies is one of the main findings of this paper. Interest rate was highly contractionary, leading to significantly lower output gap during 2013-16. Higher interest rate reduces demand and thus decreases profitability of firms which leads to default on their borrowings. Results obtained in this paper suggest that higher interest rate disrupts financial intermediation by creating bad (non-performing) assets for the banking sector.

The plan of this paper is as follows. Section 2 gives evidence from SVAR in favour of the new Keynesian model. The interest rate shocks identified using SVAR show large policy errors and excessive tightening in the aftermath of financial crisis. Section 3 describes the model. Section 4 briefly explains the data. Section 5 presents the results and analysis. This section contains the discussion on parameter estimates, estimated smoothed shocks, impulse responses, forecast error variance decomposition and counterfactual simulation. This is followed by concluding remarks in Section 6.

2 Evidence From VAR

2.1 Identification using Cholesky Decomposition and Max Share

A reduced form VAR with l lags is given by:

$$Y_t = B_1 Y_{t-1} + B_2 Y_{t-2} + ... + B_l Y_{t-l} + u_t$$

Where Y_t is a vector of n variables. One can obtain the moving average representation of the same as given below:

$$Y_t = C(L) u_t$$

Where $C(L) = \sum_{l=0}^{\infty} C_l L^l$. The reduced from shocks (u_t) and their variance covariance matrix (Σ) is known; $\Sigma = E\left(u_t u_t'\right)$. One can assume structural errors with unit variances and therefore the objective is to find A matrix satisfying:

$$\Sigma = AE\left(v_t v_t'\right) A' = AA' \quad \text{Where } E\left(v_t v_t'\right) = I$$

Since there are only $n^2 - \frac{n^2-n}{2} = \frac{n(n-1)}{2}$ free elements in Σ, we can only identify $\frac{n(n-1)}{2}$ elements of A. Literature suggest zero restrictions to achieve that. One particular form of zero restrictions is well known which is Cholesky decomposition. Let $\tilde{A}$ be the Cholesky decomposition

$$\Sigma = \tilde{A}\tilde{A}' \quad u_t = \tilde{A}\tilde{v}_t$$

Using this we can obtain structural moving average which gives us impulse responses and forecast error variance decomposition.

$$Y_t = C(L)\tilde{A}\tilde{v}_t$$

We are not interested in all shocks, but one. Therefore, we want to identify only first column of A, see Uhlig (2004) for definition and details. Start with Cholesky decomposition of Σ (we can use any other decomposition as well). Cholesky decomposition identifies n shocks as given above. The main insight from Uhlig (2004) is that there must be an orthogonal matrix Q, i.e., an $n \times n$ matrix Q satisfying $QQ' = I$ so that $A = \tilde{A}Q$. This is because $\tilde{A}\tilde{A}' = AA' = \tilde{A}QQ'\tilde{A}' = \Sigma$. We can obtain the impulse response given by Cholesky decomposition as given below:

$$\tilde{R}(L) = C(L)\tilde{A}$$

The impulse response from any arbitrary decomposition is given by

$$R(L) = C(L)A$$

Since $A = \tilde{A}Q$

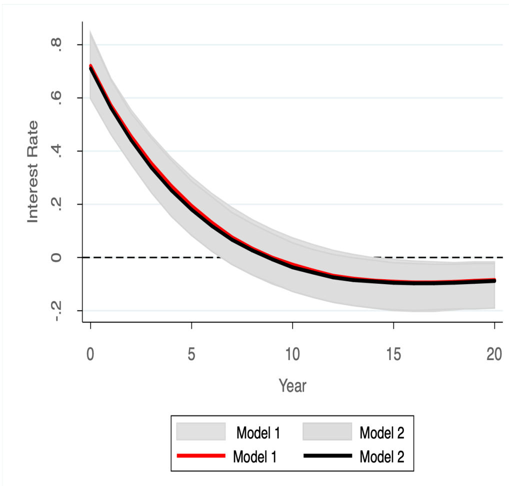
$$R(L) = C(L)\tilde{A}Q \implies R(L) = \tilde{R}(L)Q$$

The point is that the impulse response to any arbitrary decomposition can be obtained by multiplying the impulse response from Cholesky decomposition with an orthonormal matrix of $n \times n$. The response at time l is related as $R_l = \tilde{R}_l Q$. Thereafter, we can calculate forecast error variance. We identify the first column of Q i.e., interest rate shock as the shock which explains maximum forecast error variance of interest rate over forty quarters. We order interest rate as the first variable in our VAR.

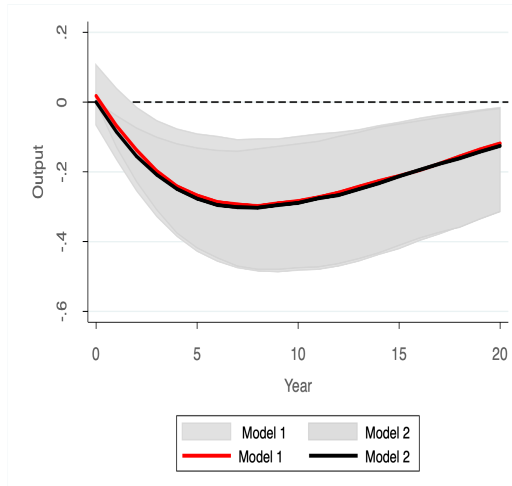
2.2 Cholesky decomposition

We start with a simple three variable VAR. We use linearly detrended output gap, inflation and interest rate. We use lag length 1, as all information criteria suggest lag length 1. We use two different identification (Cholesky) schemes to identify interest rate shock. In the first identification scheme called 'Model 1' interest rate is most exogenous variable and does not respond to output and inflation contemporaneously. Interest rate is followed by output and inflation. In the second identification scheme called 'Model 2' interest rate responds to output and inflation contemporaneously and it appears at the end. Output appears first and is followed by inflation.

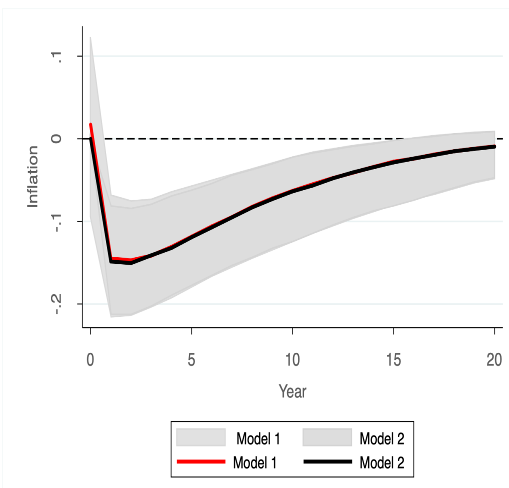
Figure 3(d) gives the interest rate shocks identified using these two schemes. Both these schemes identifies similar shocks and therefore we can say that the shock is not driven by a particular ordering. The interest rate shocks clearly show excessive stimulus during the crisis and excessive tightening after that.



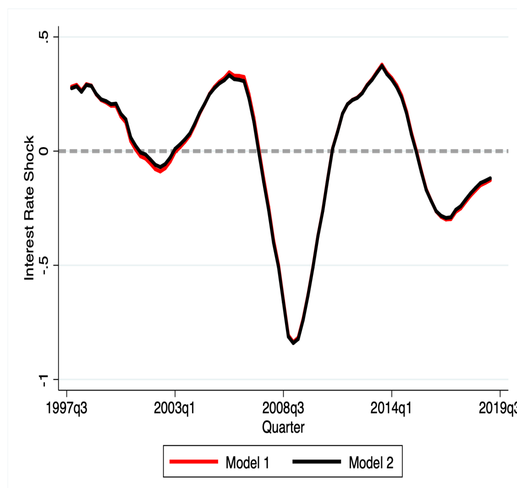
(a) Response of Interest Rate



(b) Response of Output

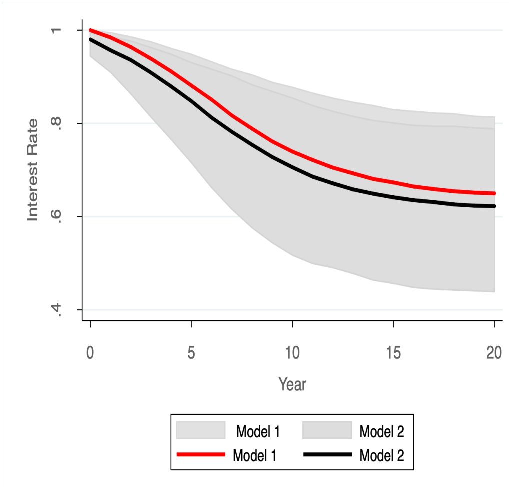


(c) Response of Inflation

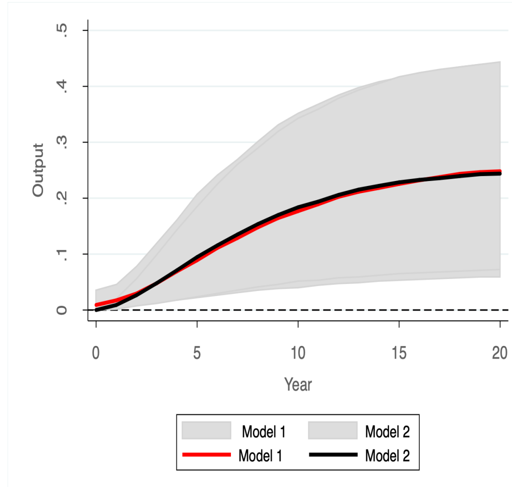


(d) Interest Rate Shocks

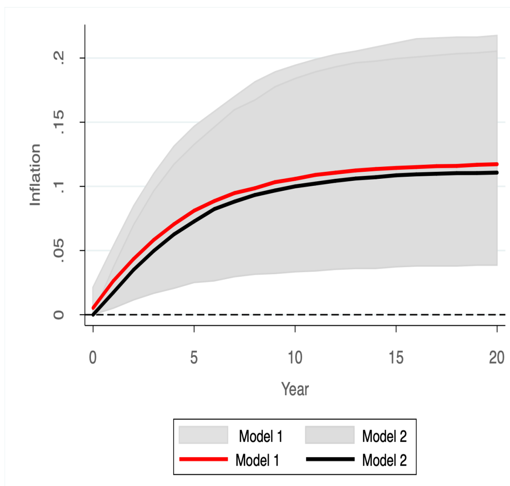
Figure 3: Response of inflation, output, and interest rate due to interest rate shock from Models 1 and 2. Variable ordering in Model 1: interest rate, output and inflation. Variable ordering in Model 2: output, inflation, and interest rate.



(a) Forecast Error Variance of Interest Rate



(b) Forecast Error Variance of Output



(c) Forecast Error Variance of Inflation

Figure 4: Variance decomposition of inflation, output, and interest rate due to interest rate shock from Model 1 and Model 2. Variable ordering in Model 1: interest rate, output and inflation. Variable ordering in Model 2: output, inflation, and interest rate.

This gives credence to our hypothesis in this paper that interest rate shock suggests large policy errors which led to growth slowdown. The responses of model variables, interest rate, output gap, and inflation due to interest rate shock are given in figure 3.

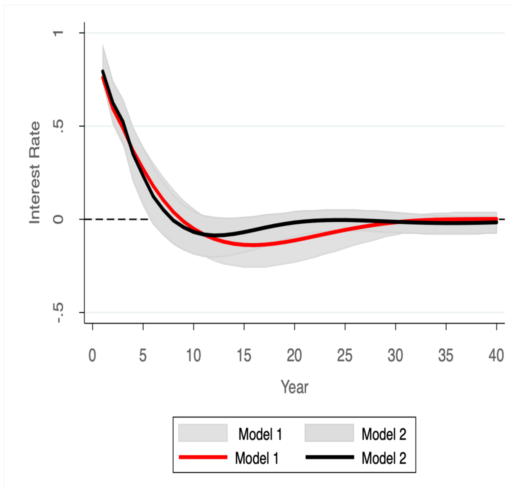
These are same as expected in a new Keynesian model. Both output gap and inflation fall due to interest rate shock. Figure 4 gives the forecast error variance of model variables: interest rate, output gap, and inflation due to interest rate shock. Interest rate shock explains about 50% of the forecast error variance of interest rate by the end of five years. Also, interest rate shock explains around 30% of the forecast error variance of output and 10% of the forecast error variance of inflation by the end of five years.

2.3 Max Share Identification

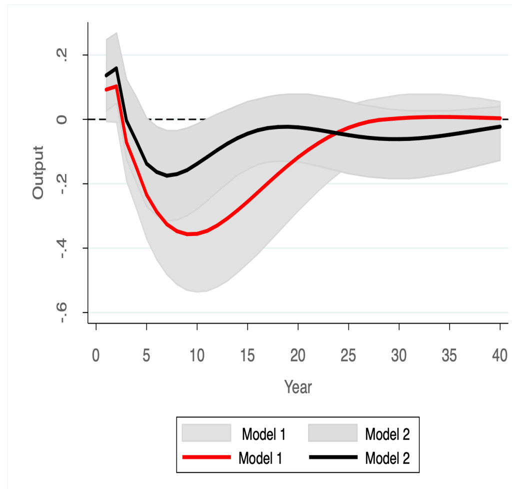
Again, We start with a simple three variable VAR, using linearly detrended output gap, inflation and interest rate. We use lag length 2 as we identify only one shock in this case i.e., interest rate shock. This is called 'Model 1'. We extend the model by including linearly detrended investment, credit and government expenditure. This is called 'Model 2'. We use these same six variables to estimate the new Keynesian model in the next section. In both cases, we identify the interest rate shock as the shock which explains maximum forecast error variance of interest rate over 40 quarters.

Figure 5(d) gives the interest rate shocks identified from these two models. Both these schemes identify similar shocks but the extended model identifies slightly more contractionary interest rate policy post-financial crisis where the interest rate shock attains maximum value in our sample too. The interest rate shocks clearly show excessive stimulus during the crisis and excessive tightening after that.

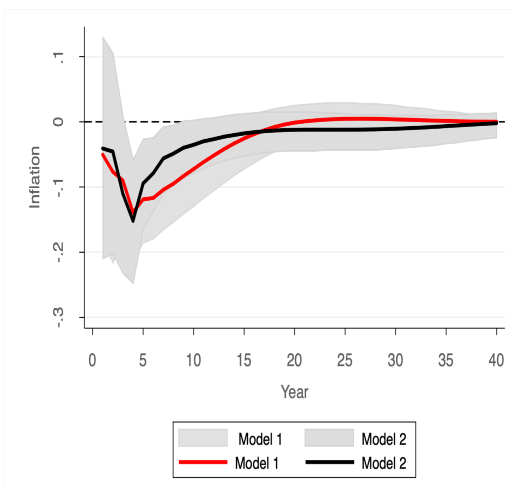
The responses of model variables: interest rate, output gap, and inflation, due to interest rate shock are given in figure 5. Both output gap and inflation fall due to interest rate shock. But the extended model leads to much less peak response of output in comparison to the model 1. Figure 6 gives the forecast error variance of model variables: interest rate, output gap, and inflation, due to the interest rate shock. Interest rate shock explains about 60-80% of the forecast error variance of interest rate by the end of ten years. Also, interest rate shock explains around 10-40% of the forecast error variance of output and around 10% of the forecast error variance of inflation by the end of ten years.



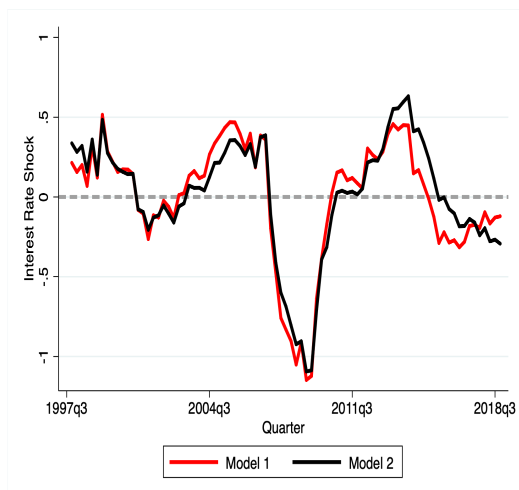
(a) Response of Interest Rate



(b) Response of Output

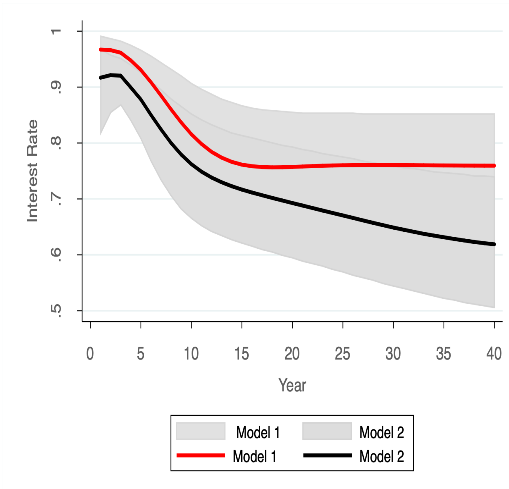


(c) Response of Inflation

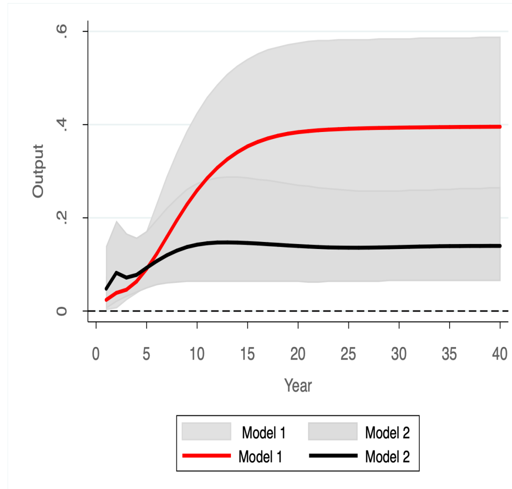


(d) Interest Rate Shocks

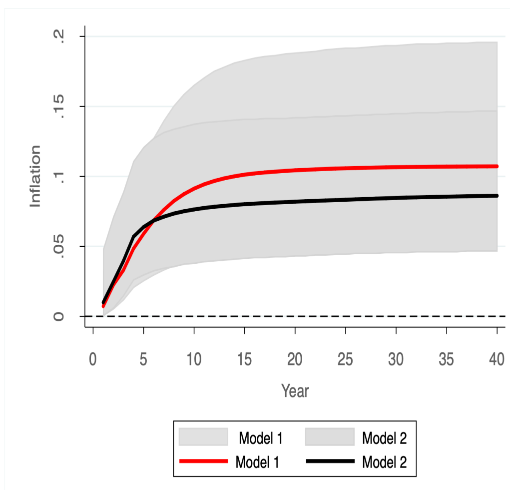
Figure 5: Response of inflation, output, and interest rate due to interest rate shock from model 1 and model 2. Model 1 is with linearly detrended output gap, inflation and interest rate. Model 2 is further includes linearly deterended investment, credit and government expenditure. In both cases, we identify the interest rate shock as the shock which explains maximum forecast error variance of interest rate over 40 quarters.



(a) Forecast Error Variance of Interest Rate



(b) Forecast Error Variance of Output



(c) Forecast Error Variance of Inflation

Figure 6: Variance decomposition of inflation, output, and interest rate due to interest rate shock from Model 1 and Model 2. Model 1 is with linearly detrended output gap, inflation and interest rate. Model 2 further includes linearly deterended investment, credit and government expenditure. In both cases, we identify the interest rate shock as the shock which explains maximum forecast error variance of interest rate over 40 quarters.

In the next section, we estimate a new Keynesian model and compare the interest rate shock from the model with VAR based shocks obtained in this section. Thereafter, we do counterfactual analysis to understand the extent of policy error.

3 Model

3.1 Household

The household enters period t holding B_{t-1} units of one-period nominal loans made to the firm. In addition to this endowment, the household pays a lump sum tax T_t. It is given by $t_t = \frac{T_t}{p_t}$ in real terms where p_t is aggregate price index. During period t households supply $n_{i,t}$ units of labour to each intermediate goods producing firm indexed over $i \in [0, 1]$ for a total of n_t and receive real wage $w_t = \frac{W_t}{p_t}$ where W_t is nominal wage. They own intermediate goods producers and receive real profits, $d_t = \frac{D_t}{p_t}$ from firms where D_t is nominal profit. Their loan or bonds issued to firms in real terms is given by $b_t = \frac{B_t}{p_t}$. Using this one can write the real value of last period loan in the current period t as $\frac{B_{t-1}/p_{t-1}}{p_t/p_{t-1}} = \frac{b_{t-1}}{\pi_t}$ [4]; where $\pi_t = \frac{p_t}{p_{t-1}}$ is the gross inflation. Consumption is measured in real terms and all other prices are given in terms of consumption unit. The household carries b_t amount of loan to the next period. r_t is one period nominal rate of interest. The budget constraint of the household for each period t in real terms is given by:

$$\frac{b_{t-1}}{\pi_t} + w_t n_t + d_t = c_t + \frac{b_t}{r_t} + t_t$$

The Lagrange is given by:

$$\begin{aligned} \ell &= E_0 \sum_{t=0}^{t=\infty} \beta^t \left[a_t \left(log(c_t - \gamma c_{t-1}) - \frac{n_t^{(1+1/\eta)}}{1+1/\eta} \right) \right] \\ &+ \beta^t \lambda_t \left(\frac{b_{t-1}}{\pi_t} + w_t n_t + d_t - c_t - \frac{b_t}{r_t} - t_t \right) \end{aligned}$$

[4]We use nominal debt contract instead of real debt contract and this allows for debt deflation.

Where β is the discount factor. Inter-temporal preference shock or shock to β, a_t follows a stationary autoregressive process given by:

$$log(a_t) = \rho_a log(a_{t-1}) + \epsilon_{a,t} \qquad 0 \leq \rho_a < 1 \qquad \epsilon_{a,t} \sim N(0, \sigma_a^2) \tag{E.1}$$

Households choose c_t, n_t, b_t. First order conditions are given below:

First order condition with respect to c_t:

$$\lambda_t = \frac{a_t}{c_t - \gamma c_{t-1}} - \beta\gamma E_t\left(\frac{a_{t+1}}{c_{t+1} - \gamma c_t}\right) \tag{1}$$

First order condition with respect to n_t:

$$n_t^{1/\eta} = \lambda_t w_t \tag{2}$$

First order condition with respect to b_t:

$$\frac{\lambda_t}{r_t} = \beta\frac{\lambda_{t+1}}{\pi_{t+1}} \tag{3}$$

First order condition with respect to λ_t:

$$\frac{b_{t-1}}{\pi_t} + w_t n_t + d_t = c_t + \frac{b_t}{r_t} + t_t \tag{4}$$

3.2 Final Good Producer

The final good is produced by a firm in a perfectly competitive market, which combines the intermediate goods using the constant returns to scale technology given by:

$$y_t \leq \left[\int_0^1 {y_{i,t}}^{(\theta_t-1)/\theta_t} di\right]^{\theta_t/(\theta_t-1)}$$

Where θ_t is the elasticity of substitution between intermediate goods $y_{i,t}$ with given price $p_{i,t}$. Profit maximization leads to the following demand for intermediate goods:

$$y_{it} = \left[\frac{p_{i,t}}{p_t}\right]^{-\theta_t} y_t$$

Where

$$p_t = \left[\int_0^1 {p_{i,t}}^{1-\theta_t} di\right]^{1/(1-\theta_t)}$$

And θ_t which gives markup follows an autoregressive process as given by:

$$log\,(\theta_t) = (1-\rho_\theta)log(\theta) + \rho_\theta log(\theta_{t-1}) + \epsilon_{\theta,t} \qquad 0 \leq \rho_\theta < 1 \qquad \epsilon_{\theta,t} \sim N(0, \sigma_\theta^2) \quad \text{(E.2)}$$

$\epsilon_{\theta,t}$ gives markup shock in the model.

3.3 Intermediate Goods Producers

Each intermediate good is produced by a monopolistically competitive firm according to a constant returns to scale technology by using labour from households and capital. The production technology is given by:

$$y_{i,t} = z_t k_{i,t-1}^\alpha n_{it}^{1-\alpha}$$

Where α and $1-\alpha$ is capital and labour share of output respectively. The above equation can be written using demand from the final goods producer as:

$$\left(\frac{p_{i,t}}{p_t}\right)^{-\theta_t} y_t = z_t k_{i,t-1}^\alpha n_{i,t}^{1-\alpha}$$

z_t is a stationary technology shock given by:

$$log\,(z_t) = \rho_z log\,(z_{t-1}) + \epsilon_{z,t} \quad 0 \leq \rho_z < 1 \qquad \epsilon_{\mu,t} \sim N(0, \sigma_z^2) \qquad \text{(E.3)}$$

Their earning before interest, tax and depreciation is given by

$$e_{i,t} = y_{i,t} - w_{i,t} n_{i,t} = z_t k_{i,t-1}^\alpha n_{it}^{1-\alpha} - w_{i,t} n_{i,t}$$

This earning can be used as a collateral to secure loan. They produce capital using final good obtained from the final good producer. The capital producing technology is given by:

$$k_{i,t} = (1-\delta)\, k_{i,t-1} + \mu_t \left(1 - S\left(\frac{i_{i,t}}{i_{i,t-1}}\right)\right) i_{i,t}$$

Where $S\left(\frac{i_t}{i_{t-1}}\right)$ is investment adjustment cost as in Christiano, Eichenbaum and Evans (2005). We assume adjustment cost as given below.

$$S\left(\frac{i_{i,t}}{i_{i,t-1}}\right) = \frac{S}{2}\left(\frac{i_{i,t}}{i_{i,t-1}} - 1\right)^2$$

μ_t is investment specific technology shock as in Justiniano, Primiceri and Tambalotti (2009) and Dogan (2019).

$$log\,(\mu_t) = \rho_\mu log\,(\mu_{t-1}) + \epsilon_{\mu,t} \quad 0 \leq \rho_\mu < 1 \qquad \epsilon_{\mu,t} \sim N(0, \sigma_\mu^2) \tag{E.4}$$

Furthermore, the adjustment of its nominal price p_{it} is assumed to be costly, where the cost function is convex in the size of the price adjustment. Following Rotemberg (1982, 1987), these quadratic adjustments costs are defined as [5]:

$$\frac{\varphi_p}{2}\left[\frac{p_{i,t}}{\pi_{t-1}^{\tau}\pi^{1-\tau}p_{i,t-1}} - 1\right]^2 y_t$$

Where $\varphi_p > 0$ is the price adjustment cost and π represents the steady rate of inflation being targeted by the central bank with $0 \leq \tau \leq 1$. Extent of backward and forward looking inflation depends upon τ. When $\tau = 0$, then price setting is purely-forward looking and for $\tau = 1$ price setting is purely backward-looking. This specification leads to partial indexation when $0 < \tau < 1$ implying that some prices are set in a backward looking manner. Firms are owned by household and they maximize the value of the firm as perceived by the household. Their flow budget constraint in real terms is given by:

$$d_{i,t} + i_{i,t} + \frac{b_{i,t-1}}{\pi_t} + \left[\frac{p_{i,t}}{\pi_{t-1}^{\tau}\pi^{1-\tau}p_{i,t-1}} - 1\right]^2 y_t = \frac{p_{i,t}}{p_t} y_{i,t} - w_{i,t}n_{i,t} + \frac{b_{i,t}}{R_t}$$

[5] See Orland and Roos (2019) for experimental evidence about these quadratic adjustment cost.

One can substitute the value of $i_{i,t}$ from capital accumulation equation in above (ignoring the adjustment cost) to obtain; $d_{it} + \frac{k_{i,t}}{\mu_t} + \frac{b_{i,t-1}}{\pi_t} = \frac{p_{i,t}}{p_t} y_{i,t} - w_{i,t} n_{i,t} + \frac{b_{i,t}}{R_t} + (1-\delta)\frac{k_{i,t-1}}{\mu_t}$. $1/\mu_t$ is the relative price of capital and thus a positive shock to μ_t will lead to decline in the price of the capital. Therefore, in case of assets based collateral constraint, a shock to marginal efficiency of capital will lead to lower borrowing as the value of collateral goes down.

The effective interest rate faced by intermediate goods producing firm is given by:

$$R_t = 1 + (r_t - 1)(1 - \text{tax rate}) \tag{5}$$

It is because r_t represent gross interest rate received/demanded by the household. R_t is less than the interest rate received by the household. The interest payment is tax deductible for firms whereas it is not for the household. Since the household does not receive this tax rebate, there is a heterogeneity in the desire to borrow and save across sectors of the economy. The household wants to lend funds, and debt is in positive net supply in equilibrium (Drechsel, 2018). Effectively the tax advantage makes the firms less impatient and firms borrow up to their constraint. This type of tax exists in many countries and the related modeling assumption follows Hennessy and Whited (2005). One can model this in another way without tax also. This will require another set of households as bank and firms with lower discount factor as in Iacoviello (2015). Using the demand from final goods producer the flow budget constraint for the firm is given by:

$$d_{i,t} + i_{i,t} + \frac{b_{i,t-1}}{\pi_t} + \left[\frac{p_{i,t}}{\pi_{t-1}^{\tau}\pi^{1-\tau}p_{i,t-1}} - 1\right]^2 y_t = \left[\frac{p_{i,t}}{p_t}\right]^{1-\theta_t} y_t - w_{i,t}n_{i,t} + \frac{b_{i,t}}{R_t}$$

One can solve for d_{it} whose discounted present value needs to be maximized:

$$d_{i,t} = \left[\frac{p_{i,t}}{p_t}\right]^{1-\theta_t} y_{i,t} - w_{i,t}n_{i,t} + \frac{b_{i,t}}{R_t} - i_{i,t} - \frac{b_{i,t-1}}{\pi_t} - \left[\frac{p_{i,t}}{\pi_{t-1}^{\tau}\pi^{1-\tau}p_{i,t-1}} - 1\right]^2 y_t$$

Apart from this, firm faces a borrowing constraint. There are two types of collateral possible, earning as well as assets based collateral. We use a linear combination of earning and assets as collateral:

$$\frac{b_{i,t}}{r_t} < \omega \underbrace{\theta_e \left(z_t k_{i,t-1}^{\alpha} n_{i,t}(i)^{1-\alpha} - w_{i,t} n_{i,t}\right)}_{\text{Earning}} + (1-\omega) \underbrace{\theta_k p_{k,t+1} \pi_{t+1} (1-\delta) k_{i,t}}_{\text{Assets}}$$

ω is the weight attached to earning based borrowing. θ_e and θ_k are similar to loan to value ratio. Loan to value ratio is defined as the amount of loan one can have for one unit value of assets/earning. In our model, these loan to value ratios are fixed but one can allow them to vary exogenously and that will give rise to a shock to loan to value ratio. This shock can be utilized to explore the role of macro prudential policy as well as the interaction between macro prudential policy and interest rate policy[6]. Firms maximize present value of dividend payments as valued by the saver household. Firms choose n_{it}, b_{it}, k_{it}, i_{it} and p_{it}. Their problem is given by:

$$\begin{aligned}
&\sum \beta^t \lambda_t \left(\left[\frac{p_{i,t}}{p_t}\right]^{1-\theta_t} y_t - w_{i,t} n_{i,t} + \frac{b_{i,t}}{R_t} - i_{i,t} - \frac{b_{i,t-1}}{\pi_t} \right) \\
&-\beta^t \lambda_t \frac{\varphi_p}{2} \left[\frac{p_{i,t}}{\pi_{t-1}^{\tau} \pi^{1-\tau} p_{i,t-1}} - 1 \right]^2 y_t + \beta^t \lambda_t \Omega_t \left((1-\delta)\, k_{i,t-1} + \mu_t \left(1 - S\left(\frac{i_{i,t}}{i_{i,t-1}} \right) \right) i_{i,t} - k_{it} \right) \\
&+\beta^t \lambda_t \Lambda_t \left(\omega \theta_e \left(z_t k_{i,t-1}^{\alpha} n_{i,t}^{1-\alpha} - w_{i,t} n_{i,t} \right) + (1-\omega) \theta_k p_{k,t+1} \pi_{t+1} (1-\delta) k_{i,t} - \frac{b_{i,t}}{r_t} \right) \\
&+\beta^t \lambda_t \Pi_t \left(z_t k_{i,t-1}^{\alpha} n_{i,t}^{1-\alpha} - \left(\frac{p_{i,t}}{p_t} \right)^{-\theta_t} y_t \right)
\end{aligned}$$

Since these firm are identical and make same choices, we write the first order condition without the i subscript (symmetric equilibrium). Firm's optimality conditions with respect to k_t:

[6] We do some robustness exercise with loan to value ratio shock in the next section.

$$\lambda_t \Omega_t = \beta \lambda_{t+1} \Omega_{t+1}(1-\delta) + \lambda_t \Lambda_t (1-\omega)\theta_k p_{k,t+1}\pi_{t+1}(1-\delta)$$

$$+\beta\lambda_{t+1}\Lambda_{t+1} w \theta_e \alpha z_{t+1} k_t^{\alpha-1} n_{t+1}^{1-\alpha} + \beta \lambda_{t+1} \mathit{\Pi}_{t+1} \alpha z_{t+1} k_t^{\alpha-1} n_{t+1}^{1-\alpha} \quad (6)$$

Firm's optimality conditions with respect to i_t:

$$\lambda_t = \lambda_t \Omega_t u_t \left(1 - S\left(\frac{i_t}{i_{t-1}}\right)\right) - \lambda_t \Omega_t \mu_t \frac{i_t S}{i_{t-1}} \left(\frac{i_t}{i_{t-1}} - 1\right) + \beta \lambda_{t+1} \Omega_t \mu_{t+1} \frac{i_{t+1}^2 S}{i_t^2} \left(\frac{i_{t+1}}{i_t} - 1\right) \quad (7)$$

Firm's optimality conditions with respect to n_t:

$$w_t n_t = (1-\alpha)\mathit{\Pi}_t y_t + (1-\alpha)\Lambda_t \omega \theta_e y_t - \Lambda_t \omega \theta_e w_t n_t \quad (8)$$

Firm's optimality conditions with respect to b_t:

$$\lambda_t \frac{1}{R_t} = \frac{\beta \lambda_{t+1}}{\pi_{t+1}} + \frac{\lambda_t \Lambda_t}{r_t} \quad (9)$$

By definition the price of capital $p_{k,t}$ is given by the (this is the marginal value (measured in goods)) value of an additional unit of installed capital.

$$p_{k,t} = \frac{\lambda_t \Omega_t}{\lambda_t} \quad (10)$$

First order condition with respect to p_{it}:

$$0 = (1-\theta_t)\lambda_t \left[\frac{p_t}{p_t}\right]^{-\theta_t} \frac{y_t}{p_t} + \theta_t \lambda_t \mathit{\Pi}_t \left(\frac{p_t}{p_t}\right)^{-\theta_t - 1} \frac{y_t}{p_t} - \varphi_p \lambda_t \left[\frac{p_t}{\pi_{t-1}^{\alpha} \pi^{1-\tau} p_{t-1}} - 1\right] \left[\frac{1}{\pi_{t-1}^{\tau} \pi^{1-\tau} p_{t-1}}\right] y_t$$

$$+\beta \varphi_p E_t \lambda_{t+1} \left[\frac{p_{t+1}}{\pi_t^{\tau} \pi^{1-\tau} p_t} - 1\right] \left[\frac{p_{t+1}}{\pi_t^{\tau} \pi^{1-\tau} p_t^2}\right] y_{t+1}$$

Multiplying with p_t and dividing by y_t:

$$0=(1-\theta_t)\lambda_t\left[\frac{p_t}{p_t}\right]^{-\theta_t}+\theta_t\lambda_t\Pi_t\left(\frac{p_t}{p_t}\right)^{-\theta_t-1}-\varphi_p\lambda_t\left[\frac{p_t}{\pi_{t-1}^{\alpha}\pi^{1-\tau}p_{t-1}}-1\right]\left[\frac{p_t}{\pi_{t-1}^{\tau}\pi^{1-\tau}p_{t-1}}\right]$$

$$+\beta\varphi_pE_t\lambda_{t+1}\left[\frac{p_{t+1}}{\pi_t^{\tau}\pi^{1-\tau}p_t}-1\right]\left[\frac{p_{t+1}}{\pi_t^{\tau}\pi^{1-\tau}p_t}\right]\left[\frac{y_{t+1}}{y_t}\right] \tag{11}$$

First order condition with respect to Ω_t:

$$(1-\delta)\,k_{t-1}+\mu_t\left(1-S\left(\frac{i_t}{i_{t-1}}\right)\right)i_t=k_t \tag{12}$$

First order condition with respect to Π_t:

$$z_tk_{t-1}^{\alpha}n_t^{1-\alpha}=y_{it} \tag{13}$$

First order condition with respect to Λ_t:

$$\omega\theta_e\left(z_tk_{t-1}^{\alpha}n_t^{1-\alpha}-w_tn_t\right)+(1-\omega)\theta_kp_{k,t+1}\pi_{t+1}(1-\delta)k_t=\frac{b_t}{r_t} \tag{14}$$

3.4 Government

The government balances budget. The tax requirement is subsidy given to the firm because of differences in interest rate and public spending G_t. The tax (T) in nominal term is given by:

$$T_t=\frac{B_t}{R_t}-\frac{B_t}{r_t}+P_tG_t$$

Which we can write in real terms as:

$$t_t=\frac{b_t}{R_t}-\frac{b_t}{r_t}+G_t \tag{15}$$

Real public spending (G_t) evolves as a time varying fraction of real output.

$$G_t = \left(1 - \frac{1}{g_t}\right) y_t \tag{16}$$

One can shock the nominal government spending too but we will shock real government spending. The government spending shock (g_t) follows the stationary stochastic process given by:

$$log(g_t) = (1 - \rho_g) log(g) + \rho_g log(g_{t-1}) + \epsilon_{g,t} \quad 0 \leq \rho_g < 1 \qquad \epsilon_{g,t} \sim N(0, \sigma_g^2) \tag{E.5}$$

$(1 - \frac{1}{g})$ gives steady state value to government consumption to output ratio which we calibrate from the data.

3.5 Monetary Authority

Monetary policy is represented by a generalized Taylor (1993) rule of the form:

$$log\left(r_t\right) = \rho_r log\left(r_{t-1}\right) + (1 - \rho_r)\left[\rho_\pi log\left(\frac{\pi_t}{\pi}\right) + \rho_y log\left(\frac{y_t}{y}\right)\right] + \epsilon_{r,t} \qquad \epsilon_{r,t} \sim N(0, \sigma_r^2) \tag{17}$$

Central bank responds to deviation of inflation (π_t) from inflation being targeted by the central bank (π) and output gap $\hat{y}_t$. In the model, the central bank targets steady state inflation. Yoshida (2007) presents theoretical details of this type of interest rate rule.

3.6 Aggregate Resource Constraints

Aggregate resource constraint is given by (ignoring adjustment cost as they are zero in steady state):

$$c_t + i_t + G_t = y_t \tag{18}$$

Dividend condition is given by:

$$d_t = y_t - w_t n_t + \frac{b_t}{R_t} - i_t - \frac{b_{t-1}}{\pi_t} \tag{19}$$

There are eighteen $(c_t, n_t, b_t, d_t, k_t, i_t, G_t, t_t, y_t\ R_t, r_t, \pi_t, \lambda_t, \Omega_t, \Lambda_t, \mathit{\Pi}_t, p_{k,t}, w_t,)$ endogenous variables in the system and 19 equations. One equation out of (4), (18) and (19) is redundant due to Walras law. Remaining 18 equations can be used to solve for 18 endogenous variables in the system. $a_t, \theta_t, z_t, \mu_t, g_t$ gets determined from (E.1-E.5). We compute the steady state of the model and log linearize it around the steady state.

Then we use Klein (2000) algorithm to solve the model and obtain a state space representation. Kalman filter is used to write the likelihood, and the Bayesian method is used to estimate the model.

3.7 Discussion on Earning and Assets Based Constraint

One can substitute the value of $i_{i,t}$ from capital accumulation equation in flow budget constraint for the firm ignoring the adjustment cost to obtain $d_{it} + \frac{k_{i,t}}{\mu_t} + \frac{b_{i,t-1}}{\pi_t} = \frac{p_{i,t}}{p_t} y_{i,t} - w_{i,t} n_{i,t} + \frac{b_{i,t}}{R_t} + (1-\delta)\frac{k_{i,t-1}}{\mu_t}$. $1/\mu_t$ is the relative price of capital and thus a positive shock to μ_t will lead to decline in the price of capital.

A positive investment specific technology shock decreases the value of collateral and decreases borrowing in the case of assets based collateral. But a positive investment specific technology shock increases earnings and therefore increases borrowing in case of earning-based borrowing constraint. This is shown in figure 7. As we can see investment specific technology shocks are likely to reduce borrowing in the case of assets-based constraint both in the long run as well as short run. Whereas in the case of earning based constraint, borrowing is likely to increase in the short run. As explained in the introduction, the credit growth has slowed down substantially in the recent years and part of the decline could be due to these technology shocks and loan agreement in place. Therefore, we allow both types of loan agreement to be there and estimate their proportion from data.

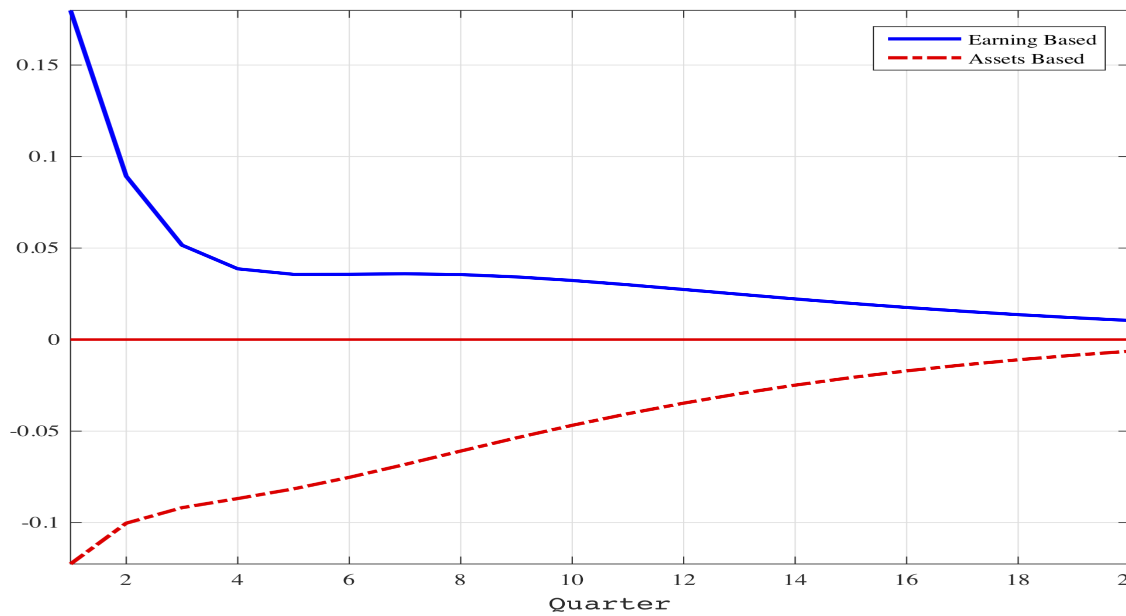


Figure 7: Response of Borrowing to a Permanent Investment Specific Technology Shock

4 Data

We estimate the model using linear de-trended natural logarithm of real GDP[7], real government final consumption expenditure, gross fixed capital formation, private final consumption expenditure[8], aggregate deposit, aggregate non food credit, quarter-to-quarter changes in the natural logarithm of consumer price index and short-term nominal interest rate i.e, 15-91 days treasury bills rate. All variables are seasonally adjusted except

[7]Ideally it should be in per capita terms, but since there is no quarterly data on working population, we used the growth rate only.

[8]Given three different base years (1999-00, 2004-05 and 2011-12) for the national accounts data, we create a comparable continuous series by employing a commonly used linking procedure which generally involves the backward retropolation of the most recent available series using the growth rates of older series called retropolation between the benchmark years of successive series (Fuente, 2009). Given two series on an economic variable, we calculate the log difference between the old and new series (when the new series starts and we have data for both series) and add this difference to old series to create a uniform series thus preserving the growth rate of the old series. The implicit assumption is that the "error" contained in the older series remains constant over time, that is, it already existed at time 0 and that its magnitude, measured in proportional terms, has not changed between 0 and the time when the new series start.

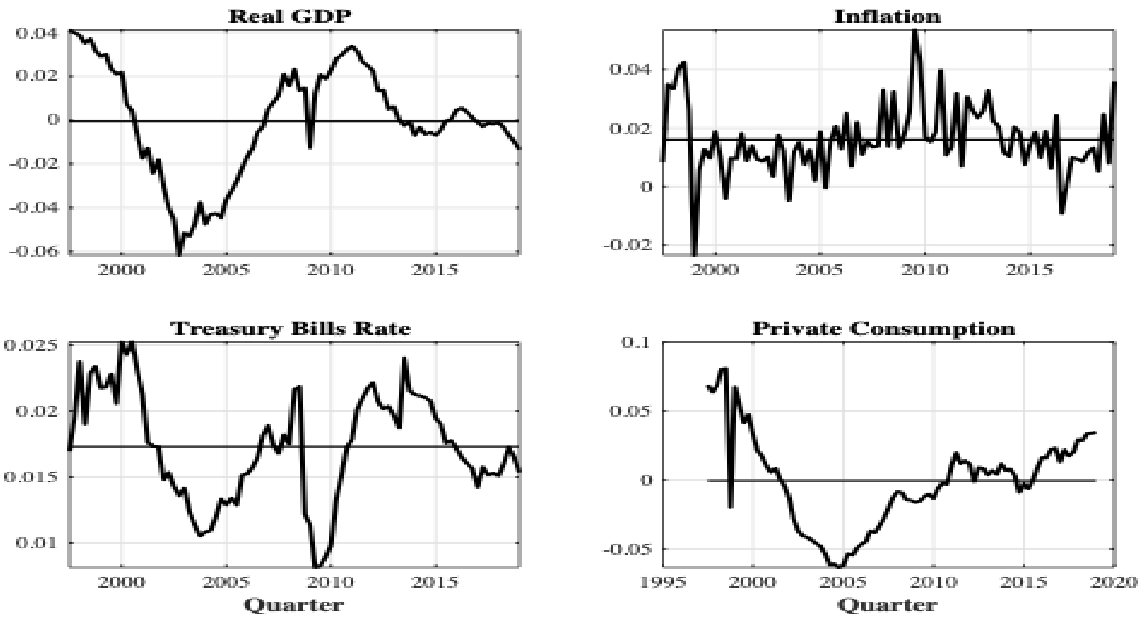


Figure 8: Linearly Detrended Data Used in Estimation

15-91 days treasury bills rate.

National accounts variables are available from 1996:Q2 onwards but credit and deposit are available from 1997:Q2 onwards only. Therefore, we use data from 1997:Q2 to 2019:Q1. Figures 8 and 9 give data used in the estimation.[9]

4.1 The relationship between income and borrowing

Given that we are using both income and asset based collaterals in determining the amount of borrowing, it is important to show in this section the correlation between income and borrowing using micro-data. We provide this evidence using BSE (Bombay Stock Exchange) 500 companies of India, in support of the relationship between income and borrowing during a year.

[9]Garcia-Cicco et al. (2009) criticize using short quarterly data particularly due to the inability to characterize non-stationary shocks using a short span of data. But we are limited by the availability of the quarterly data set.

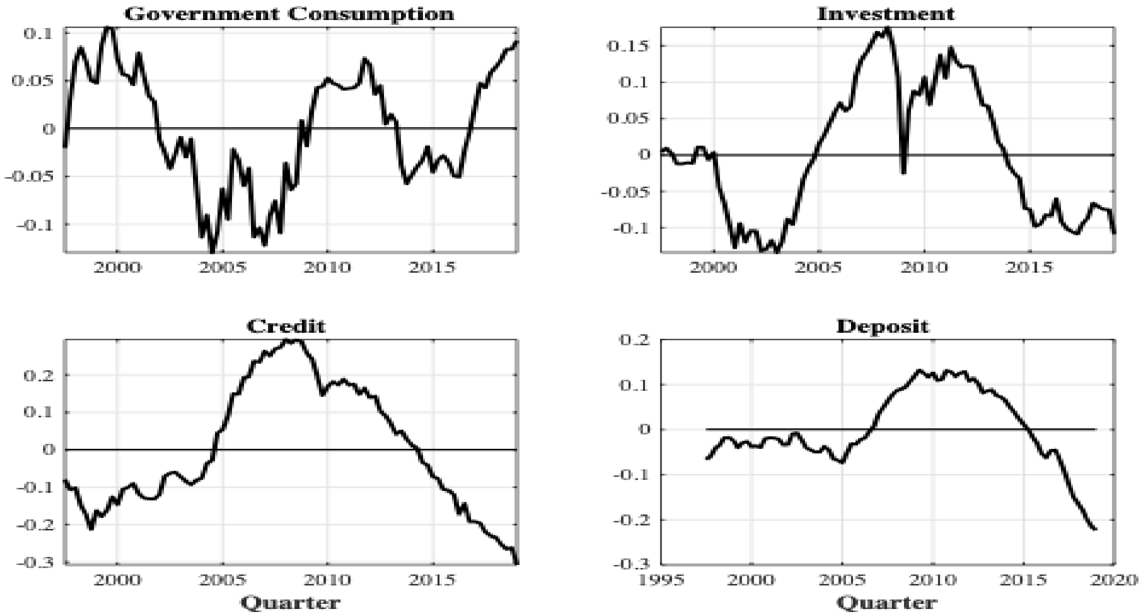
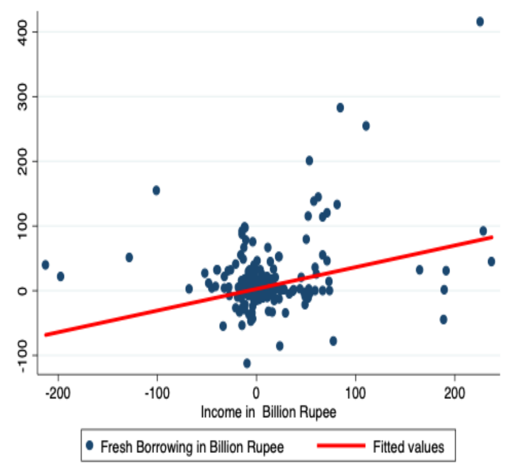
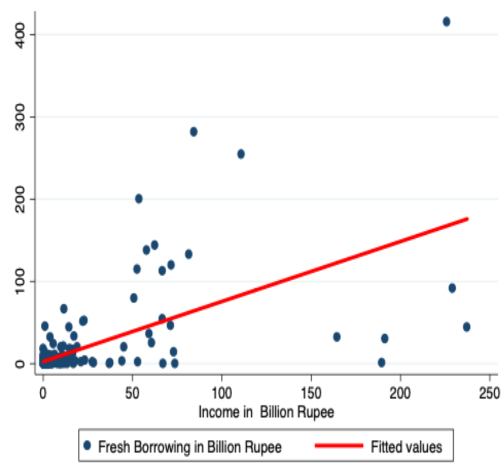


Figure 9: Linearly Detrended Data Used in Estimation



(a) Income and Fresh Borrowing



(b) Income and Fresh Borrowing

Figure 10: (a) all companies. (b) companies with Negative income and Negative Borrowings Dropped

BSE 500 is an index of largest 500 companies listed on the BSE. The data has been obtained from CMIE Prowess database, over the time period 2016-2019. Net borrowing is calculated by adding cash inflow due to total borrowings (including Finance lease obligations) and cash outflow due to total borrowings (including Finance lease obligations). Income is calculated by subtracting total expenses from continued operations from sales before tax.

In figure 10(a), we show the relationship for all firms for which data is available. The correlation between income and fresh borrowing is 0.31 and is significant at 5 percent. In figure 10(b), we show this relationship for a smaller set of companies. Since firms experienced corporate deleveraging and debt stress during this period, we drop all firms with negative income and negative net borrowing, which makes the correlation stronger (0.61) and significant at 5 percent level.

It is important to clarify that the above figures show mere correlation without any causal interpretation. It is difficult to establish causality between new borrowing and income, mainly due to three reasons. First, income is likely to be an endogenous variable. Second, the regression is also likely to suffer from omitted variable bias. Third, it is very difficult to find a relevant instrument for income for a panel of firms. Therefore we do not attempt to give a causal impact of income on borrowing.

Furthermore, borrowing and income are intuitively related for several reasons. It is possible that high income gives signal about better future prospects and firms borrow for expansion. Income is likely to affect borrowing as documented by Lian and Ma (2018), i.e., firms can pledge their income for borrowings. In a country like India, where the bankruptcy process is weak and time consuming[10], lenders would prefer to lend keeping in mind earnings of the firm. Also, valuing assets provided for collateral purposes can be difficult due to unclear property rights and information asymmetry, which can lead to more earning based lending. At the same time, due to large presence of informal sector

[10] India did not have a modern bankruptcy law for most of the time period in our sample. The new bankruptcy law came into effect from 2016 onwards: https://www.ibbi.gov.in

activity, independent and easy verification of earning could be difficult, which will give impetus to assets based collateral in lending. Based on these arguments, we allow firms to pledge a linear combination of earnings and assets for borrowings.

5 Results and Analysis

5.1 Parameter Estimates

In the model we have six shocks, therefore, we can use maximum six variables to estimate the model to avoid stochastic singularity. Classical identification results are typically derived under the assumption that the number of endogenous variables equals the number of shocks, and that the innovations are 'fundamental' (Komunjer and Ng (2009)). We use, GDP, gross fixed capital formation, government final consumption expenditure, consumer inflation, interest rate and aggregate nonfood credit. Since, our model implies that deposit and credit are equivalent, we estimate another model in which we replace aggregate nonfood credit with aggregate deposit and since the results are similar, here we report results with nonfood credit only .

Table 1: Estimated Parameters: Model Estimated with Output, Inflation, Interest Rate, Government Consumption, Investment and Credit

Parameter	Prior Mean	Post Mean	90% HPD Interval		Prior	Post st.dev.
ω	0.400	0.874	0.651	0.994	beta	0.200
η	0.400	0.105	0.100	0.113	beta	0.200
τ	0.400	0.276	0.002	0.691	beta	0.200
γ	0.400	0.824	0.791	0.858	beta	0.200
ρ_a	0.600	0.136	0.042	0.221	beta	0.200
ρ_θ	0.600	0.854	0.794	0.926	beta	0.200
ρ_μ	0.600	0.806	0.749	0.865	beta	0.200
ρ_z	0.600	0.873	0.749	0.950	beta	0.200
ρ_g	0.600	0.911	0.874	0.950	beta	0.200
ρ_π	0.400	0.405	0.147	0.694	beta	0.200
ρ_y	0.400	0.617	0.390	0.826	beta	0.200
ρ_r	0.500	0.507	0.359	0.640	beta	0.200
σ_a	0.015	0.036	0.029	0.043	invg	0.010
σ_θ	0.025	0.011	0.008	0.014	invg	0.010
σ_μ	0.015	0.025	0.020	0.030	invg	0.030
σ_z	0.015	0.007	0.004	0.011	invg	0.030
σ_r	0.015	0.012	0.010	0.015	invg	0.030
σ_g	0.015	0.004	0.003	0.004	invg	0.030

Notes:ω is the share of earning based borrowing and η is elasticity of labour supply for households. γ is habit persistence in consumption for both households. τ is the backward looking component of inflation in Phillips curve. ρ_a, ρ_θ, ρ_μ, ρ_z and ρ_g are autoregressive coefficients of preference, mark-up, investment specific technology, neutral technology and government expenditure shocks respectively. $1+\rho_\pi$, ρ_y and ρ_r are coefficients associated with inflation, output gap and one period lagged interest rate in Taylor rule respectively. σ_a, σ_θ, σ_μ, σ_z, σ_r and σ_g are standard deviation of error associated with preference, mark-up, investment specific technology, neutral technology, interest rate and government expenditure shocks respectively.

We do not use private final consumption expenditure to estimate the model, as this has some excess volatility in the beginning of the sample which is not there in other aggregates (this could be due to the measurement error in the data). We calibrate depreciation rate ($\delta = 0.025$, which implies a annual depreciation rate of 10%, tax rate=0.2,[11] loan

[11] Corporate tax rate lies between 15-30% in India depending upon several characteristics. We choose a value of 20%.

to earning ratio ($\theta_e = 2$), loan to assets ratio ($\theta_k = 0.8$) and share of capital in national output ($\alpha = 0.35$). Our calibration implies steady state of government consumption to output ratio at 16.67 percent which is similar to the value in actual data. Remaining Parameters are estimated using Bayesian method (see Lubik and Schorfheide (2005, 2007) for details about Bayesian estimation) and are given in Table 1. These estimates suggest that the share of earning based constraint in borrowing is approximately 0.9, which means that roughly 90 percent of the borrowing is earning based and 10 percent is assets based. Estimates suggest that households have lower frisch elasticity of labour supply.

Habit persistence in consumption is estimated to be 0.82[12]. The coefficient of past interest rate in Taylor rule is 0.507. Bhoi et al. (2019) obtain this coefficient to be 0.83 for a slightly smaller sample using reduced form estimation. Coefficient associated with autoregressive term in mark-up shock is estimated to be 0.854. The backward looking component in Philips curve is estimated to be 0.276. Goyal and Kumar (2020) obtain this coefficient to be 0.09. The weight attached to inflation is significantly higher than the weight attached to output gap[13].

5.2 Smoothed Estimates of Shocks

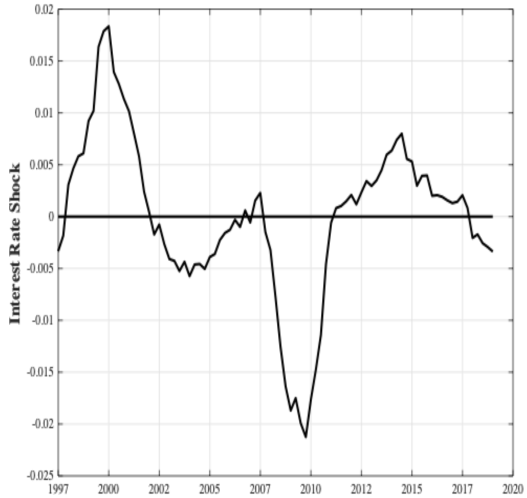
The new Keynesian model has six shocks: preference, mark-up, investment specific technology, neutral technology, government expenditure and interest rate shocks. Two shocks are important from stabilization of business cycle fluctuation in Keynesian sense: government expenditure and interest rate shocks. Since, starting from 2014 onwards, India

[12] Goyal and Kumar (2020) using a small new Keynesian model estimate habit persistence to be 0.65. One can write $c_t - \gamma c_{t-1}$ as $c_t - \gamma c_t + \gamma c_t - \gamma c_{t-1}$. From that, we can write $c_t\,(1-\gamma) + \gamma\,(c_t - c_{t-1})$. Higher value of γ implies that consumers attach more weight to growth of consumption in utility.

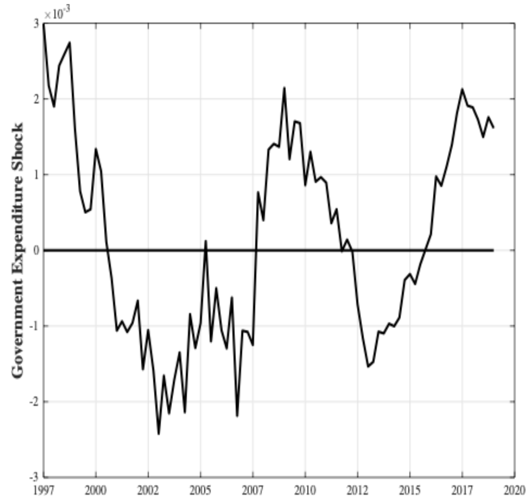
[13] There is one fundamental difference between estimation done in Goyal and Kumar (2020) and our current study. Goyal and Kumar (2020) use growth rate of GDP to estimate the model. In their model, there is an unit root technology shock that is used to make model variables stationary. Also a steady state growth exists in their model. We estimate the model using linearly de-trended variables. Since, we are using several variables, it becomes difficult to assume that all these variables have a common trend. Therefore, in our case, technology shock is a stationary autoregressive process and we estimate the model using linearly de-trended variables. The linear de-trending gives us business cycle components of these variables. One can use other ways of finding business cycle components and the results may slightly differ.

started to move towards an inflation targeting regime, inflation became an important aspect of stabilization policy. Therefore, we provide the nine quarter moving average smoothed estimates of three model shocks: markup, interest rate and government expenditure. Figure 11 gives the smoothed estimates of markup shock. The model is able to identify the inflationary pattern observed in the Indian economy. Starting with financial crisis, oil prices increased, and inflation started increasing further in India. From 2012 onwards, oil prices started declining and markup shock became negative. This was also a period of decelerating inflation.

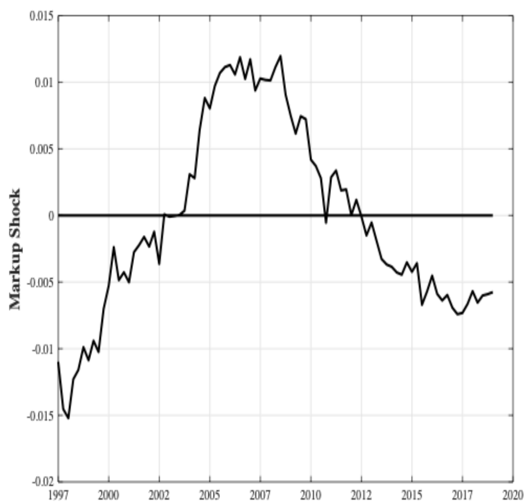
Figure 11(a) gives the smoothed estimates of the interest rate shock. The model is able to identify the interest rate shock in the Indian economy. High positive interest rate shock is estimated during east Asian crisis. India effectively started using interest rate as a policy instrument since 2000 onwards and then the deviation from the Taylor rule substantially declined.



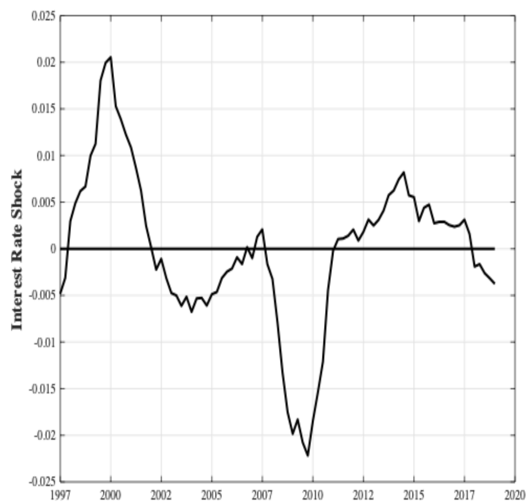
(a) Interest Rate Shock



(b) Gov. Exp. Shock



(c) Markup Shock



(d) Markup Shock

Figure 11: 9 Quarter moving average of smoothed estimates of shock from the model. (a), (b), and (c) are from linearly detrended data. (d) is from HP filtered data.

During the financial crisis, the interest rate was lowered sharply. Starting from 2011:Q2 till 2017:Q4, interest rate shock remained positive. During taper tantrum, it was substantially higher. During all these years, mark-up shock was negative and inflation was on downward trajectory. Despite this, interest rate was kept high which led to substantial output cost. Very lately interest rate became accommodative in our sample. Bhoi et al. (2019) find similar pattern of interest rate shock using a reduced form Taylor rule. Our identified interest rate shock from the model is highly correlated with shock identified using VAR in the previous section. This gives us confidence that the model and the estimation is able to pick salient features of the economy and the results obtained from this model are not completely hypothetical.

Figure 11(b) gives the smoothed estimates of government expenditure shock. The model is able to identify the government expenditure shock. From 2000 onwards till the financial crisis, the economy was obsessed with FRBM (fiscal responsibility and budget management act, 2003) and government expenditure shock was largely negative (contractionary). Starting with financial crisis, large fiscal stimulus came in and the government expenditure shock became highly positive (expansionary). From 2011:Q2 the government went into fiscal consolidation phase and the expenditure shock became contractionary. .

Note that this was the same period when the interest rate became contractionary in light of inflation and remained at elevated level despite the decreasing trend in inflation. In majority of the period of the recent government, the government expenditure shock was expansionary (2015:Q2 onwards). As we can see from the above discussion two policy shocks obtained from the model exhibit the true policy instances seen in the economy. The markup shock also broadly picks up the inflationary trend in the economy, see figure 11(c).

5.3 Impulse Responses

The new Keynesian model has six shocks: preference, markup, investment specific technology, neutral technology, government expenditure and interest rate shocks. Figure 12 gives the response of model output, inflation and interest rate. Figure 13 gives the response of investment, government expenditure and credit. Output, inflation, consumption and investment falls due to a positive (contractionary) interest rate shock as expected.

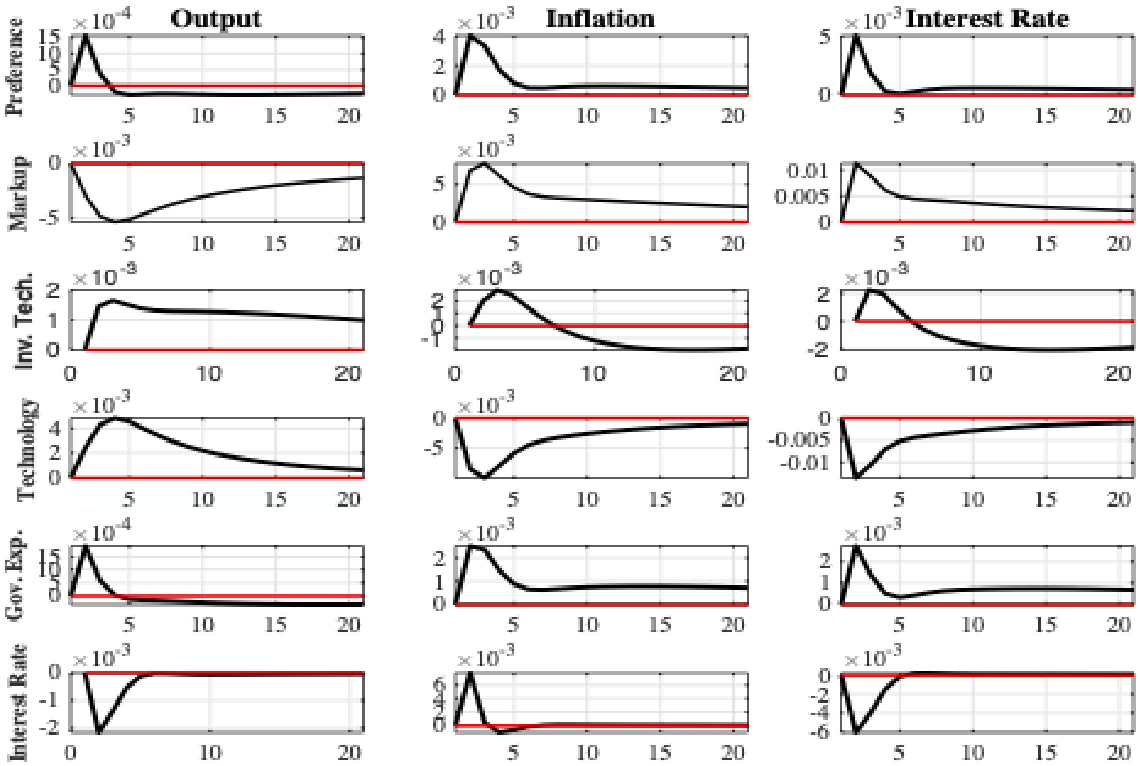


Figure 12: Response of model variables(column) due to shock(row)

New Keynesian model is based on the real interest rate transmission and these variables should fall when real rate rises. Remember nominal rigidity implies that prices are sticky; so when there is a nominal interest rare shock, it effectively implies a real rate shock. Credit increases due to rise in interest rate and thus generates positively sloped loan supply curve. This could be because with the increase in interest rate, household wants to save more due to inter-temporal substitution giving higher credit.

Preference shock increases inflation, output, interest rate, consumption. It decreases investment as households consume more (preference for consumption). Credit falls in the beginning for the same reason and then overshoots before stabilizing. Government expenditure increases output, interest rate and decreases consumption, and investment. Credit decreases on impact, then overshoots and stabilises. The fiscal multiplier is pos-

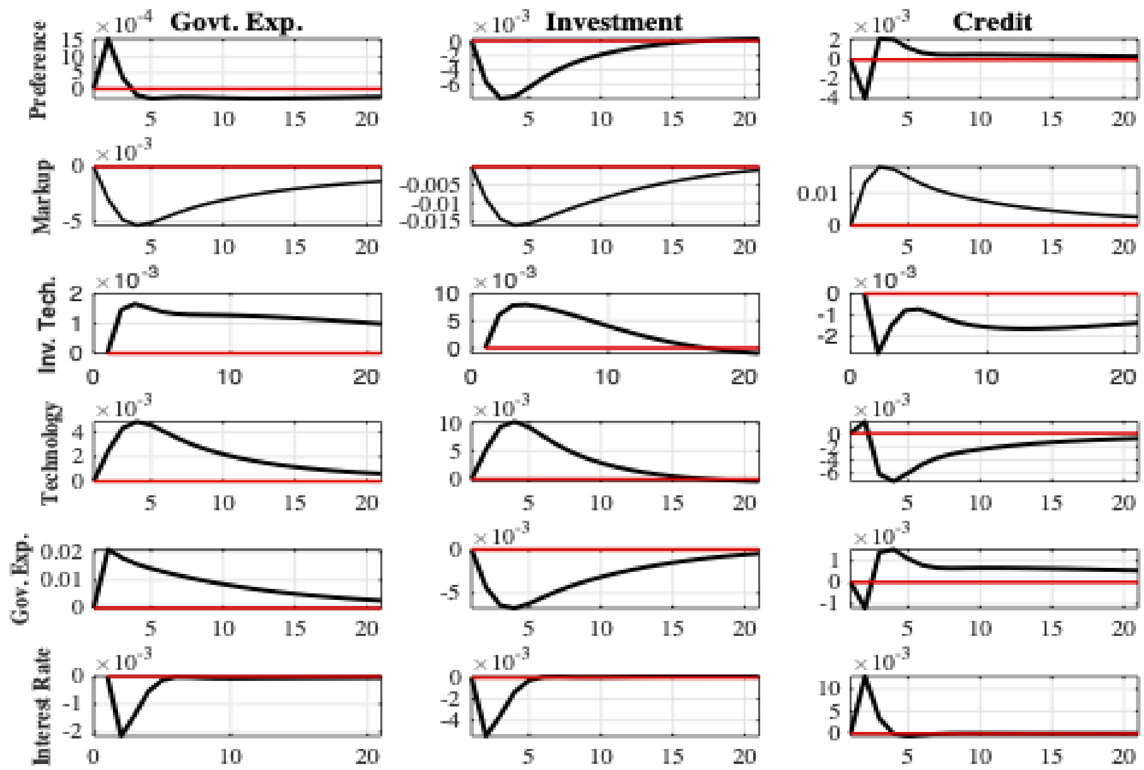


Figure 13: Response of model variables(column) due to shock(row)

itive and significant. Consumption falls because increases in government expenditure implies higher taxation. The effect of consumption is estimated to be very persistent. Investment and credit falls because government consumes more resources and interest rate increases. Thus, government expenditure crowds out private investment.

Markup shock decreases output, investment and increases interest rate, inflation and credit. Credit increases because higher markup implies higher earnings for the firms and the earning based constraint allows them to borrow more. Central bank increases rates due to higher inflation, through the real rate channel as explained above. Consumption increases in the beginning because higher markup leads to higher dividend payments to the household.

A positive technology shock increases output and investment. Consumption falls on impact but increases soon. Interest rate increases on impact but decreases after 6 quarters and remains lower. Credit decreases and this is due to the impact of assets based collateral constraint. Investment specific technology shock decreases the price of capital, value of collateral goes down and thus borrowing also decreases. Increase in share of assets based borrowing will lead to further decrease in credit. Inflation decreases due to a positive investment specific technology shock.

5.4 Forecast Error Variance Decomposition

Table 2 gives the forecast error variance decomposition (FEVD) of model variables due to each shock. Output is mainly determined by markup shock, technology shock, interest rate shock and government expenditure shock . Preference and investment specific technology shocks explain less than 10 percent of variation in output on impact. Inflation is mostly determined by technology, markup and interest rate shock. Interest rate is determined by technology, markup and its own shocks. This suggests that interest rate responds to movement in markup shock and this is how the markup shock affects output.

Credit is mainly explained by markup and interest rate shocks. Forecast error variance decompositions reported here are similar to the one reported in Goyal and Kumar (2017) based on a small scale new Keynesian model. But there are two important distinctions. First, the importance of technology shock is far higher in our case and the role of interest rate shock is lower. It is likely due to two reasons. First, we estimate the model using output gap, whereas Goyal and Kumar (2017) estimated it using quarter to quarter growth of output gap. Quarter to quarter growth of output is very volatile in comparison to linearly de-trended output gap.

Second, contrary to Goyal and Kumar (2018), our model includes government expenditure. As we have seen from the estimates of smoothed shocks, these two shocks are contractionary and expansionary at the same time. Therefore, it is possible that in our case government expenditure picks those effects instead of interest rate shock.

Table 2: Forecast Error Variance Decomposition

Quarter	Preference	Markup	Investment	Technology	Government	Interest
			Output			
1	7.7	38.2	7.7	20.0	11.8	14.7
4	1.4	52.4	5.4	35.2	2.0	3.6
8	0.9	52.4	6.0	37.2	1.3	2.2
12	0.9	51.8	7.2	37.0	1.2	1.8
20	1.0	50.8	9.5	35.8	1.3	1.6
			Inflation			
1	8.2	34.9	1.8	41.1	2.1	12.0
4	5.1	35.3	1.9	46.2	1.5	10.0
8	4.5	36.1	2.2	47.2	1.4	8.5
12	4.2	36.5	3.5	46.5	1.4	7.8
20	4.0	36.6	6.3	44.4	1.7	7.0
			Interest Rate			
1	9.2	22.8	2.6	29.9	3.3	32.2
4	6.8	27.0	5.7	44.6	2.9	13.1
8	5.9	27.2	5.2	47.7	2.7	11.3
12	5.6	27.8	5.8	47.7	2.7	10.3
20	5.3	28.5	8.7	45.3	3.0	9.2
			Investment			
1	14.5	38.7	16.4	11.4	7.9	11.1
4	11.8	47.4	13.9	16.3	8.2	2.3
8	9.6	49.9	15.2	15.6	8.2	1.4
12	8.9	50.7	15.6	15.1	8.4	1.3
20	8.7	51.2	15.5	14.8	8.6	1.2
			Credit			
1	5.1	47.3	1.0	1.3	0.5	44.8
4	2.2	75.9	0.3	6.8	0.5	14.3
8	1.8	79.0	0.3	7.6	0.4	10.9
12	1.6	79.4	0.6	7.8	0.5	10.1
20	1.6	79.1	1.2	8.0	0.5	9.6

5.5 Counterfactual Simulations

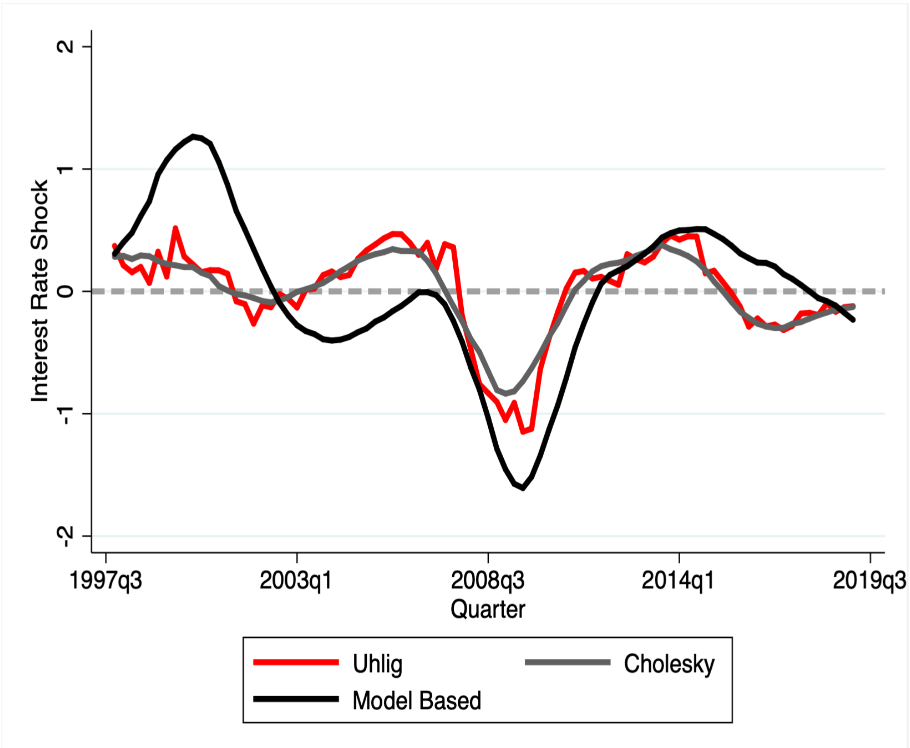
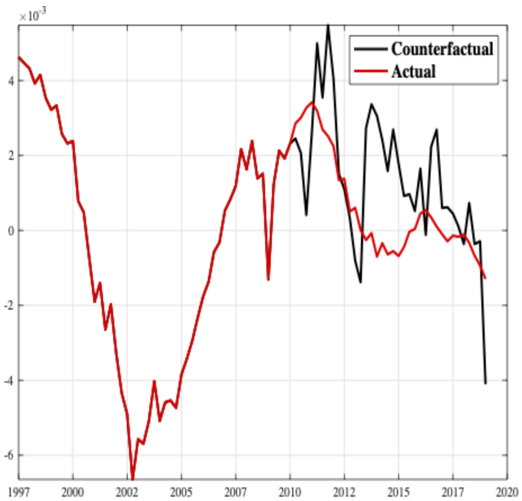
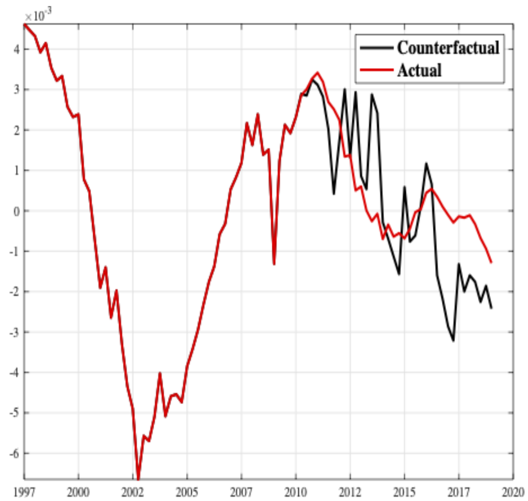


Figure 14: Nine Quarter Moving Average of Estimated Smoothed Shock: Government Expenditure Shock

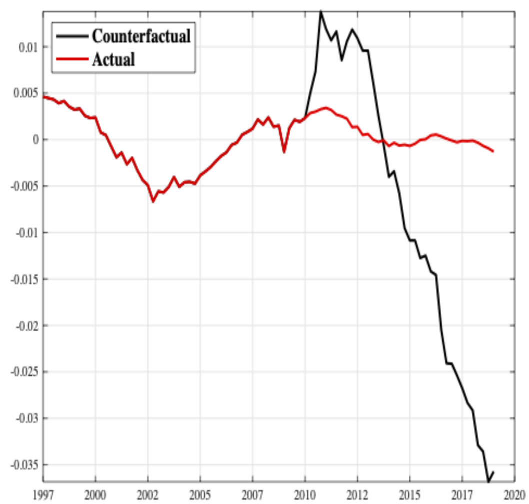
Figure 14 gives the 9 quarter moving average of interest rate shocks obtained from Model 1 of Cholesky decomposition and Max Share identification as well as from the new Keynesian model. Our model based shock suggests significantly more interest rate stimulus during the financial crisis as well much prolonged post crisis tightening. In the pre-crisis period, the model based and VAR based interest rate shocks are of different nature; the model based shock suggests expansionary monetary policy whereas the VAR based shock suggests contractionary monetary policy. In late 1990s, all these shocks suggest contractionary interest rate policy, but the magnitude suggested by model based shock is much higher compared to the VAR based shocks.



(a) Interest Rate Shock



(b) Gov. Exp. Shock



(c) Markup Shock

Figure 15: Counterfactual Output in Absence of given Shock and Actual Output

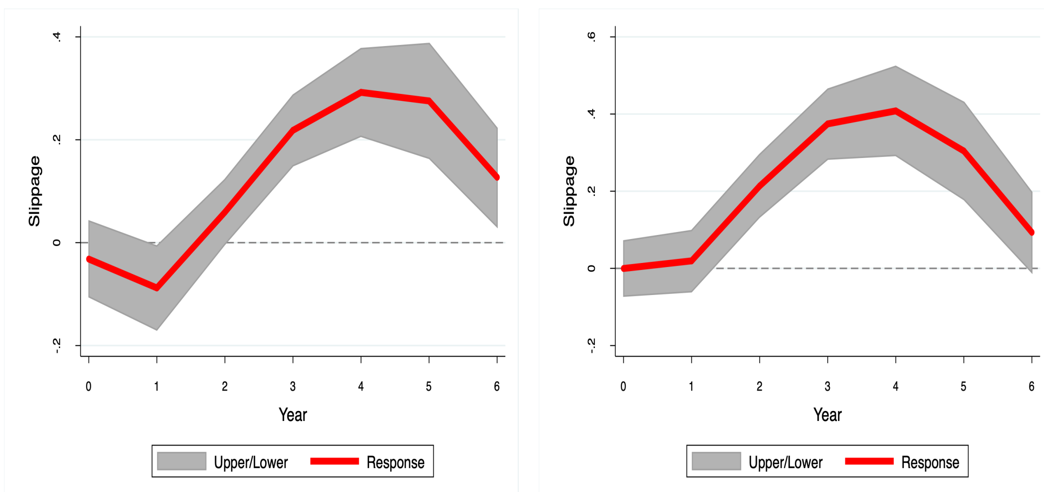
Our new Keynesian model has two policy shocks: government expenditure and interest rate shocks. We report counterfactual output obtained from selectively shutting down these shocks from 2010:Q2 onwards. We choose 2010:Q2 because the peak of the moving average growth of output was achieved in 2010:Q1. As we can see from figure 15(a), interest rate shock was highly contractionary during 2013 to 2016. Output Gap would have been higher in absence of the interest rate shock. Recently interest rate shock has become expansionary and output gap would have been lower in the absence of that policy.

As we can see from figure 15(b), government expenditure shock was also contractionary during 2012 to 2016. Output Gap would have been higher in absence of the government expenditure shock. Recently the government expenditure shock has become expansionary and the output gap would have been lower in the absence of that policy. As we can see, both policy shocks were contractionary during the period 2013-16. This certainly contributed to the growth slowdown. As we can see from the above discussion, in post crisis period both these shocks have moved in the same direction, both contractionary or both expansionary. Whether this policy co-movement is bad or good is a matter of debate, but our analysis suggests that this has harmed growth in the recent times. But government expenditure has kept output at a higher level in the recent times. Together, this implies that government expenditure has not brought significant negative consequence for the economy.

As we can see, the interest rate was kept high despite the softening of inflation and that led to sufficient output cost. To judge how contractionary the interest rate shock was, we generate counterfactual output in the absence of markup shock. In this model inflation gets determined from markup shock, and interest rate responds to inflation. This raises real interest rate and decreases output through the real rate channel. Therefore, inflation could be highly contractionary depending upon the weight attached to inflation in Taylor rule. At the same time, softening of inflation may favour the economy as the interest rate does not need to be raised despite high weight attached to inflation. Inflation substantially softened after 2012, which should have stopped any further increase in interest rate. As we can see from figure 15(c), if markup shock has not turned negative and inflation has not softened, then the output gap would have been substantially lower. This makes the point that interest rate was aggressively targeting inflation during this period without paying enough attention to the output gap that led to significant output cost.

5.6 Implications of the Identified Policy Errors

The new Keynesian model works via the real interest rate channel and inter-temporal substitution. But higher interest rate can also affect the economy by disrupting financial intermediation. Higher interest rate may reduce demand for credit by firms through inter-temporal substitution and that can affect profitability of firms adversely. With dwindling profitability, firms are likely to default and that will create bad assets in the banking sector which will reduce the credit supply from banks, affecting growth. In this section, we test for this financial intermediation channel.



(a) Response of slippage due to interest rate shock from model 1

(b) Response of slippage due to interest rate shock from model 2

Figure 16: Response of slippage due to interest rate shock from Model 1 and Model 2. Model 1 is with linearly detrended output gap, inflation and interest rate. Model 2 further includes linearly deterended investment, credit and government expenditure. In both cases, we identify the interest rate shock as the shock which explains maximum forecast error variance of interest rate over 40 quarters.

We estimate the response using local projection regressions given by:

$$Slippage_{i,t+j} = \phi_i + \beta_0 IR_t + \beta_1 Slippage_{i,t-1} + \varepsilon_{it} \quad \text{for} j = 0, 1, ...6$$

Where $Slippage_{it}$ is the new addition to gross non-performing assets as percent of standard advances for bank i in year t. IR_t is the interest rate shock obtained from Max Share identification. Our data-set contains fifty five banks over the time period 2005-2020. Figure 16 gives the the response of slippage over time due to interest rate shock. Both these measures of interest rate shock lead to significant increase in slippage ratio. There is no effect on slippage on impact as expected and the peak effect occurs after 4 years. Interest rate shock from extended model gives slightly higher effect on slippage in comparison to the model containing only output, inflation, and interest rate. Results from figure 16 suggest that excessively high interest rate can also harm growth by disrupting financial inter-mediation.

6 Concluding Remarks

In this paper we explore the recent business cycle fluctuations in India using a medium scale new Keynesian model. In the model firms face linear combination of earning based as well as assets based collateral constraint. This is because the response of borrowing to investment specific technology or neutral technology shock can be markedly different under these two possible borrowing constraints. Since in the case of India, the micro evidence for these types of borrowing constraints faced by the firm is not available, it becomes imperative to allow data to give inference about prevalence of these borrowing constraints. Our estimates suggest the weight attached to earning based collateral constraint is around 0.9. Thus most of the borrowing is earnings-based in the case of India. Our VAR based interest rate shocks are very similar to smoothed estimates of interest rate shock from the new Keynesian model, giving us confidence in the counterfactual analysis using the new Keynesian model.

Smoothed estimates of markup, government expenditure and interest rate shocks are in line with prevailing narratives about the economy in recent times. This validates our model and estimation. Markup shock identifies the spike and fall in inflation due to increase and decrease in oil price in the post crisis period. Government expenditure shock identifies the period of fiscal stimulus in the aftermath of crisis, subsequent fiscal consolidation and recent expansionary fiscal policy. Similarly, interest rate shock identifies very loose interest rate policy in the aftermath of crisis, delayed tightening and higher interest rate despite fall in inflation during 2013-16. Recent stance of loose interest rate policy is also identified by the interest rate shock.

Smoothed estimates obtained from the estimation suggest that in the post crisis period, two policy shocks in our model, government expenditure shock and interest rate shock move together (both contractionary or both expansionary). These two shocks are responsible for stabilizing business cycle fluctuations. Whether the comovement of policy shock is good or bad is a matter of debate and needs further explorations. Our results suggest that positive government expenditure shock leads to significant crowding out of private investment but increase in output through fiscal multiplier. Therefore the overall growth effect of government expenditure shock is positive based on results obtained in this paper. The effect of interest rate on investment is not as significant as the effect of interest rate on output. This could be partly due to the fact that high interest rate episodes in our sample are also associated with fiscal consolidation and vice versa. Interest rate was highly contractionary during 2013-16 despite softening of inflation which led to significantly lower output gap. Higher interest rate also disrupts financial intermediation by creating bad assets in the baking sector. This way the effect of prolonged excessively high interest rate on growth could be much more harmful than usually thought via intertemporal substitution channel and sacrifice ratios. These results have important implications about aggregate demand management in the economy.

References

[1] Andres, J., David Lopez-Salido, J. and Valles, J., 2006. Money in an estimated business cycle model of the euro area. The Economic Journal, 116(511), pp.457-477.

[2] Banerjee, S., Basu, P. and Ghate, C., 2020. A monetary business cycle model for India. Economic Inquiry, 58(3), pp.1362-1386.

[3] Barrail, Z., 2020. Business cycle implications of rising household credit market participation in emerging countries, Journal of Economic Dynamics and Control, 103917, available on-line.

[4] Barsky, R.B. and Sims, E.R., 2011. News shocks and business cycles. Journal of monetary Economics, 58(3), pp.273-289.

[5] Bernanke, B.S., Gertler, M. and Gilchrist, S., 1999. The financial accelerator in a quantitative business cycle framework. Handbook of macroeconomics, 1, pp.1341-1393.

[6] Bhoi, B.K., Kumar, A. and Parab, P.M., 2019. Aggregate Demand Management, Policy Errors and Optimal Monetary Policy in India. Indira Gandhi Institute of Development Research, WP-2019-029

[7] Brunnermeier, M.K. and Sannikov, Y., 2014. A macroeconomic model with a financial sector. American Economic Review, 104(2), pp.379-421.

[8] Campbell, J.Y. and Mankiw, N.G., 1989. Consumption, income, and interest rates: Reinterpreting the time series evidence. NBER macroeconomics annual, 4, pp.185-216.

[9] Cascaldi-Garcia, D. and Galvao, A.B., 2018. News and uncertainty shocks. FRB International Finance Discussion Paper, (1240).

[10] Christiano, L.J., Eichenbaum, M. and Evans, C.L., 2005. Nominal rigidities and the dynamic effects of a shock to monetary policy. Journal of political Economy, 113(1), pp.1-45.

[11] Debortoli, D. and Gali, J., 2017. Monetary policy with heterogeneous agents: Insights from TANK models. Manuscript, September.

[12] Dogan, A., 2019. Investment specific technology shocks and emerging market business cycle dynamics. Review of Economic Dynamics, 34, pp.202-220.

[13] Drechsel, T., 2019. Earnings-Based Borrowing Constraints and Macroeconomic Fluctuations (No. pdr141). Job Market Papers.

[14] Francis, N., Owyang, M.T., Roush, J.E. and DiCecio, R., 2014. A flexible finite-horizon alternative to long-run restrictions with an application to technology shocks. Review of Economics and Statistics, 96(4), pp.638-647.

[15] Gabriel, V., Levine, P., Pearlman, J. and Yang, B., 2012. An estimated DSGE model of the Indian economy. Chapter in Ghate, C. (ed.) The Oxford Handbook of the Indian Economy. New Delhi: Oxford University Press. DOI: 10.1093/oxfordhb/9780199734580.013.0029.

[16] Gali, J., Lopez-Salido, J.D. and Valles, J., 2004. Rule-of-thumb consumers and the design of interest rate rules (No. w10392). National Bureau of Economic Research.

[17] Gali, J., Lopez-Salido, J.D. and Valles, J., 2007. Understanding the effects of government spending on consumption. Journal of the european economic association, 5(1), pp.227-270.

[18] Garcia-Cicco, J., Pancrazi, R. and Uribe, M., 2010. Real business cycles in emerging countries?. American Economic Review, 100(5), pp.2510-31.

[19] Ghate, C., Gupta, S. and Mallick, D., 2018. Terms of trade shocks and monetary policy in India. Computational Economics, 51(1), pp.75-121.

[20] Goyal, A. and Kumar, A., 2020. A DSGE model-based analysis of the Indian slowdown. Journal of International Commerce, Economics and Policy, 11(01), p.2050004.

[21] Goyal, A. and Kumar, A., 2018. Money and business cycle: Evidence from India. The Journal of Economic Asymmetries, 18, p.e00105.

[22] Goyal, A. and Kumar, A., 2021. News, Noise and Indian Business Cycle. Bulletin of Economic Research, DOI: 10.1111/boer.12306

[23] Hart, O. and Moore, J., 1994. A theory of debt based on the inalienability of human capital. The Quarterly Journal of Economics, 109(4), pp.841-879.

[24] Holmstrom, B. and Tirole, J., 1997. Financial intermediation, loanable funds, and the real sector. The Quarterly Journal of economics, 112(3), pp.663-691.

[25] Hennessy, C.A. and Whited, T.M., 2005. Debt dynamics. The Journal of Finance, 60(3), pp.1129-1165.

[26] Holtemoller, O., and S. Mallick, 2016. Global food prices and monetary policy in an emerging market economy: The case of India, Asian Journal of Economics, 46: 56-70.

[27] Iacoviello, M., 2015. Financial business cycles. Review of Economic Dynamics, 18(1), pp.140-163.

[28] Ireland, P.N., 2001. Money's role in the monetary business cycle (No. w8115). National Bureau of Economic Research.

[29] Justiniano, A., Primiceri, G.E. and Tambalotti, A., 2010. Investment shocks and business cycles. Journal of Monetary Economics, 57(2), pp.132-145.

[30] Kaplan, G., Moll, B. and Violante, G.L., 2018. Monetary policy according to HANK. American Economic Review, 108(3), pp.697-743.

[31] Kiyotaki, N. and Moore, J., 1997. Credit cycles. Journal of political economy, 105(2), pp.211-248.

[32] Klein, P., 2000. Using the generalized Schur form to solve a multivariate linear rational expectations model. Journal of economic dynamics and control, 24(10), pp.1405-1423.

[33] Komunjer, I. and Ng, S., 2009. Dynamic identification of DSGE models. Unpublished manuscript, University of California, San Diego and Columbia University

[34] Krishnamurthy, A. and Vissing-Jorgensen, A., 2012. The aggregate demand for treasury debt. Journal of Political Economy, 120(2), pp.233-267.

[35] Kumar, A., S. Mallick and A. Sinha, 2021. Is Uncertainty the Same Everywhere? Advanced Versus Emerging Economies, Economic Modelling, 101, 105524.

[36] Kurmann, A. and Otrok, C., 2013. News shocks and the slope of the term structure of interest rates. American Economic Review, 103(6), pp.2612-32.

[37] Lian, C. and Ma, Y., 2018. Anatomy of corporate borrowing constraints. Unpublished working paper.

[38] Lubik, T.A. and Schorfheide, F., 2007. Do central banks respond to exchange rate movements? A structural investigation. Journal of Monetary Economics, 54(4), pp.1069-1087.

[39] Lubik, T. and Schorfheide, F., 2005. A Bayesian look at new open economy macroeconomics. NBER macroeconomics annual, 20, pp.313-366.

[40] Mallick, S. K., and R. M. Sousa (2013) Commodity prices, inflationary pressures, and monetary policy: Evidence from BRICS economies, Open Economies Review, 24 (4): 677-694.

[41] Orland, A. and Roos, M.W., 2019. Price-setting with quadratic adjustment costs: Experimental evidence. Journal of Economic Behavior Organization, 163, pp.88-116.

[42] Rotemberg, J.J., 1982. Sticky prices in the United States. The Journal of Political Economy, pp.1187-1211.

[43] Rotemberg, J., 1987. The new Keynesian microfoundations. In NBER Macroeconomics Annual 1987, Volume 2 (pp. 69-116). The MIT Press.

[44] Shleifer, A. and Vishny, R.W., 1992. Liquidation values and debt capacity: A market equilibrium approach. The Journal of Finance, 47(4), pp.1343-1366.

[45] Smets, F. and Wouters, R., 2007. Shocks and frictions in US business cycles: A Bayesian DSGE approach. American economic review, 97(3), pp.586-606.

[46] Stiglitz, J.E. and Weiss, A., 1981. Credit rationing in markets with imperfect information. The American economic review, 71(3), pp.393-410.

[47] Townsend, R.M., 1979. Optimal contracts and competitive markets with costly state verification. Journal of Economic theory, 21(2), pp.265-293.

[48] Uhlig, H., 2004. What moves GNP?. In Econometric Society 2004 North American Winter Meetings (No. 636). Econometric Society.

[49] Wieland, V., Cwik, T., Muller, G.J., Schmidt, S. and Wolters, M., 2012. A new comparative approach to macroeconomic modeling and policy analysis. Journal of Economic Behavior Organization, 83(3), pp.523-541.

[50] Yoshida, H., 2007. Monetary policy and economic fluctuations in a sticky-price model. Journal of Economic Behavior Organization, 62(3), pp.428-439.