Business Cycle Accounting analysis of Monetary Policy Transmission in India

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Abstract

We study the monetary policy transmission (MPT) or lack of it in Indian context using a Business Cycle Accounting (BCA) framework. In the standard BCA setup we introduce a simple banking sector motivated by Lahiri and Patel [9] where we capture MPT as transmission from change in Treasury bill rate to lending rates. We show using Bayesian MCMC methods that 1) MPT in India is weak, 2) labor wedges are responsible for up to 30% of the fluctuations in MPT, with share of other real wedges varying from 17-25% and no role for nominal wedges. We then further augment the model to include a statutory liquidity ratio, and show that it does not affect transmission from lending rate to real variables, and changes in SLR only affect the nominal interest rate.

1 Introduction

India adopted inflation targeting in the later half of 2016 with the intent to improve price and fiscal stability and reducing output and exchange rate volatility. In emerging market economies (EMEs) however there is considerable debate whether monetary policy transmission is adequate for enough for the central banks to be able to affect aggregate demand. Lahiri and Patel [9] note that specific institutional constraints, persistent shocks, legacy structures, multiple and conflicting policy

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objectives and poor financial integration can be a impeding factor in achieving monetary policy goals in EMEs.

Studies done on data prior to 2016 (Das [7], Mishra et al. [10]) look at the bank lending channel (from monetary policy to bank lending rates) and show that MPT in India is while in theoretically expected direction, is incomplete. The latter paper also finds no evidence of changes in output and inflation from changes in monetary policy, and also finds no evidence of exchange rate channel being important for the Indian economy. In recent work by Banerjee et al. [1], they use a DSGE framework to find that monetary transmission may not be weak if we use change in monetary base as indicator of monetary policy, but is much weaker if we focus only on the policy rate as the instrument. In this paper we attempt to use Business Cycle Accounting methodology developed by Chari et al. [6] to study MPT in the Indian economy.

Business Cycle Accounting models (BCA), introduced by [6] introduce multiple time varying wedges in a stochastic optimal growth model, which capture deviations of the model from the data. There are four wedges in their model: *efficiency*, *investment*, *labor* and a *government consumption wedge*, which account for the entire variation in output, hours worked, investment and consumption. Variations in these wedges capture propagation of primitive shocks through frictions and distortions in a detailed structural macroeconomic model ([13]). Sustek builds a extended monetary business cycle accounting model (MBCA), with a central bank where they include two additional nominal wedges: an *asset market wedge* and a *Taylors rule wedge*. They then apply the model to explain movements in inflation and nominal interest rate.

Chari et al. [6] and Brinca et al. [3] show that detailed economies with primitive shocks and frictions distorting the first order equilibrium conditions can be mapped via *equivalence results* into the above defined wedges distorting the first order conditions in a BCA model (also referred as the prototype economy). The four real wedges distort the following equilibrium conditions in the prototype economy respectively: the production function, the inter-temporal consumption investment trade-off equation, the labor-leisure intra-temporal choice equation, and the aggregate resource constraint. Of the nominal wedges, the asset market wedge distorts the inter-temporal equation for bonds and the Taylors Rule wedge distorts the Taylors Rule followed by the Central bank.

The business cycle accounting exercise has two components, first being the equivalence results, which are described in next section. Accounting of the business cycles makes up the second component, where we ascertain the role of each wedge in explaining macroeconomic fluctuations via a decomposition exercise. By definition of the model prototype economy, all wedges combined should explain the entire variation in each of the observables, in the decomposition exercise we study how the wedges impact each aggregate variable individually, by feeding in only one wedge at a time (and also feeding all but one wedge a time), generating simulated data of the observables and comparing it to the actual series observed in the data.

The banking sector we introduce in the BCA setup is simple: the representative bank takes deposits from household, uses those deposits to invest in government bonds or lends to firms. In the first model we dont have any frictions, thus MPT is perfect. In the second model we add a Statutory Liquidity Ratio requirement, which makes MPT imperfect.

Our results point out to efficiency wedge as a prime factor in explaining fluctuations in output upto 68%. These results are similar for to an earlier exercise where we estimated the Monetary Business Cycle Accounting model for the Indian economy. Labor wedges in the first model are responsible for accounting up to 30% of monetary policy transmission, while other real wedges explain it from 17-25%. Some of our preliminary results are in sync with Banerjee et al. [1], where they also find that TFP shocks explain up to 50% of output with no more than 20% contribution by monetary policy shocks. We do not however find any role for nominal wedges in accounting for MPT. In the second model, similarly to Banerjee et al. [1] we dont find any impact of SLR on hindering MPT from nominal interest rate to lending rates. Also SLR does not affect transmission from lending rates to output or hours worked. We also intend to expand the model to look at the role non-performing assets MPT in India.

2 Equivalence Results

Business Cycle Accounting models (or the prototype economy) are useful to understand business cycle fluctuations because they nest several models of detailed economies, which thus provides theoretical foundations for each of the wedges. Efficiency wedge represents frictions at firm level which cause inefficient allocation of inputs. Chari et al. [6] show that a prototype model with efficiency wedges is equivalent to a detailed economy with input-financing restrictions (say for smaller firms), or a detailed economy with variable capital utilization. A prototype economy with only labor wedge is similarly shown equivalent to a detailed economy with sticky wages.
A prototype model with only investment wedge is shown to be equivalent to a detailed economy with fluctuations in investment specific technological change in Brinca et al. [3]. They also show that certain financial frictions like collateral constraints show up in a prototype economy as investment wedge. Sustek [13] shows that a detailed economy with sticky prices is equivalent to labor and

capital wedges, where capital wedges imply a tax on capital unlike on investment as done the prototype BCA model. These authors however show that a tax (or wedge) on capital or investment are same in theory and practice, at least in the case of US economy.
Sustek also shows that bond and labor wedge in the prototype model are equivalent to a detailed economy with limited participation in asset markets with a variable working capital requirements setup. Monetary policy wedge according to Sustek is equivalent to a economy with varying inflation targets, which thus creates uncertainty in the implementation of a dedicated monetary policy rule by the central bank.

3 The Model

In this section we describe the BCA model augmented with a simple banking sector. It is a neoclassical growth model which consists of a) a representative household, b) a representative firm, c) government and a representative bank, with 6 exogenous wedges. The household maximizes its lifetime utility by maximizing consumption, leisure and investment. The firm maximizes profits by selecting optimal labor and capital in each time period. The government collects distortionary taxes in order to finance its exogenous expenditure. The bank invests in government securities and also loans to firms, and collects deposits from households and also pays a return on those deposits. The wedges are efficiency wedge a_t, investment wedge $1/(1+\tau_{xt})$, labor wedge $(1-\tau_{lt})$, government wedge g_t, deposit wedge $1/(1+\tau_{dt})$ and Taylor's Rule wedge $\tilde{R}_t$. We add an extra wedge in the SLR model.

Note that we have replaced the bond wedge in the standard Monetary Business Cycle Accounting model Sustek [13] with a deposit wedge, however they both are equivalent, except here the household deposits savings in bank which then invests in Treasury bills and lends to firms.

3.1 Model Description (with Perfect Monetary Policy transmission)

The representative household maximizes expected lifetime utility by optimizing consumption c_t, labor l_t, investment x_t and nominal deposits D_t in banks:

$$\max_{\{c_t,x_t,l_t,b_t,D_t\}} E_t \sum_{t=0}^{\infty} \beta_t U(c_t, 1-l_t) \tag{1}$$

where

$$U(c, 1-l) = (c(1-l)^{\psi})^{(1-\sigma)})/(1-\sigma) \tag{2}$$

s.t.

$$c_t + (1+\tau_{xt})x_t + (1+\tau_{dt})(\frac{D_t}{p_t(1+i_t^d)} - \frac{D_{t-1}}{p_t}) = r_t k_t + (1-\tau_{lt})w_t l_t + tr_t \tag{3}$$

where i^d is the interest rate paid by the banks on deposits by households. and the capital accumulation equation

$$(1+\gamma_z)(1+\gamma_a)k_{t+1} = (1-\delta)k_t + x_t - \phi(\frac{x_t}{k_t}) \tag{4}$$

where x_t is the investment, tr_t is the government transfer, w_t is the wage rate, r_t is the rental rate on capital, β is the subjective discount factor, k_t is the capital stock, δ is the depreciation rate, $(1+\gamma_z)$ is the growth rate of population and $(1+\gamma_a)$ is the growth rate of labor augmenting technology. $\phi(.)$ is the investment adjustment cost given by common specification:

$$\phi(\frac{x}{k}) = \frac{a}{2}(\frac{x}{k} - b)^2 \tag{5}$$

where b = $(1+\gamma_a)(1+\gamma_z) - 1 + \delta$. The representative firm solves the following problem:

$$\max_{\{k_t, l_t\}} F(k_t, a_t l_t) - r_t k_t - w_t l_t(1 + w_c i_t^f) \tag{6}$$

where i^f is the lending rate from banks to firms, and

$$F(k, al) = k^\theta (a(1-l))^{1-\theta} \tag{7}$$

The central bank manages the nominal interest rate on bonds via the following rule:

$$R_t = (1-\rho_r)[R + \omega_y(\ln y_t - \ln \bar{y}) + \omega_\pi(\pi_t - \bar{\pi})] + \rho_r R_{t-1} + \tilde{R}_t \tag{8}$$

where $\rho_r \in [0,1]$, and $\pi_t = \ln p_t - \ln p_{t-1}$, where p is the price level.

The government sets taxes (τ_{lt} and τ_{xt}) and transfers each period to satisfy its budget constraint:

$$g_t + tr_t = \tau_{lt} w_t l_t + \tau_{xt} x_t \tag{9}$$

Banks take deposits as given, and choose loans L_t and government bonds Z_t by solving the following problem:

$$\max_{L_t, Z_t} E_t \sum_{t=0}^{\infty} (1 + i_{t-1}^f)L_{t-1} + (1 + R_{t-1})Z_{t-1} + (1 + i_{t-1}^d)D_{t-1} + D_t - Z_t - L_t \tag{10}$$

subject to the following constraints:

$$D_t = Z_t + L_t + M_t \tag{11}$$

where M_t are the mandated amount of reserves (as a fraction δ_r of deposits) with the Central bank, at return at i_r.

The variables y, x, c, k, w, tr are in de-trended per-capita terms (say with a aggregate variable V_t, $\hat{v}_t = \frac{V_t}{N_t(1+\gamma_a^t)}$, where N_t is the population at time t).

3.2 Model Description (with Statutory Liquidity Ratio)

In the augmented model with a exogenous SLR requirement imposed by the government, we need to change the banking problem slightly:

$$\max_{L_t, Z_t} E_t \sum_{t=0}^{\infty} (1 + i^f_{t-1}) L_{t-1} + (1 + R_{t-1}) Z_{t-1} + (1 + i^d_{t-1}) D_{t-1} + D_t - Z_t - L_t \tag{12}$$

subject to the following constraints:

$$D_t = Z_t + L_t + M_t \tag{13}$$

and

$$Z_t = \alpha D_t \tag{14}$$

where α is the statutory liquidity ratio.

Now since we have only one identifying equation for i^f_t and R_t, we define a additional wedge $B_t = R_t - i^f_t$. This is a wedge because if the transmission was perfect as in the first model, then B_t would always equal zero.

3.3 Solving the Model

F.O.C. with respect to D_t:

$$\frac{-\lambda_t}{p_t} + \frac{\lambda_{t+1}}{p_{t+1}} \beta^h (1 + i^d_t) = 0 \tag{15}$$

From consumption F.O.C. we know that

$$U'_{c_t} = \lambda_t = \hat{c_t}^{-\sigma} (1 - l_t)^{\psi(1-\sigma)} \tag{16}$$

substituting which into the above equation gives us:

$$\frac{\hat{c_t}^{-\sigma} (1 - l_t)^{\psi(1-\sigma)} p_{t+1}}{p_t} + \frac{\hat{c_{t+1}}^{-\sigma} (1 - l_{t+1})^{\psi(1-\sigma)}}{p_{t+1}} \hat{\beta} (1 + i^d_t) = 0 \tag{17}$$

Solving Bank's optimization problem with respect to L_t and R_t we get two equations:

$$i^d_t = (1 - \delta) R_t + \delta i_r \tag{18}$$

and

$$i^f_t = R_t \tag{19}$$

Substituting the second in first equation we get $i^d_t = i^f_t - \delta R_t + \delta i_r$. We define LR Diff $= i^f_t - \delta R_t$ as our key variable to capture monetary policy transmission.

In the second model with a SLR requirement, our FOC is

$$i^d_t = \alpha R_t + (1 - \alpha - \delta_r) i^f_t + \delta_r i_r \tag{20}$$

From equations (19) and (20) in perfect MPT case and the case with SLR resp., we can see why having a mandatory SLR requirement can reduce monetary policy transmission. In the first equation changes in nominal interest rate are transmitted immediately to deposit rate and lending rates (one-to-one), but in case of SLR, for every rupee of deposits, the bank has to invest a fraction δ_r in government securities, and then the leftover amount can be used for lending to firms. Thus if nominal interest rate changes, it is possible that only deposit or lending rate may change [9].

3.4 Equilibrium Analysis

The four real wedges are thus defined in such a away that an increase in them leads to a increase in output (Chakraborty and Otsu [4]). If efficiency wedge a_t increases, production efficiency increases. If labor wedge $(1 - \tau_{lt})$ increases, it leads to higher returns from labor for the representative household, thus incentivizing a greater supply of labor leading to higher output. Similarly, with investment wedge $1/(1 + \tau_{xt})$, a higher value of the investment wedge increases investment, thus increasing production, and a similar argument holds for the deposit wedge $1/(1+\tau_{dt})$. An increase in government wedge also increases total output via increasing aggregate demand, but also crowds out consumption and investment via increasing interest rates, so it cant be considered as a 'improvement'.

An increase in $\tilde{R}_t$ cannot be construed as an improvement either, as it represents shocks to the Taylor's rule, representing frictions in the central bank's design and implementation of the Taylor's monetary policy rule. Tien et al. [14] call shocks to Taylors rule as the shocks that cause a difference between a targeted federal funds rate based on Taylors rule with perfect foresight and a Taylors rule with federal funds rate actually set by using forecasts of output and inflation.

The Competitive Equilibrium is thus defined as a sequence of prices $[r_t, w_t, R_t, p_t]_{t=0}^{\infty}$, and quantities $[y_t, c_t, x_t, b_t, g_t, l_t, k_{t+1}, tr_t]_{t=0}^{\infty}$ and 6 exogenous wedges efficiency wedge a_t, investment wedge $1/(1 + \tau_{xt})$, labor wedge $(1 - \tau_{lt})$, government wedge g_t, deposit wedge $1/(1 + \tau_{dt})$, and Taylor's rule wedge $\tilde{R}_t$ such that:

1. The household maximizes its expected lifetime utility assuming $[r_t, w_t, p_t, \tau_{lt}, \tau_{xt}, \tau_{bt}]_{t=0}^{\infty}$ and the initial value of capital k_0 as given;
2. The firm maximizes its profit every time period assuming $[r_t, w_t, a_t]_{t=0}^{\infty}$ to be given;
3. Capital and labor markets clear every time period;
4. Central bank sets the nominal interest rate on bonds in accordance with the Taylor's rule;
5. The resource and government budget constraint hold every time period;
6. The stochastic process $s_t = (\ln a_t, \tau_{lt}, \tau_{xt}, \ln g_t, \tau_{bt}, \tilde{R}_t)'$ follows the VAR(1) process: $s_{t+1} = P_0 + Ps_t + Q\epsilon_{s,t+1}, \epsilon \sim N(0, V)$ where ϵ follows a standard normal distribution with mean

zero and positive-semidefinite variance-covariance matrix V. P_0 is a 6x1 column vector, P is a 6x6 transition matrix. We thus have total of 63 parameters to estimate.

Note that this is the description for a competitive equilibrium for the Model with perfect Monetary policy transmission. In the case with SLR, we have seven wedges, hence the modified stochastic process will be $s_t = (\ln a_t, \tau_{lt}, \tau_{xt}, \ln g_t, \tau_{bt}, \tilde{R}_t, B_t)'$, and we need to estimate 84 parameters.

The first order conditions that characterize the competitive equilibrium (besides Taylors Rule) are as follows:

$$\hat{c}_t + \hat{g}_t + (1+\gamma_a)(1+\gamma_z)\hat{k_{t+1}} - (1-\delta)\hat{k}_t = \hat{y}_t = \hat{k}_t^{\theta}(a_t l_t)^{\theta-1} \tag{21}$$

$$\frac{\psi c_t(1 + w_c(i_t^f - 1))}{1 - l_t} = (1-\tau_{lt})(1-\theta)\hat{k}_t l_t^{-\theta} z_t^{1-\theta} \tag{22}$$

The labor FOC is the same as in the standard BCA model except the working capital term.

$$(1+\tau_{xt})\hat{c}_t^{-\sigma}(1-l_t)^{\psi(1-\sigma)} = \hat{\beta} E_t \hat{c_{t+1}}^{-\sigma}(1-l_{t+1})^{\psi(1-\sigma)}[\theta \hat{k_{t+1}}^{\theta-1}(a_{t+1}l_{t+1})^{1-\theta} + (1-\delta)(1+\tau_{xt+1})] \tag{23}$$

$$\frac{(1+\tau_{dt})}{p_t(1+R_t)}\hat{c}_t^{-\sigma}(1-l_t)^{\psi(1-\sigma)} = \hat{\beta} E_t \hat{c_{t+1}}^{-\sigma}(1-l_{t+1})^{\psi(1-\sigma)}\frac{(1+\tau_{dt+1})}{p_{t+1}} \tag{24}$$

The efficiency wedge is thus equivalent to a labor-augmenting technical shock. The labor wedge draws a friction in the intra-temporal marginal rate of substitution between the marginal product of consumption and labor. The investment wedge (bond wedge) draws a friction in the Euler equation for capital (bonds), between the inter-temporal marginal rate of substitution between marginal product of consumption today against the marginal product of investment (bond holdings) in the next time period.

3.5 Data

We apply the Business Cycle Accounting procedure to Indian quarterly data from 1996.Q1-2017.Q4. The source of data is RBI Quarterly National Accounts, with base year 2011-12. Hours worked are calculated by assuming 14 working hours in a day, multiplied by number of days factories worked in each year (data from Annual Survey of Industries). Capital stock is calculated via perpetual inventory method, using the investment data and assuming a initial value of capital stock (Chari et al. [5]). Data on lending rates is from SBI Prime Lending Rate.

Figure 1 shows the deseasonalized macroeconomic aggregates.

3.6 Empirical Methodology

We first calibrate parameter values based on the data and existing literature. In the second step we solve the log-linearized model using the Gensys method by (Sims [12]) and then estimate the linearized decision rules for the wedges using Bayesian MCMC methods (Herbst and Schorfheide [8]). In the last step, we explain the role of wedges in business cycle fluctuations by carrying out the decomposition exercise: we hold all but one wedge constant to isolate the marginal impact of that wedge on observables.

3.6.1 Calibration

We borrow the CKM values for the following parameters: (quarterly) subjective discount rate, time allocation parameter ψ and capital share. γ_z is the growth rate of population calculated from the data. γ_a is the growth rate of labor augmenting technology (labor productivity) calculated from the data such that the detrended log output has a zero mean. b is the adjustment cost parameter set equal to $\gamma_a + \gamma_z + \delta$, and the adjustment cost parameter a is calculated such that the elasticity, η of the price of capital with respect to the investment-capital ratio is 0.25. At the steady state, η = ab, so knowing η and b can allow us to calculate a.

Table 1 lists the parameter values.

3.6.2 Solution and Estimation of the Model

We solve the log-linearized model using Gensys (Brinca et al. [2]), and then estimate it using a linearized state space model:

$$X_{t+1} = AX_t + B\epsilon_{t+1} \tag{25}$$

$$Y_t = CX_t + \omega_t \tag{26}$$

Table 1: Parameters

Parameter	Description	Value
δ	Depreciation rate	10%
γ_a	Growth rate of labor productivity	.0138
γ_z	Growth rate of population	.0037
ψ	Leisure Preference	2.5
θ	Capital share	1/3
β	Subjective discount rate	.99
δ_r	Fraction of Deposits as Reserves	5%
i_r	Interest rate on Reserves	1%
w_c	Working Capital	0.5

$$\omega_t = D\omega_{t-1} + \eta_t \tag{27}$$

where

$$X_t = [log(k_t), log(a_t), \tau_{lt}, \tau_{xt}, log(g_t), \tau_{dt}, \tilde{R}_t, 1]'$$

and

$$Y_t = [log(y_t), log(x_t), log(l_t), log(g_t), i_t^f - \delta_r R_t, \pi_t]$$

and matrices A and B are calculated from Gensys.

We estimate the variable $i_t^f - \delta_r R_t$ because with perfect monetary policy transmission, it should equal $i_t^d - \delta_r i_r$. Since this equality does not hold in data, the discrepancies will be captured in the wedges.

Our aim here is to estimate the stochastic process s_t for the wedges

$$s_{t+1} = P_0 + Ps_t + Q\epsilon_{s,t+1}, \epsilon \sim N(0, V)$$

where

$$s_t = (log(a_t), \tau_{lt}, \tau_{xt}, log(g_t), \tau_{dt}, \tilde{R}_t)$$

and ϵ is i.i.d. and follows standard normal distribution with mean zero and variance-covariance matrix V.

In the second model with a SLR requirement, X_t and Y_t are changed as follows:

$$X_t = [log(k_t), log(a_t), \tau_{lt}, \tau_{xt}, log(g_t), \tau_{dt}, \tilde{R}_t, B_t, 1]'$$

and

$$Y_t = [log(y_t), log(x_t), log(l_t), log(g_t), R_t, \pi_t, i_t^f]$$

It is important to note that estimating this stochastic process is necessary only because of the investment and deposit wedges. The efficiency wedge can be directly calculated using the firm's FOC. The labor wedge similarly can be calculated from the households FOC. The government wedge is just the government expenditure plus net exports taken directly from the data. Estimating investment/bond wedge is necessary because in equations (23) and (24), the RHS contains expectations over the future values of capital stock, consumption and wedges.

We estimate the model using Bayesian RWMH-MCMC method [1]. The reason why we used Bayesian methods is because our data is considerably short: we have 88 observations to estimate 63 parameters (6 in P_0, 36 in P and 21 in V). When applying Bayesian methods, the prior information specified acts as extra information, and thus Bayesian methods are useful in cases of low sample size. The estimated scale potential reduction factor was 1.07.

The priors for P_0, P and Q matrices are given in Table 2.

For the SLR case with 84 parameters (7 in P_0, 49 in P and 27 in V), the priors are in Table 3.

4 Results

We plot the normalized (by base year values) output and wedges in Figure 2 for the Perfect MPT case, and Figure 3 and Figure 4 for SLR=0.15 and 0.25 resp. (note that the output and the wedges are de-trended).

First thing we see is that output and efficiency wedges follow each other very closely. A fall in efficiency wedge directly implies below trend growth in labor productivity. In our data we face three such major declines, first around 1999-02, then 2008-09, and lastly during 2011-12. All these three periods correspond to recessions in India ([11]).

We also see that labor wedges seem to follow a pattern opposite to output from 1999-2008, suggesting some improvements in labor wedge (reductions in labor market frictions), and but then fall consistently from 2008 onwards. Investment wedges however seem to rise, and from 2004-2001 seem to be associated with rise seen in output. Thus improvements in investment wedges possibly led to lower decline in de-trended output than otherwise.

[1] We borrow the MATLAB codes for Bayesian analysis from Herbst and Schorfheide [8].

4.1 Decomposition

Next we discuss the results of our experiment to isolate marginal impact of wedges, which answers the following question: how much of variation in an observable is attributable to the individual wedges. That is, say for output, we ask how much would output fluctuate if only the efficiency wedge fluctuated while others were held constant.

We now feed each of the wedges into the model while holding the other wedges constant. For example, we hold all except efficiency wedges constant, and then generate efficiency-wedge alone components of output, consumption, investment and hours. An easy way to capture the variation thus in an observable because of single wedge is the following f_Y^i statistic:

$$f_Y^i = \frac{1/(\sum_t (y_t - y_{it})^2)}{\sum_j \sum_t ((1/(y_t - y_{jt})^2))}$$

where $i, j = a, \tau_l, \tau_x, g, \tau_b, \tilde{R}$. Y_t is the actual data, and Y_{jt} is the data component due wedge j. We show the results of the decomposition exercise in **??**.

As mentioned earlier, the results in this modified model are similar in some aspects to our previous exercise of applying BCA model to Indian data. We can see from Table 13 (with perfect MPT) that up to 68% variation in output is explained by the efficiency wedge, and it also explains up to 50% of investment, 25% of hours worked.

The surprising result though is the our variable to capture monetary policy transmission (LR Diff) is explained almost equally by all except any role from nominal wedges. It implies that frictions embodied in real wedges play a important role in hindering monetary policy transmission.

Next when we introduce SLR in the model, we get that SLR by itself is not very important in understanding dynamics of MPT in India. The results from Table 14 almost same as in Table 15, except that our MPT wedge explains 55% of nominal interest rates when SLR=0.25, vs 67% when SLR=0.15. Changes in SLR thus only affect nominal interest rates. Since lending rates and nominal interest rates are accounted for very differently by the wedges, it shows considerable gap between them, which is another indicator of poor monetary policy transmission.

Conclusion

In this paper we apply the Montary Business Cycle Accounting model with an added simple banking sector to look at monetary policy transmission in India. We do so using two models, one where MPT should be perfect, and then we show that the four real wedges are almost equally responsible for lack of MPT in India. Next we add an exogenous SLR requirement to above, which by itself impedes MPT. We then show that SLR does not affect the transmission, but only the nominal interest rates.

Table 2: Priors (Model with Perfect MPT)

Parameter	Distribution	Mean	Std
P_0(1:3,5:6)	Normal	0	1/25
P_0(4)	Normal	-2.50	1/25
P_{diag}(1:2)	Normal	1	1/25
P_{diag}(3)	Normal	0.95	1/25
P_{diag}(4)	Normal	0.90	1/25
P_{diag}(5:6)	Normal	0	1/25
$P_{non-diag}$	Normal	0	1/25
Q_{diag}	Inverse Gamma	0.05	∞
$Q_{non-diag}$	Normal	0	1/25

Table 3: Priors (Model with SLR)

Parameter	Distribution	Mean	Std
P_0(1:3,5:7)	Normal	0	1/25
P_0(4)	Normal	-2.50	1/25
P_{diag}(1:2)	Normal	1	1/25
P_{diag}(3)	Normal	0.95	1/25
P_{diag}(4)	Normal	0.90	1/25
P_{diag}(5:7)	Normal	0	1/25
$P_{non-diag}$	Normal	0	1/25
Q_{diag}	Inverse Gamma	0.05	∞
$Q_{non-diag}$	Normal	0	1/25

These were priors for SLR=0.15 and 0.25. For SLR=0.20, the means for $P_{diag}(3)$ and $P_{diag}(4)$ are 0.80 and 0.75 resp.

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A Appendix

A.1 Log-linearized Equations

In this section we mention the log-linearized equations for output and hours worked which are same from Chari et al. [5] except for an additional term including the lending rates (note that these conditions are same for both the models above):

$$logy_t = \phi_{yk'} log\hat{k_{t+1}} + \phi_{yz} logz_t + \phi_{yl}\tau_{lt} + \phi_{yk} log\hat{k_t} + \phi_{yL} i_t^f$$

where $\phi_{yL} = (1-\theta)\phi_{ll}$.

$$logl_t = \phi_{lk'} log\hat{k_{t+1}} + \phi_{lz} logz_t + \phi_{ll}\tau_{lt} + \phi_{lk} log\hat{k_t} + \phi_{lg} logg_t + wc_l i_t^f$$

where $wc_l = \frac{\psi \hat{c} w_c}{\phi_{lh}}$, where w_c is the working capital parameter.

ϕ_{yL} and wc_l are our variables to capture the second stage of bank lending channel: transmission from lending rates to real variables output and hours worked.

The conditions for investment, deposit and inflation remain the same (See Brinca et al. [2]).

A.2 MLE estimates - Perfect MPT

Table 4: P

0.9748	0.0126	0.0402	0.0009	-0.0039	0.0054
-0.0234	0.9632	0.0218	-0.0054	-0.0029	-0.0390
-0.0120	0.0166	0.9267	0.0002	-0.0045	-0.0087
0.0056	-0.0302	0.0357	0.8215	-0.0035	0.0169
0.0006	0.0033	-0.0029	0.0004	0.1849	0.1442
-0.0118	0.0077	-0.0158	0.0050	0.0188	-0.0333

Table 5: P0

0.0235	-0.0754	0.0826	-0.4565	-0.0002	0.0540

Table 6: Q

0.0266	0.0108	-0.0142	-0.0297	-0.0045	0.0178
0.0108	0.0341	-0.0438	0.1368	-0.0027	-0.0122
-0.0142	-0.0438	0.0134	0.0110	0.0041	-0.0092
-0.0297	0.1368	0.0110	0.3755	0.0006	0.0170
-0.0045	-0.0027	0.0041	0.0006	1.8484	0.1400
0.0178	-0.0122	-0.0092	0.0170	0.1400	0.1084

A.3 MLE estimates - SLR (=0.25)

Table 7: P

0.9753	0.0173	0.0433	0.0060	0.0060	0.0208	0.0392
-0.0288	0.9724	0.0159	0.0009	0.0017	-0.0396	-0.0088
-0.0086	0.0248	0.9185	0.0038	0.0005	0.0083	0.0671
0.0050	-0.0306	0.0368	0.8249	0.0024	0.0217	0.0137
0.0016	0.0041	-0.0033	0.0051	0.1926	0.1232	-0.0146
-0.0164	0.0021	-0.0106	0.0018	0.0283	-0.0207	0.0319
-0.0248	-0.0317	0.0307	-0.0030	-0.0006	-0.0258	0.1346

Table 8: P0

0.0215	-0.0796	0.0862	-0.4479	0.0042	0.0524	-0.0010

Table 9: Q

0.0259	0.0102	-0.0121	-0.0287	-0.0026	0.0245	0.0146
0.0102	0.0359	-0.0446	0.1338	0.0069	-0.0075	-0.0061
-0.0121	-0.0446	0.0136	0.0143	0.0061	-0.0095	-0.0011
-0.0287	0.1338	0.0143	0.3730	0.0080	0.0147	0.0080
-0.0026	0.0069	0.0061	0.0080	1.5780	0.1977	0.0453
0.0245	-0.0075	-0.0095	0.0147	0.1977	0.1218	0.0483
0.0146	-0.0061	-0.0011	0.0080	0.0453	0.0483	0.1359

A.4 MLE estimates - SLR (=0.15)

Table 10: P

0.9773	0.0193	0.0408	0.0002	0.0095	0.0239	0.0373
-0.0284	0.9715	0.0169	-0.0026	-0.0061	-0.0413	-0.0113
-0.0059	0.0248	0.9236	0.0055	0.0052	0.0065	0.0665
0.0057	-0.0308	0.0370	0.8275	-0.0018	0.0244	0.0193
0.0019	0.0037	-0.0029	0.0030	0.1908	0.1273	-0.0219
-0.0174	0.0031	-0.0108	0.0030	0.0386	-0.0328	0.0413
-0.0235	-0.0312	0.0284	0.0018	-0.0067	-0.0309	0.1499

Table 11: P0

0.0236	-0.0795	0.0860	-0.4401	-0.0095	0.0605	0.0452

Table 12: Q

0.0259	0.0097	-0.0120	-0.0245	0.0044	0.0266	0.0131
0.0097	0.0352	-0.0454	0.1362	0.0079	-0.0092	-0.0099
-0.0120	-0.0454	0.0137	0.0025	0.0102	-0.0084	0.0006
-0.0245	0.1362	0.0025	0.3819	0.0025	0.0163	0.0077
0.0044	0.0079	0.0102	0.0025	1.5715	0.1816	0.0256
0.0266	-0.0092	-0.0084	0.0163	0.1816	0.1256	0.0656
0.0131	-0.0099	0.0006	0.0077	0.0256	0.0656	0.1351

Table 13: Decomposition - Perfect MPT

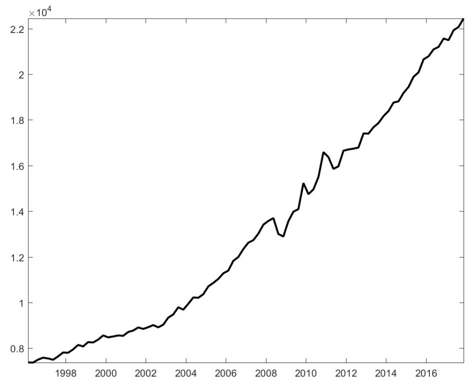
Observable(O)	f_A^O	$f_{\tau_l}^O$	$f_{\tau_x}^O$	f_G^O	$f_{\tau_d}^O$	$f_{\tilde{R}}^O$
Output	70.10	5.30	6.70	5.80	6.20	5.90
Hours	25.70	13.10	8.90	19.30	17.00	15.90
Investment	45.30	9.70	13.60	11.10	10.00	10.40
Consumption	21.10	19.70	8.90	17.40	16.10	16.70
Inflation	16.20	16.70	16.70	16.70	17.20	16.40
LR Diff	19.10	28.00	27.40	25.20	0.20	0.30

Table 14: Decomposition SLR=0.15

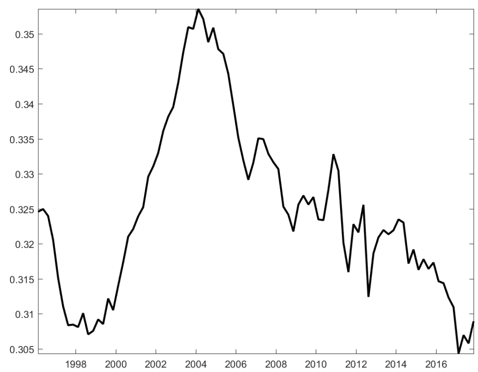
Observable(O)	f^O_A	$f^O_{\tau_l}$	$f^O_{\tau_x}$	f^O_G	$f^O_{\tau_d}$	$f^O_{\tilde{R}}$	f^O_B
Output	66.20	5.10	6.20	5.50	5.80	5.70	5.60
Hours	22.60	11.50	7.80	16.80	14.20	13.90	13.20
Investment	43.20	9.00	11.00	9.80	8.90	9.20	8.90
Consumption	9.50	16.20	13.40	17.60	14.60	14.80	13.90
Inflation	13.60	14.00	14.00	14.00	13.00	13.70	17.50
NIR	6.40	7.30	7.30	7.20	3.20	1.80	66.80
Lending Rate	17.20	20.40	20.20	19.30	1.40	20.60	0.90

Table 15: Decomposition SLR=0.25

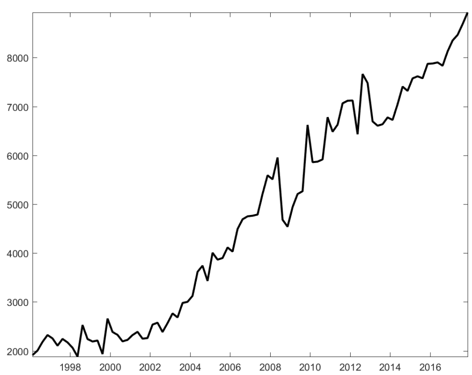
Observable(O)	f^O_A	$f^O_{\tau_l}$	$f^O_{\tau_x}$	f^O_G	$f^O_{\tau_d}$	$f^O_{\tilde{R}}$	f^O_B
Output	66.20	5.00	6.30	5.50	5.80	5.70	5.50
Hours	22.90	11.40	7.80	16.70	14.20	13.80	13.10
Investment	42.80	8.90	11.30	9.90	8.90	9.20	9.00
Consumption	9.40	16.30	13.40	17.50	14.60	14.70	14.00
Inflation	13.60	14.00	14.00	14.00	13.30	13.80	17.10
NIR	8.50	9.70	9.80	9.70	4.80	2.30	55.20
Lending Rate	17.20	20.50	20.40	19.40	1.30	20.50	0.80



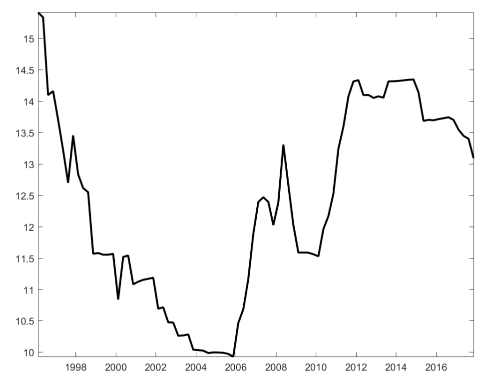
(a) Output per capita



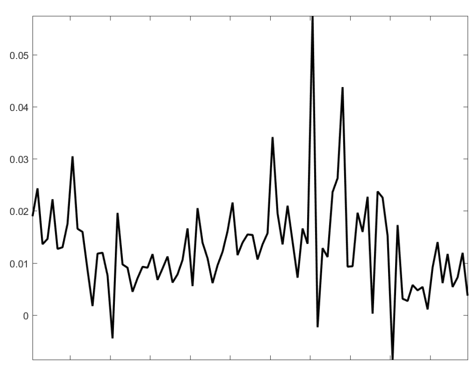
(b) Hours



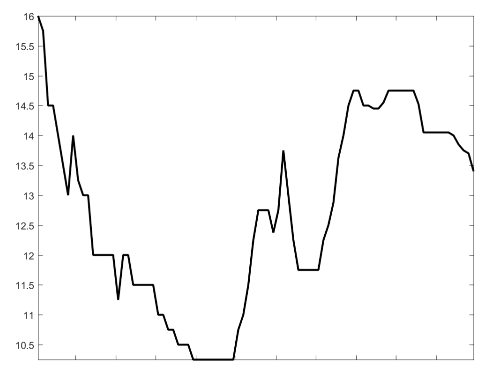
(c) Investment per capita



(d) LR Diff

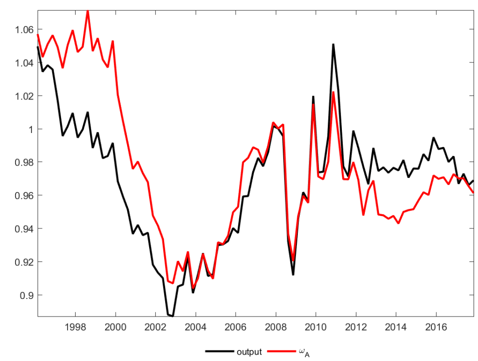


(e) Inflation

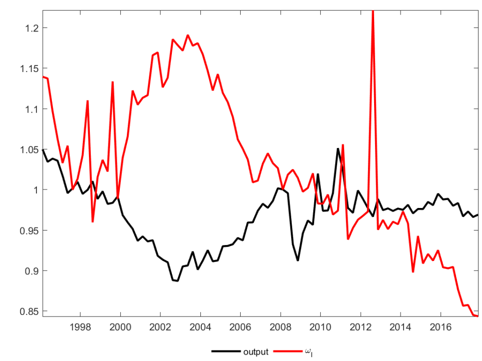


(f) Lending Rate

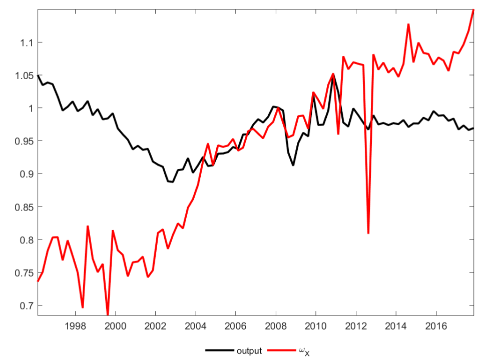
Figure 1: Plots of Observables



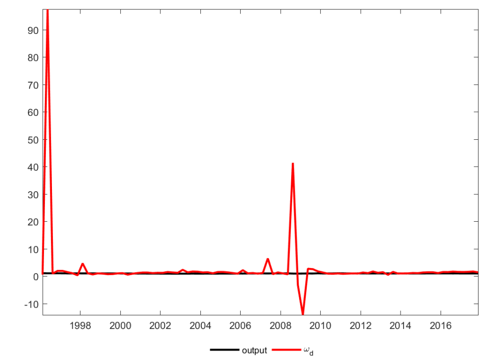
(a) Efficiency Wedge



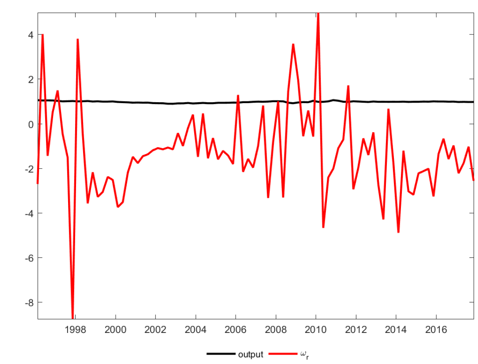
(b) Labor Wedge



(c) Investment Wedge

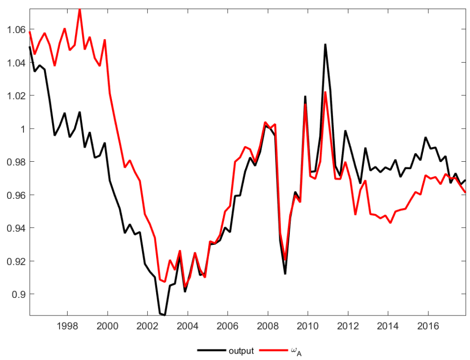


(d) Deposit Wedge

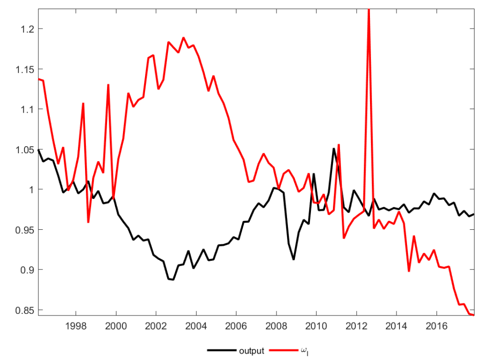


(e) Taylors Rule Wedge

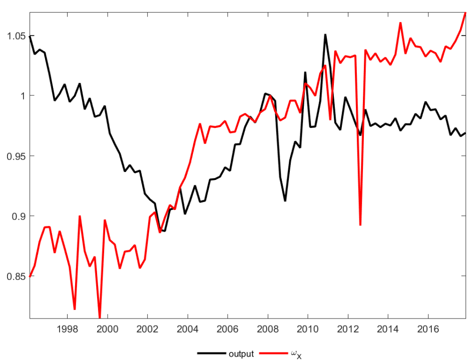
Figure 2: Plots of Wedges



(a) Efficiency Wedge

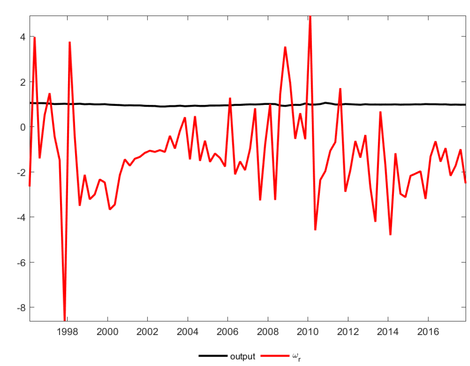


(b) Labor Wedge

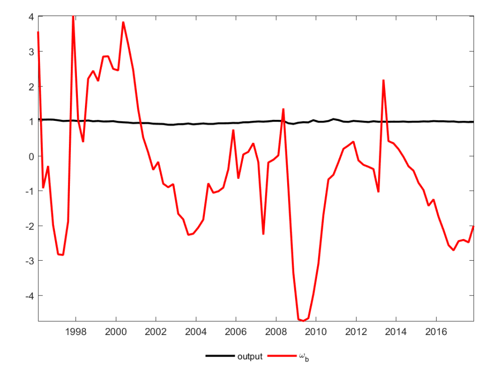


(c) Investment Wedge

(d) Deposit Wedge

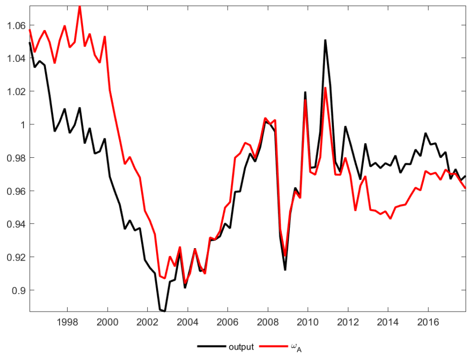


(e) Taylors Rule Wedge

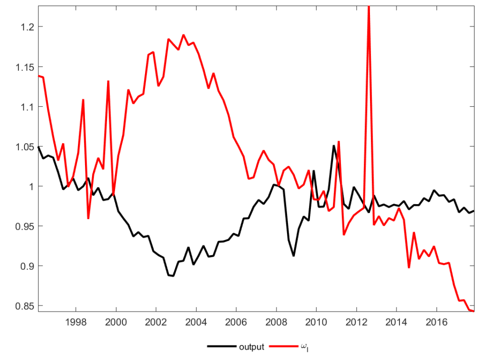


(f) MPT Wedge

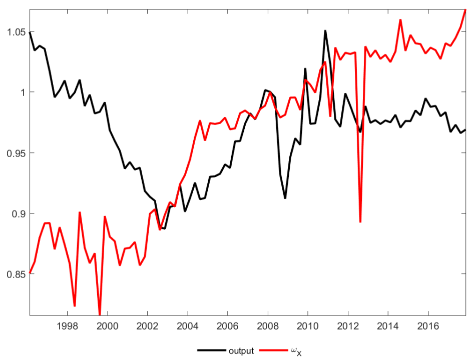
Figure 3: Plots of Wedges - SLR=0.15



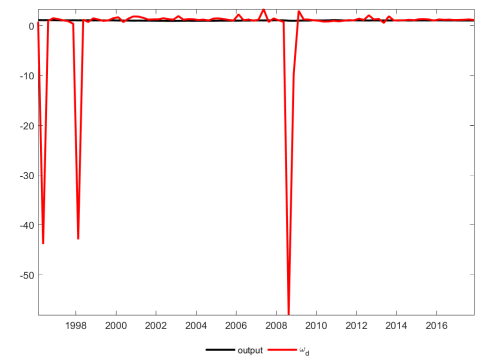
(a) Efficiency Wedge



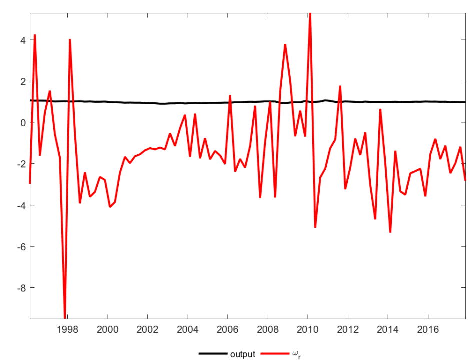
(b) Labor Wedge



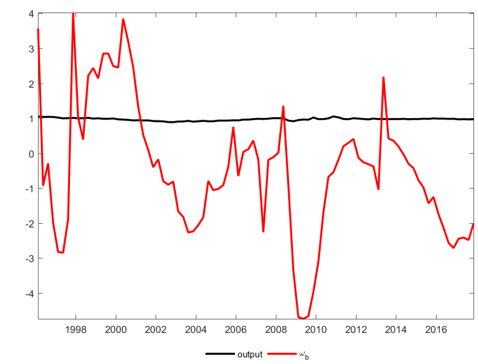
(c) Investment Wedge



(d) Deposit Wedge



(e) Taylors Rule Wedge



(f) MPT Wedge

Figure 4: Plots of Wedges - SLR=0.25