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# Active monetary policy and the slowdown: Evidence from DSGE based Indian aggregate demand and supply

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## ABSTRACT

We explore reasons for the strongly asymmetric Indian monetary transmission and response to other shocks, compared to those of the United States, obtained in a standard New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model. While counterfactual analysis moderates other impulse responses, it suggests large cost shocks remain a primitive cause of inflation, and the strong transmission comes from large interest rate changes. Reducing the variance of the interest rate shock can significantly moderate the large output cost. Asymmetric excess volatility due to preference and technology shocks is reduced on introducing regime switching between multiple steady-states. The estimated model including multiple regimes is therefore used to obtain aggregate demand and aggregate supply schedules, which incorporate the policy reaction function, and to identify their shifts during the Indian slowdown. The correlation between factors shifting aggregate demand and supply is estimated. Since it is negative it aggravates the shocks. The post 2011 slowdown is explained by severe demand contraction in response to adverse supply shocks. Habit persistence in consumption changes the slope of both aggregate demand and supply curves significantly.

## 1. Introduction

Before the onset of the global financial crisis, the Indian economy was growing at more than 9%. There were signs of inflationary pressure but it was largely presumed to be the result of high growth rate and high world food inflation. As the crisis unfolded both monetary and fiscal authorities responded quickly to maintain the growth momentum. Between August 2008 and April 2009 the policy repo rate was reduced from 9% to 4.75% and the 15–91 days treasury bill rate followed that cut. There was a quick growth recovery following macroeconomic stimulus. In the very beginning of the crisis crude oil prices crashed but soon started increasing. Inflation followed crude oil prices and food inflation that had remained high. Reserve Bank of India (RBI) started interest rate tightening to counter inflation in 2010 (Fig. 1). But from 2011 onwards growth rates started declining as multiple shocks occurred including a fall in export growth due to the Euro-debt crisis. But interest rates continued to increase. The repo rate peaked at 8.5 in October 2011. A slight decrease in 2012 was quickly reversed from mid 2013 as part of interest rate defense used following the US-led taper-on crisis. The decline in growth led to a debate in India about the role of monetary policy in stifling growth. Fig. 1 shows high levels of interest rates after 2011 despite low growth and a fall in oil prices in 2014, which reduced inflation. Apart from this the RBI has also been criticised for more than necessary post-crisis stimulus and late response to inflation. None other than the former Governor of the RBI accepted these

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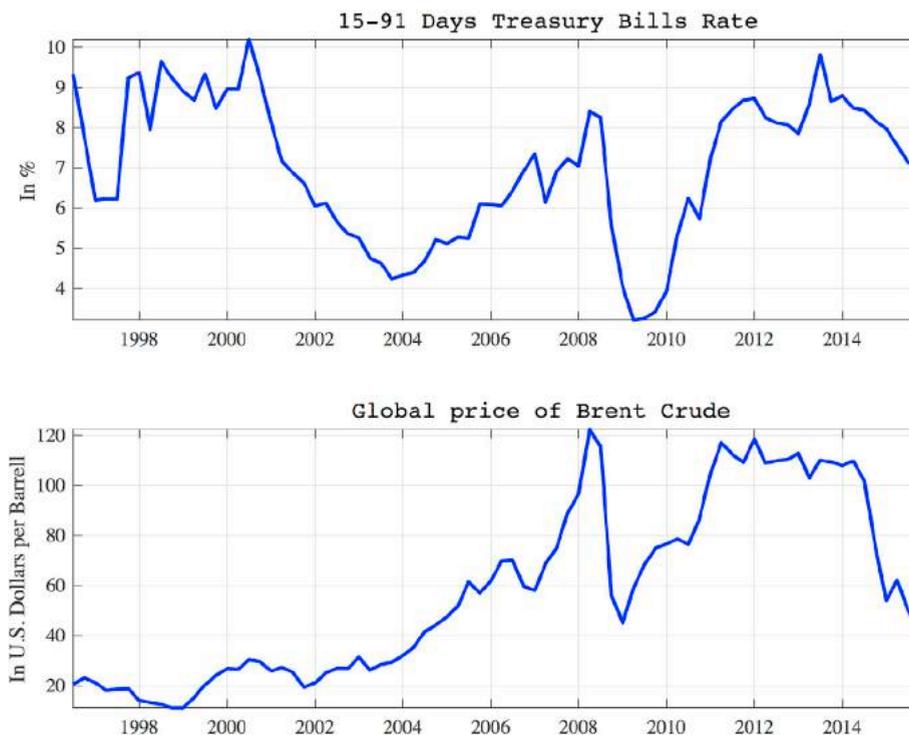


Fig. 1. 15–91 days treasury bills rate in India and global crude oil prices.

criticisms while defending the role of RBI.

"In 2008, massive infusion of liquidity was seen as the best bet. Indeed, in uncharted waters, erring on the side of caution meant providing the system with more liquidity than considered adequate. This strategy was effective in the short-term, but with hindsight, we know that excess liquidity may have reinforced inflation pressures. With the benefit of hindsight, of course, I must admit in all honesty that the economy would have been better served if our monetary tightening had started sooner and had been faster and stronger. Why do I say that? I say that because we now know that we had a classic V-shaped recovery from the crisis, that growth had not dipped in the Lehman crisis year as low as had been feared, and that growth in the subsequent two years was stronger than earlier thought ... Note that the objective of monetary tightening is to compress aggregate demand, and so some sacrifice of growth is programmed into monetary tightening. But this sacrifice is only in the short-term; there is no sacrifice in the medium term (Duvvuri Subbarao, 2013)".

Is Indian monetary response excessive? Goyal and Kumar (2017) compare Indian and United States transmission in a minimal estimated New Keynesian Dynamic Stochastic General Equilibrium (DSGE) with relevant frictions, based on Ireland (2011). They exploit variation in output, inflation and interest rate series in this period, to estimate basic demand and supply shocks. Features such as marginal cost shocks arising from intermediate goods, inclusion of habit persistence and backward-looking behavior, make the model relevant for an emerging market (EM). Additional features would complicate the theory and reduce its ability to extract insights from the data.

Goyal (2011), which also has a dual economy structure, shows that such a structure and volatile terms of trade can be reduced to factors that shift or change the slope of demand and supply curves derived from a DSGE model. As the informal sector shrinks, the curves reduce to those of an advanced economy (AE). Policy interventions, such as maintaining a constant real exchange rate, often dampen terms of trade shocks affecting the slopes. Moreover, as Ireland (2011) points out, financial malfunctions are often endogenous to more basic macroeconomic fundamentals. Therefore, the simple estimated DSGE, albeit with a richer set of demand and supply shocks, is useful for a first set of insights. DSGE models have been extensively used to explore monetary transmission and the policy implications that follow but very few studies have derived aggregate demand (AD) and aggregate supply (AS) from a DSGE.

Goyal and Kumar (2017) find an excessive and asymmetric response to shocks in general, and of inflation and output to interest rate shocks in particular, for India compared to the United States. This paper first searches for structural features that can explain these differences. Understanding factors that leads to excessive response, and could therefore have caused the slowdown, can suggest possible ways to reduce the output cost of interest rate policy. Second, AD and AS, derived from the estimated model including multiple regimes, are used to analyze the Indian economy during the crisis and the Indian slowdown after 2011. This allows us to map movements in interest rates and oil prices to movements in AD and AS. Third, we report significant differences in AD and AS that can arise from changing the model specification, by comparing the AD and AS derived from Ireland (2004) with that from Ireland (2011). Jones and Kulish (2016) estimate the AD and AS representation of Ireland (2004, 2011) differs from Ireland (2004) mainly on two counts, introduction of habit persistence ( $\gamma$ ) in consumption and of partially backward looking price setting ( $\alpha$ ).

Sensitivity analysis shows estimated asymmetric EM volatility due to preference and technology shocks is reduced on introducing

regime switching between multiple steady-states. The counterfactual impulse responses are able to moderate other large responses, but large cost shocks remain a primitive cause of inflation. Varying other parameters do not affect these. Strong transmission is found to be due to large monetary policy shocks. The excessive output cost of interest rate shocks can be moderated by reducing the variance of the interest rate shock. Since the persistence of supply shocks is found to be low there is no need to over-react to such shocks.

AD and AS schedules that include the policy reaction function are obtained and their shifts are identified. Shifts are due to exogenous expected and lagged variables, and to shocks. The correlation between shifts to aggregate demand and supply is estimated. Since it is negative it aggravates shocks. The slowdown is explained by a severe demand contraction in response to adverse supply shocks, that triggered a move to a lower growth steady-state. Comparison of our estimated aggregate demand and supply with those obtained by Jones and Kulish (2016) suggest that habit persistence changes the slope of derived aggregate demand and supply curve significantly.

The remainder of the paper is structured as follows: Section 2 give the log linearized version of the model and the baseline parameter estimation impulse response. Section 3 explores monetary transmission using counterfactual impulse responses. Section 4 analyzes dynamic aggregate demand and supply and is followed by the conclusion. Appendices A to E give the matching of the model to the data, counterfactual impulse responses, derivations and analysis of the aggregate demand and supply schedules and estimated parameters.

## 2. Log linearized model

The simple New Keynesian model used derives three key equations from a DSGE model with a representative household, representative finished good producing firm, continuum of intermediate goods producing firms and a central bank. First, the IS curve is derived from the optimization of the representative household. Second, the New Keynesian Phillips curve (NKPC) gives optimal price setting under monopolistic competition and costs of nominal price adjustment. Third, the monetary policy rule gives the behavior of the central bank.

Habit formation is introduced in preferences so the IS curve is partially backward and partially forward-looking. Intermediate goods producing firms operate in a monopolistic output market. The representative finished good firm converts the goods obtained from the intermediate goods firm into a final good in a competitive market. There are four shocks: technology, preference, markup and interest rate (or monetary policy shock). Preference and monetary policy shocks are demand shocks while markup and technology shocks are supply shocks. Marginal cost shocks arise from intermediate goods. These features make the model relevant for an EM.

The basic first order conditions for such a model are well known and are available in Goyal and Kumar (2017). Below the variables are made stationary using the technology or labour productivity shocks,  $Z_t$ , and linearized around a symmetric steady-state with linearized variables denoted by ' $\hat{\cdot}$ '. We start with the shocks. For example, preference shocks  $\hat{a}_t = \ln(a_t/a)$ , can be linearized as:

$$\hat{a}_t = \rho_a \hat{a}_{t-1} + \varepsilon_{a,t} \quad (1)$$

Markup shock process can be linearized as:

$$\hat{\theta}_t = \rho_\theta \hat{\theta}_t + \varepsilon_{\theta,t} \quad (2)$$

Technological shock process can be linearized as:

$$\hat{z}_t = \varepsilon_{z,t} \quad (3)$$

The household first order condition with respect to consumption  $C_t$ , which together with Equation (5) gives the IS, is:

$$(z - \beta\gamma)(z - \gamma)\hat{\Omega}_t = z\gamma\hat{y}_{t-1} - (z^2 + \beta\gamma^2)\hat{y}_t + \beta\gamma z\hat{y}_{t+1} + (z - \beta\gamma\rho_a)(z - \gamma)\hat{a}_t - \gamma z\hat{z}_t \quad (4)$$

Where  $\Omega_t = \lambda_t Z_t$ , where  $\lambda_t$  is the Lagrangian multiplier of household optimization problem and  $y_t = Y_t|Z_t$  is stationary output.

First order condition with respect to bond holding,  $B_t$ , is:

$$\hat{\Omega}_t = E_t \hat{\Omega}_{t+1} + \hat{r}_t - E_t \hat{\pi}_{t+1} \quad (5)$$

From steady state we have  $c = y$  and thus we have:

$$\hat{y}_t = \hat{c}_t \quad (6)$$

Intermediate goods firms first order condition, derived with respect to prices,  $P_t(i)$ , the basic NKPC, is:

$$(\beta\alpha + 1)\hat{\pi}_t = \alpha\hat{\pi}_{t-1} + \beta\hat{\pi}_{t+1} + \Psi\hat{a}_t - \Psi\hat{\Omega}_t + \hat{\Theta}_t \quad (7)$$

This uses  $\Psi = \frac{\theta-1}{\theta p}$ ,  $\hat{\Theta}_t = -\frac{\hat{\theta}_t}{\theta p}$ , where  $\theta_p > 0$  is the price adjustment cost and  $\Psi$  is the elasticity of inflation to changes in marginal cost and  $\hat{a}_t - \hat{\Omega}_t$  is the real marginal cost of production. The latter depends on the stickiness of prices, and is low where prices are sticky.

Substituting  $\hat{\Theta}_t = -\frac{\hat{\theta}_t}{\theta p}$  leads to a new form of Equation (2) as given below in which  $\sigma_\theta = \frac{\sigma_\theta}{\theta}$ :

$$\hat{\Theta}_t = \rho_\theta \hat{\Theta}_t + \varepsilon_{\theta,t} \quad (2')$$

Growth rate  $g$ , is:

**Table 1**  
Estimated coefficients: Baseline and with regimes.

Parameters	India		United States
	2	3	4
	Baseline	With Three Growth Regimes	Ireland (2011)
$\gamma$	0.6770	0.5411	0.3904
$\alpha$	0.0806	0.0141	0.0000
$\rho_\pi$	0.1326	0.1736	0.4153
$\rho_g$	0.1825	0.3968	0.1270
$\rho_a$	0.9586	0.9628	0.9797
$\rho_\theta$	0.1656	0.3816	0.0000
$\sigma_a$	0.0992	0.1016	0.0868
$\sigma_\theta$	0.0101	0.0082	0.0017
$\sigma_z$	0.0075	0.0019	0.0095
$\sigma_r$	0.0026	0.0035	0.0014

Notes:  $\gamma$  is measure of habit persistence,  $\alpha$  is extent of backward looking inflation,  $\rho_\pi$  and  $\rho_g$  are weight of inflation and growth respectively in Taylor rule.  $\rho_a$  and  $\rho_\theta$  are persistence of preference and mark up shock respectively.  $\sigma_a$ ,  $\sigma_\theta$ ,  $\sigma_z$ ,  $\sigma_r$  are standard deviation of preference, markup, technology and interest rate shocks respectively.

$$\widehat{g}_t = \widehat{y}_t - \widehat{y}_{t-1} + \widehat{z}_t \tag{8}$$

Potential output  $q_t$  is:

$$0 = z\gamma\widehat{q}_{t-1} - (z^2 + \beta\gamma^2)\widehat{q}_t + \beta\gamma z\widehat{q}_{t+1} + \beta\gamma(z - \gamma)(1 - \rho_a)\widehat{a}_t - \gamma z\widehat{z}_t \tag{9}$$

Output gap  $x_t$  is:

$$\widehat{x}_t = \widehat{y}_t - \widehat{q}_t \tag{10}$$

Monetary policy rule can be linearized as:

$$\widehat{r}_t = \widehat{r}_{t-1} + \rho_\pi\widehat{\pi}_t + \rho_g\widehat{g}_t + \varepsilon_{r,t} \tag{11}$$

Three equations IS, AS, the monetary policy rule, and their parameters, are estimated using time series of three variables, output, inflation, and short-term nominal rates, with certain parameters calibrated to match the data (see Appendix A). The calibration amounts to demeaning the data.

The model is first solved using the Klein (2000) method and a state space is obtained. Using the respective observed variables  $\widehat{g}_t$ ,  $\widehat{\pi}_t$  and  $\widehat{r}_t$  log likelihood is maximized to estimate the parameters for India and United States. Estimation details are available in Goyal and Kumar (2017) and in Ireland (2011). The maximum likelihood estimations of the parameters are given in Table 1 (column 2). Parameters for US (column 4) are the same as reported in Ireland (2011). Estimated parameters are used to obtain the impulse responses for India and for United States (Fig. 2). The models have a similar structure, but are estimated with the data of the respective countries.

The impulse responses for India compared to those for the US, show much higher volatility in the Indian response to shocks. The two demand shocks in the model, preference and monetary policy shocks, move output and inflation in the same direction. Preference shocks increase output and the interest rate. The cost-push and technology shocks are supply-side disturbances and move output and inflation in opposite directions.

The impact of the preference and the monetary shock on output, inflation and interest rate in India is higher. Since impulse responses are drawn to one standard deviation shock, there are two possible explanations of the higher impact, that is, either the shock itself has higher variance and so one standard deviation change is a bigger change and second that inherent structural differences give rise to the differential impact. The impact of monetary policy on output could be larger in case of a lower elasticity of inflation to changes in marginal cost as argued in Goyal and Pujari (2005) but the larger impact on both inflation and output is puzzling and needs further exploration.

For the cost push shock the response of both inflation and output is much higher in comparison to United States and this could be due to higher volatility of the cost push shock or to the structure of aggregate demand and supply. Response of output to technology shock is lower in the case of India even after twenty periods, suggesting output is kept below potential reducing technological catch up. Response of inflation to technology shock is much sharper in India than in US suggesting that it shifts the AS more. Response of the interest rate due to technology shock also differs—whereas in US the rate rises it falls in India. The model has a common preference shock that is applicable for both consumption and money demand. In case of technology shock money demand increases as output increases and this higher money demand would lead to increase in interest rate especially in countries like US where consumption is more borrowing dependent. In India inflation decreases by a large amount in case of technology shocks and possibly this allows the central bank to decrease the interest rate. This behavior of interest rate indicates that in the US economy demand is a major reason for inflation whereas in India supply also has an important role to play in inflation determination. In next section we explore structural features that can explain these differences.

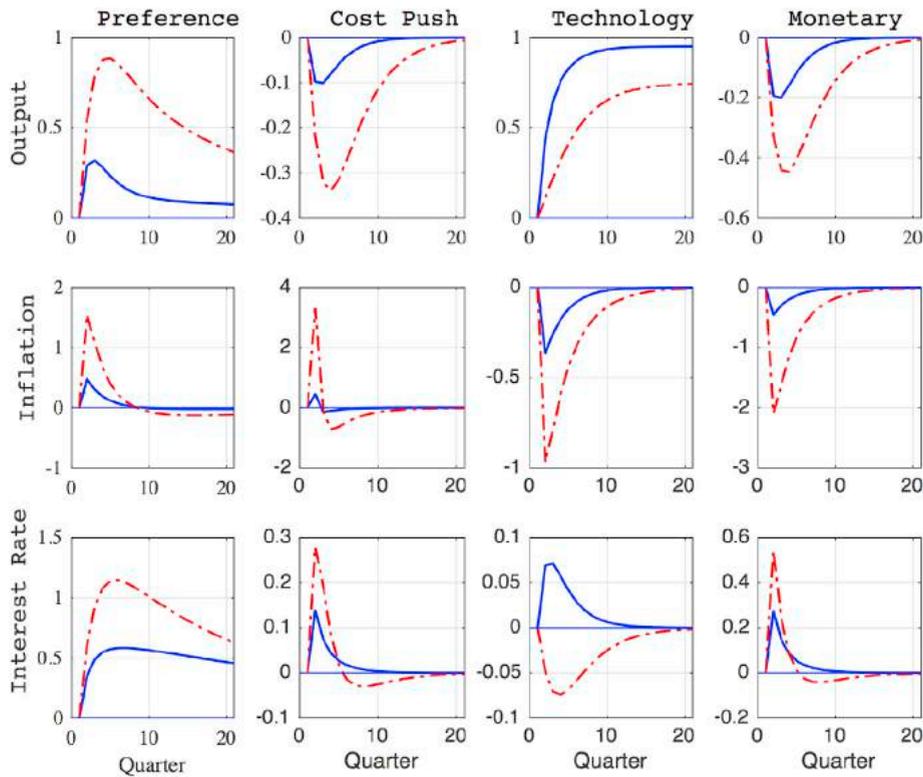


Fig. 2. Impulse Response of variables (LHS) to shocks; solid line (blue) is for US and dotted line (red) is with Indian data. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

### 3. Exploring reasons for strong estimated monetary transmission

We do sensitivity analysis with different parameter values in comparative impulse responses in order to identify the source of these variations and get a better understanding of Indian monetary transmission. Compared to our baseline estimations of  $\alpha = 0.0806$  and  $\rho_\theta = 0.1656$ , Ireland (2011) takes price-setting to be forward looking ( $\alpha = 0$ ), and persistence of the mark-up shock to be zero ( $\rho_\theta = 0$ ) based on the evidence of bootstrap simulation (Table 1). We estimate the first counterfactual impulse response by putting first  $\alpha = 0$  and then both  $\alpha = 0$  and  $\rho_\theta = 0$  (Figure E1, Appendix E) as in Ireland (2011). The impulse responses suggest results are not driven by the value of  $\alpha$  and  $\rho_\theta$  used. Strong monetary transmission persists even after taking  $\alpha = 0$  and  $\rho_\theta = 0$ .

Habit persistence  $\gamma$  estimated for India is significantly higher. The large observed increase in saving in growing economies implies high habit persistence in consumption and causation from growth to saving (Carroll, Overland & Weil, 2000). Without habit formation forward looking consumers will increase consumption and save less during high growth with the prospect of higher future income. To explore this role of habit persistence in monetary transmission we also obtain the impulse responses for India with a value of  $\gamma$  as in Ireland (2011). Lowering habit persistence, however, hardly affects the monetary transmission to inflation while giving an even stronger output response (Figure E2). Therefore, sensitivity analysis so far suggests that strong monetary transmission observed is not driven by  $\alpha$ ,  $\rho_\theta$  or  $\gamma$ .

An EM has normally not reached steady-state growth. One way of capturing this source of volatility is to introduce multiple high and low steady-state growth regimes. After the economic reforms of the early 1990s, economic growth picked up in India and it was growing almost at double digits before the onset of the global financial crisis. After that, growth was not of similar magnitude. One can identify episodes of high, medium and low growth during the period. First: September 1996 to December 2003, low average growth rate = 0.014, second: March 2004 to June 2008, high average growth rate = 0.021, third: September 2008 to December 2015, medium average growth rate = 0.017. While taking the model to the data, we work with deviations of growth rates from the steady state growth rate. In our baseline estimation the steady state growth rate is 0.0168 and is subtracted from the growth rate to obtain  $\hat{g}_t$  to be used in the estimation. We also estimate a three regime variant of the model in which we use the above three distinct steady state growth rates for the three different periods to obtain  $\hat{g}_t$  used. We obtain new impulse responses with these estimates. While these varying regime  $z$  values are used to create  $\hat{g}_t$ , their average value,  $z$ , is continued to be used elsewhere in the model.

Estimated parameters for periods divided into low, high and medium growth rates differ from baseline parameters (Table 1). The estimated variance of the technology shock is now less, as expected. There is also less habit persistence and more forward-looking behavior. The new impulse responses (Figure E3) show moderated effects of technology and preference shocks on output and

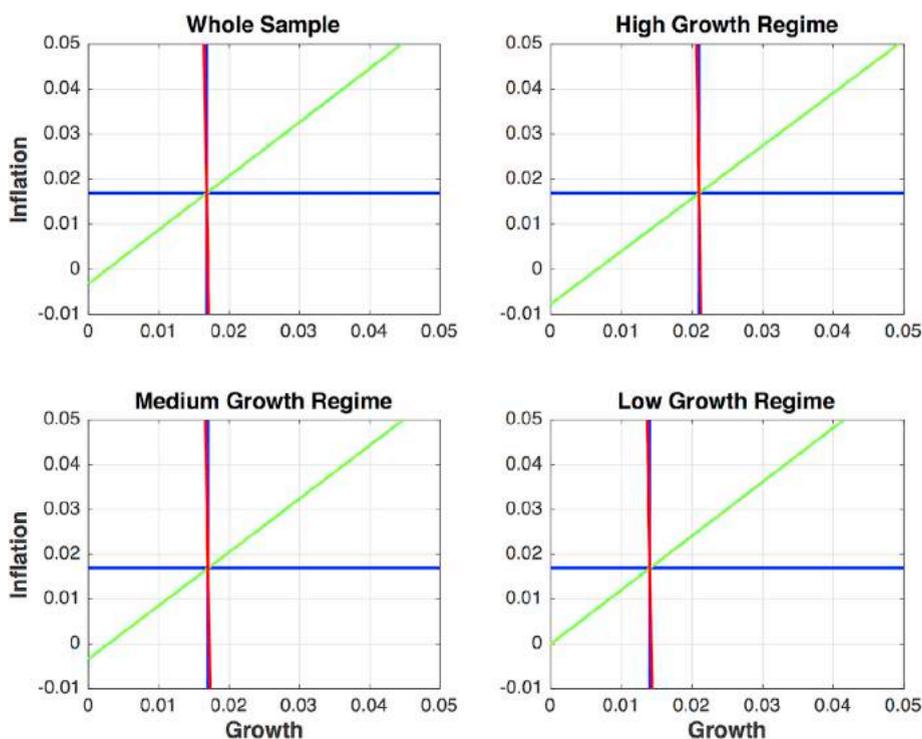


Fig. 3. Steady State Aggregate Demand and Supply: Red line is aggregate demand and green line is aggregate supply. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

inflation. The response of output to mark-up and monetary shocks increases, however, while response of inflation to mark-up and monetary shocks remains the same.

These simulations suggest estimated values of parameters in Goyal and Kumar (2017) together with multiple regimes, are adequate to capture essential Indian economic structure and its difference from the US. Introducing regimes reduces preference and technology shocks but cost shocks and a large monetary policy response as well as impact remain. Cost shocks would have to moderate to reduce monetary policy response to US levels and reduce inflation and output response to interest rates.

What happens when we enforce US monetary reaction functions in India? Goyal and Kumar (2017) estimated coefficients give a significantly different feedback rule in interest rate setting in India. In order to see whether strong monetary transmission is driven by differences in the interest rate setting rule, we obtain another counterfactual impulse response for India by implementing the Federal Reserve feedback rule. The transmission to output and inflation moderates significantly (Figure E4) and interest rate slightly increases after a technology shock as in US. But the interest rate response to markup shock increases, thus increasing the output cost of a markup shock and decreasing its inflation effect. Implementing Federal Reserve feedback rule in India, implies a significantly higher response of interest rate to inflation. Since most often this inflation is coming from a markup shock, therefore markup shocks are leading to higher interest rate and thus exacerbating the output effect of markup shock in comparison to our baseline estimated version. Impulse responses are drawn for an isolated shock. This again is evidence that supply shocks are primitive in India and critical for Indian inflation.

Our estimated Indian monetary shock variance is almost four times compared to US (Ireland, 2011). To test whether the strong monetary transmission is due to excessive variance of the interest rate shock we obtain another counterfactual impulse responses for India by imposing the variance estimated by Ireland (2011) for United States (Figure E5). Once we control for excessive interest rate shock variance, transmission to inflation and to output moderates. Contrary to the counterfactual impulse responses obtained by implementing Federal Reserve feedback rule in India, there are now no significant changes in the effects of other shocks, so that the over-reaction to cost-push shocks is no longer there. Even so, response to monetary shocks as well as impact of cost-push shocks continue to be higher in India than in the US.

Finally, we implement the same feedback rule and variance together to see whether we can attribute the strong transmission to Indian interest rate setting (Figure E.6). The response of inflation to interest rate shock becomes equal to the response of inflation in US. The response of output to interest rate shocks becomes less than the response of output in US. The lower output response can be explained by our implementation of Federal Reserve feedback rule in India (Figure E4). The interest rate response to markup shock significantly increases, however. Thus, there is a lower impact of interest rate shock but at the same time the output cost of a markup shock increases.

From the above analysis it is clear that the strong Indian monetary transmission obtained in Goyal and Kumar (2017) can be moderated by reducing the interest rate variance. Reducing the variance of monetary policy shock works best as changing the feedback

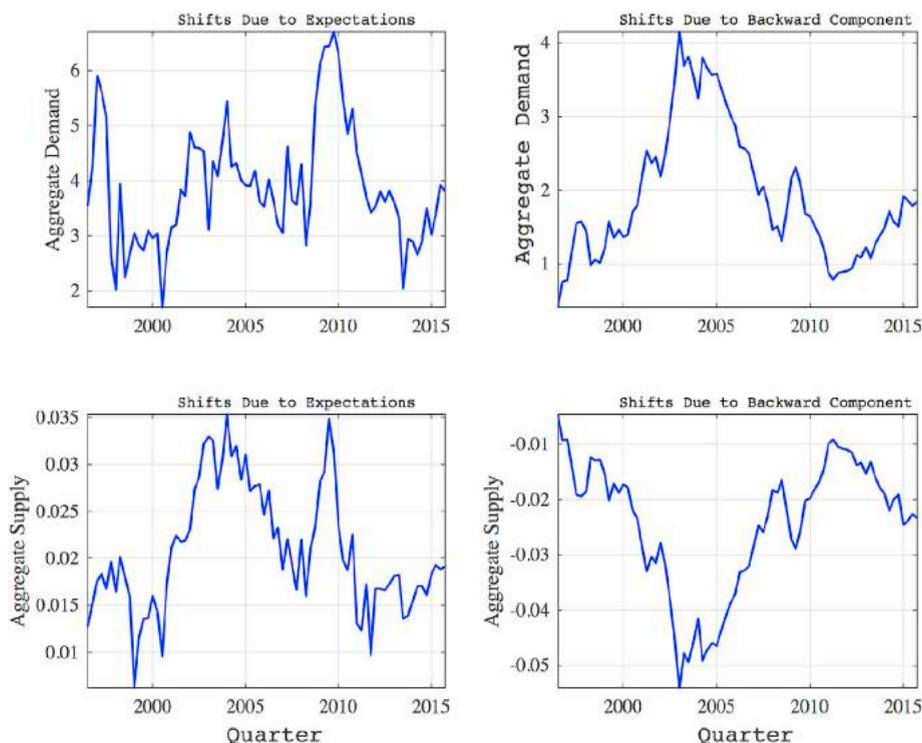


Fig. 4. Shifts in Aggregate Demand and Supply due to expected terms and backward looking terms.

rule shifts the output cost from monetary shock to the markup shock. The interest rate response to a cost shock shows signs of overshooting and then undershooting (turning negative). More smoothing could moderate this. Since the estimated persistence of the supply shock  $\rho_\theta$  is low, there is no need to overreact to it.<sup>1</sup> Although supply shocks play a very important role in the Indian economy, milder monetary policy tightening in response to such shocks can moderate the negative effects of the supply shock. This is more feasible to the extent fiscal policy is used to moderate supply shocks, which else remain a primitive that impacts inflation requiring an interest rate response.

#### 4. Aggregate demand and supply

##### 4.1. Habit persistence and aggregate demand and supply

Since sensitivity analysis finds the estimated model, together with regime change, adequate to capture aspects of Indian structure and explain monetary transmission, we next obtain the AD-AS implied by the model. Our objective is to analyze the factors responsible for shifts in dynamic AD-AS derived from the DSGE models, and estimate these shifts in the period of the Indian slowdown. The Appendix gives the derivation of AD-AS for the estimated Goyal and Kumar (2017) model, which is based on Ireland (2011). This is not the pure New Keynesian AD-AS but has the policy rule substituted in it, and is derived in growth,  $G_t$ , and inflation,  $\Pi_t$ , space.

Estimated steady state slopes of AD and AS are  $-98.57$  and  $1.19$  respectively.<sup>2</sup> Our estimates differ significantly from Jones and Kulish (2016) (see Appendix), who estimate it for Ireland (2004). Their estimated steady state slopes of AD and AS are  $-4.4$  and  $0.1$  respectively. The reason is the difference between Ireland (2011, 2004): the introduction of habit persistence ( $\gamma$ ) in consumption and of partially backward looking price setting represented by  $\alpha$ . The AS slope is just the real marginal cost of production,  $\psi_t$ , in Ireland (2004), which continues to be  $0.1$  for us. The NKPC Equation (7) in Section 2 shows this marginal cost. In Ireland (2011), however, other parameters affect the slope. Moreover, our model adds to Ireland (2011) by introducing regimes. The steady-state AS falls and AD shifts to the left in lower growth regimes (Fig. 3).

Our high estimated absolute value of AS slope is mainly because of habit persistence. This point is not noticed in the literature. If habit persistence is reduced then the slope decreases sharply. At low values of habit persistence like  $0.10$ , keeping other parameters

<sup>1</sup> This result is opposite to that of Anand, Ding, and Tulin (2014) who find, in an estimated NKE model for India, food price shocks have a persistent effect on inflation. Goyal and Baikar (2015), however, find persistence occurs only when food price shocks are sustained above a threshold.

<sup>2</sup> AD and AS slopes and constants given in Tables 2 and 4 are based on the results reported in Goyal and Kumar (2017), with estimation done in Matlab. Rest of the AD-AS analysis is based on estimation in Dynare, which gives slightly different parameters. The difference, however, is not significant enough to affect any of the results reported here.

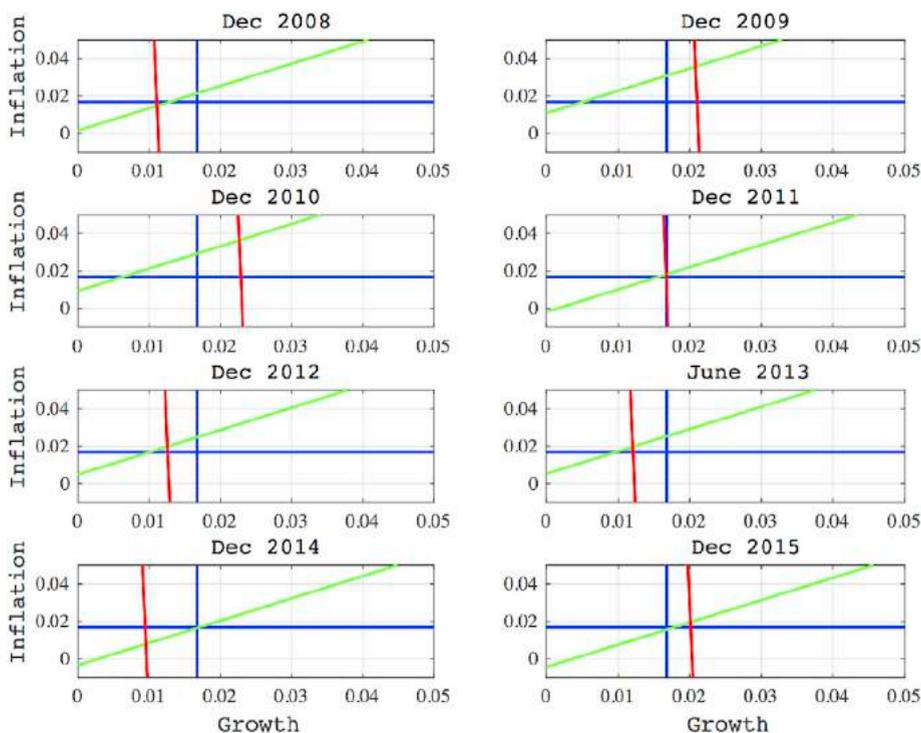


Fig. 5. Aggregate Demand and Supply Shifts: Red line is aggregate demand and green line is aggregate supply. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

constant, the slope becomes 0.11. In general, the slope of AS decreases with more backward-looking price-setting,  $\alpha$ , increase in steady state growth, that is,  $g = z = 1.0169$ , and increase in the discount factor  $\beta$ . If we put  $\gamma = \alpha = 0$ , we obtain the same slope as in Jones and Kulish (2016). The first order conditions are derived in the Appendix.

The AD curve is also very steep in comparison to Jones and Kulish (2016). Increasing the value of  $\gamma$  decreases the slope of the AD curve making it steeper. Since  $\gamma$  is found to be a major factor affecting both AD and AS we calculate the steady state slope and intercept for a range of  $\gamma$  values keeping other parameters constant. These are given in Table 2. As one can see from the table, high absolute value of the slopes are mainly due to higher values of  $\gamma$ .

Since  $\gamma$  affects the slopes significantly, we create a counterfactual impulse response by changing the value of  $\gamma$ . This is given in Figure E.7. Lower value of  $\gamma$  exacerbates the output cost of interest rate shock and the interest rate even decreases after a monetary shock. Same is true for the markup shock. This follows from the high output cost of a rise in interest rates under a flat AS.

#### 4.2. Dynamic aggregate demand and supply

Aggregate demand and aggregate supply derived in the Appendix have three main parts—steady state intercept, slope and time varying shifters which shift these curves in inflation growth space. These time varying shifters can also be factored into three main parts. The first part is associated with lagged endogenous variables, the second is associated with the forward looking components of the model endogenous variable and third is associated with the contemporaneous exogenous shocks. In general equilibrium, changes in expectations shift both demand and supply curves. Table 3 gives the correlation between these demand and supply shifters. All three

Table 2  
Habit persistence and Aggregate demand and supply.

Habit Persistence( $\gamma$ )	Aggregate Demand		Aggregate Supply	
	Slope	Intercept	Slope	Intercept
0.0	-8.9178	0.1663	0.0925	0.0153
0.25	-15.4321	0.2755	0.1725	0.0140
0.5	-37.5784	0.6466	0.4443	0.0094
0.67 (Calculated)	-98.5718	1.6688	1.1928	-0.0031
0.75	-169.8685	2.8636	2.0677	-0.0178

Note: These AD and AS slope and intercepts have been calculated at the estimated parameter values and by changing  $\gamma$ .

**Table 3**  
Correlation between AD and as shifters.

		Aggregate Demand			Aggregate Supply		
		Backward	Expected	Shock	Backward	Expected	Shock
AD	Backward	1					
	Expected	-0.9363	1				
	Shock	-0.7051	0.7128	1			
AS	Backward	-0.9996	0.9362	0.7025	1		
	Expected	0.9316	-0.9092	-0.6949	-0.9226	1	
	Shock	0.2754	-0.3159	-0.5843	-0.2741	0.3761	1

components of shifters have a negative correlation. So when a backward component increases AS and inflation, the backward component decreases demand. The same pattern can be seen in the correlation of expected and shock components of AD and AS shifters. This could aggravate contractionary shocks. Based on the strength of the correlations one can see that most of the changes in inflation output space occur because of exogenous shocks. Fig. 4 shows the negative correlations between aggregate demand and supply shifts that occurred in the 2000s.

Fig. 3 shows the steady-state AD and AS for the whole sample and the three sub-samples explained above. Steady state slopes and intercept depend on steady state growth and since steady state growth differs in these three periods, we plot AD and AS for the three sub-samples also. There is evidence that once growth decreases the AS shifts to the left and becomes steeper (Table 4), thus creating persistent effects from an initial shock.

Fig. 5 shows the shifts in AD and AS after the global financial crisis. At the end of 2009 interest rates were lower and oil prices were higher in comparison to their values in Dec 2008. Negative supply shocks shifted the supply curve leftward and positive demand shocks shifted the demand curve to the right by the end of 2009 in comparison to the end of 2008. These persisted to the end of 2010 keeping the demand curve to the right. RBI monetary stimulus was able to shift aggregate demand to the right, and was strong enough to keep aggregate demand to the right of the steady state for long. But commodity price shocks kept inflation high. As RBI started increasing interest rates, the demand curve shifted to the left. By the end of 2011 it had reached the steady state position, and then fell below it as interest rates continued to rise. Small interest rate cuts between April 2012 and May 2013 were not able to shift the demand curve to the right. It was still left of the steady-state when the next round of interest rate tightening started in mid 2013 and shifted the demand curve further left, deepening the slowdown. As oil prices started falling in 2014, supply shifted to the right and by Dec 2015, cut in interest rates were sufficient for an expansion in aggregate demand.

## 5. Conclusion

Sensitivity analysis shows asymmetric excess EM volatility, compared to the United States. That due to preference and technology shocks is reduced on introducing regime switching between multiple steady-states. Such an adjustment is intuitive since these economies have not yet reached a smooth steady-state. Reducing the interest rate variance of the monetary response reduces estimated excessive monetary transmission. But supply shocks remain a primitive in the system since they do not moderate in any of the sensitivity analyses.

Excessive interest response imposes a large output cost. Interest smoothing could reduce this cost. That estimated persistence of cost shocks is low supports interest rate smoothing, since a rise in costs tends to be reversed. Smoothing becomes more feasible to the extent supply shocks are countered using other policies. Habit persistence requires an early policy response in order to moderate lagged effects.

A negative correlation is estimated between shifts in estimated dynamic AS and AD curves. This aggravates an adverse shock, and may trigger a shift to a lower growth regime leading to persistent effects, again arguing for moderation in monetary response. The post global financial crisis slowdown is explained by excessive stimulus and then excessive tightening under conditions of adverse supply shocks.

**Table 4**  
Growth episodes and Aggregate demand and supply.

Growth	Aggregate Demand		Aggregate Supply	
	Slope	Intercept	Slope	Intercept
Whole Sample	-98.5718	1.6688	1.1928	-0.0031
High	-96.7176	2.0458	1.1700	-0.0077
Medium	-98.4841	1.6867	1.1917	-0.0033
Low	-99.8149	1.4144	1.2080	-0.0001

Note: These aggregate demand and aggregate supply slopes and intercepts have been calculated at the estimated parameter values and by changing steady state growth rate i.e.  $z$ .

**Appendix**

*A Taking the model to the data*

In the model we define growth rate gross rate:

$$g_t = \frac{Y_t}{Y_{t-1}} \quad \pi_t = \frac{P_t}{P_{t-1}}$$

From data we calculate:

$$G_t = \log\left(\frac{Y_t}{Y_{t-1}}\right) \quad \Pi_t = \log\left(\frac{P_t}{P_{t-1}}\right)$$

This implies:

$$\log(g_t) = G_t \quad \log(\pi_t) = \Pi_t$$

Now  $g$  and  $\pi$  are the average of gross rates (steady state values) in model.

$$g = \left(\prod_{t=1}^n g_t\right)^{1/n}$$

This implies:

$$\log(g) = \frac{\sum_{t=1}^n \log(g_t)}{n} = \frac{\sum_{t=1}^n G_t}{n} = \text{mean}(G_t) \Rightarrow g = \exp(\text{mean}(G_t))$$

Similarly we calculate:

$$\pi = \exp(\text{mean}(\Pi_t))$$

In the model the interest rate is gross quarterly rate. In data we have net annual net rate  $R_t^A$  and thus we calculate log of gross quarterly rate,  $\log(r_t) = \log\left[1 + \frac{R_t^A * 91}{100 * 360}\right] = R_t$  which is basically quarterly net rate. Where  $R_t$  is the net rate and  $r_t = 1 + \frac{R_t^A * 91}{100 * 360}$  is the gross rate. Now  $r$  is the average of gross rate (steady state values).

$$r = \left(\prod_{t=1}^n r_t\right)^{1/n}$$

$$\log(r) = \frac{\sum_{t=1}^n \log(r_t)}{n} = \frac{\sum_{t=1}^n R_t}{n} \Rightarrow r = \exp(\text{mean}(R_t))$$

Now we know  $z(=g)$ ,  $\pi$ , and  $r$  and we try to calculate  $\beta$  using steady state  $r = \frac{\pi z}{\beta}$ . This gives  $\beta > 1$  and so we fixed  $\beta = 0.999$ . Once we fixed it  $r$  is no more free and is calculated using steady state relations.

$$r = \frac{\pi z}{\beta} \Rightarrow \log(r) = \log(\pi) + \log(z) - \log(\beta)$$

Now we know all the values  $\log(g_t)$ ,  $\log(g)$ ,  $\log(\pi_t)$ ,  $\log(\pi)$ ,  $\log(r_t)$  and  $\log(r)$  and therefore we can do log linearization as given below:

$$\widehat{g}_t = \log(g_t) - \log(g) = G_t - \overline{G}_t = G_t - G$$

$$\widehat{\pi}_t = \log(\pi_t) - \log(\pi) = \Pi_t - \overline{\Pi}_t = \Pi_t - \Pi$$

$$\widehat{r}_t = \log(r_t) - \log(r)$$

And we estimate the model using  $\widehat{g}_t$ ,  $\widehat{\pi}_t$  and  $\widehat{r}_t$ .

The next two sections obtain our final AS and AD respectively in  $\pi_t$  and  $G_t$  space, and derive the effect of different parameters on their slopes.

B Aggregate supply

Subtract Equation (9) from (4) and using (10) in Section 2 rewrite it to obtain (B.1):

$$(z^2 + \beta\gamma^2)\widehat{x}_t = z\gamma\widehat{x}_{t-1} + \beta\gamma z\widehat{x}_{t+1} + (z - \beta\gamma)(z - \gamma)\widehat{a}_t - (z - \beta\gamma)(z - \gamma)\widehat{\Omega}_t \tag{B.1}$$

Now use (B.1) to write:

$$\widehat{a}_t - \widehat{\Omega}_t = \frac{(z^2 + \beta\gamma^2)\widehat{x}_t - z\gamma\widehat{x}_{t-1} - \beta\gamma z\widehat{x}_{t+1}}{(z - \beta\gamma)(z - \gamma)}$$

Using above one can rewrite NKPC (7, Section 2) in terms of output gap  $x_t$ :

$$(\beta\alpha + 1)\widehat{\pi}_t = \alpha\widehat{\pi}_{t-1} + \beta\widehat{\pi}_{t+1} + \Psi \left[ \frac{(z^2 + \beta\gamma^2)\widehat{x}_t - z\gamma\widehat{x}_{t-1} - \beta\gamma z\widehat{x}_{t+1}}{(z - \beta\gamma)(z - \gamma)} \right] + \widehat{\Theta}_t \tag{B.2}$$

Now write equation (B.1) and (4) as given below and subtract (4) from (B.1):

$$(z^2 + \beta\gamma^2)\widehat{x}_t = z\gamma\widehat{x}_{t-1} + \beta\gamma z\widehat{x}_{t+1} + (z - \beta\gamma)(z - \gamma)\widehat{a}_t - (z - \beta\gamma)(z - \gamma)\widehat{\Omega}_t$$

$$(z^2 + \beta\gamma^2)\widehat{y}_t = z\gamma\widehat{y}_{t-1} + \beta\gamma z\widehat{y}_{t+1} + (z - \beta\gamma\rho_a)(z - \gamma)\widehat{a}_t - \gamma z\widehat{z}_t - (z - \beta\gamma)(z - \gamma)\widehat{\Omega}_t$$

Subtracting the above two equations we get the linearized FOC in terms of output gap:

$$(z^2 + \beta\gamma^2)\widehat{x}_t = (z^2 + \beta\gamma^2)\widehat{y}_t + z\gamma(\widehat{x}_{t-1} - \widehat{y}_{t-1}) + \beta\gamma z(\widehat{x}_{t+1} - \widehat{y}_{t+1}) + (\beta\gamma\rho_a - \beta\gamma)(z - \gamma)\widehat{a}_t + \gamma z\widehat{z}_t \tag{B.3}$$

Substitute (B.3) and (8) into (B.2) one by one. First substitute (B.3) in NKPC (B.2):

$$(\beta\alpha + 1)\widehat{\pi}_t = \alpha\widehat{\pi}_{t-1} + \beta\widehat{\pi}_{t+1} + \Psi \left[ \frac{(z^2 + \beta\gamma^2)\widehat{y}_t - z\gamma\widehat{y}_{t-1} - \beta\gamma z\widehat{y}_{t+1} + (\beta\gamma\rho_a - \beta\gamma)(z - \gamma)\widehat{a}_t + \gamma z\widehat{z}_t}{(z - \beta\gamma)(z - \gamma)} \right] + \widehat{\Theta}_t$$

Now substitute Equation (8), use  $\widehat{\pi}_t = \Pi_t - \Pi$  and  $\widehat{g}_t = G_t - G$  in above to write as:

$$(\beta\alpha + 1)(\Pi_t - \Pi) = \alpha\widehat{\pi}_{t-1} + \beta\widehat{\pi}_{t+1} + \Psi \left[ \frac{(z^2 + \beta\gamma^2)(G_t - G + \widehat{y}_{t-1} - \widehat{z}_t) - z\gamma\widehat{y}_{t-1} - \beta\gamma z\widehat{y}_{t+1} + (\beta\gamma\rho_a - \beta\gamma)(z - \gamma)\widehat{a}_t + \gamma z\widehat{z}_t}{(z - \beta\gamma)(z - \gamma)} \right] + \widehat{\Theta}_t$$

Now collect all terms with  $t$  in right hand side, except  $G_t$  and  $G$  in  $s_t$  and write AS curve as below:

$$\Pi_t = \Pi - \left( \frac{\Psi}{\beta\alpha + 1} \right) \left( \frac{(z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)} \right) G + \left( \frac{\Psi}{\beta\alpha + 1} \right) \left( \frac{(z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)} \right) G_t + s_t$$

Where slope of the AS curve is  $\left( \frac{\Psi}{\beta\alpha + 1} \right) \left( \frac{(z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)} \right) = ss$  and  $s_t = \frac{\alpha}{(\beta\alpha + 1)}\widehat{\pi}_{t-1} + \frac{\beta}{(\beta\alpha + 1)}\widehat{\pi}_{t+1} +$

$$\frac{\Psi}{(\beta\alpha + 1)} \left[ \frac{(z^2 + \beta\gamma^2)(\widehat{y}_{t-1} - \widehat{z}_t) - z\gamma\widehat{y}_{t-1} - \beta\gamma z\widehat{y}_{t+1} + (\beta\gamma\rho_a - \beta\gamma)(z - \gamma)\widehat{a}_t + \gamma z\widehat{z}_t}{(z - \beta\gamma)(z - \gamma)} \right] + \frac{\widehat{\Theta}_t}{(\beta\alpha + 1)}$$

$$\frac{\partial ss}{\partial \alpha} = - \frac{\beta\Psi(z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)(\beta\alpha + 1)^2} < 0$$

AS slope falls with  $\alpha$ .

$$\frac{\partial ss}{\partial \gamma} = \frac{\Psi(z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)^2(\beta\alpha + 1)} + \frac{\Psi\beta(z^2 + \beta\gamma^2)}{(z - \beta\gamma)^2(z - \gamma)(\beta\alpha + 1)} + \frac{2\Psi\beta\gamma}{(z - \beta\gamma)(z - \gamma)(\beta\alpha + 1)} > 0$$

AS slope rises with  $\gamma$ .

$$\frac{\partial ss}{\partial \beta} = - \frac{\alpha\Psi(z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)(\beta\alpha + 1)^2} + \frac{\Psi\gamma^2}{(z - \beta\gamma)(z - \gamma)(\beta\alpha + 1)} + \frac{\Psi\gamma(z^2 + \beta\gamma^2)}{(z - \beta\gamma)^2(z - \gamma)(\beta\alpha + 1)} > 0$$

AS slope rises with  $\beta$ .

$$\frac{\partial ss}{\partial z} = \frac{\Psi 2z}{(z - \beta\gamma)(z - \gamma)(\beta\alpha + 1)} - \frac{\Psi(z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)^2(\beta\alpha + 1)} - \frac{\Psi(z^2 + \beta\gamma^2)}{(z - \beta\gamma)^2(z - \gamma)(\beta\alpha + 1)} < 0$$

AS slope falls with  $z$ . Above inequalities holds when we change the given parameter in relevant range while keeping other

parameters at estimated level.

C Aggregate demand

Rewrite (B.1) using Equation (5):

$$(z^2 + \beta\gamma^2)\hat{x}_t = z\gamma\hat{x}_{t-1} + \beta\gamma z\hat{x}_{t+1} + (z - \beta\gamma)(z - \gamma)\hat{a}_t - (z - \beta\gamma)(z - \gamma)(E_t\hat{\Omega}_{t+1} + \hat{r}_t - E_t\hat{\pi}_{t+1})$$

Now substitute (B.3) in the above equation:

$$\begin{aligned} z\gamma\hat{x}_{t-1} + \beta\gamma z\hat{x}_{t+1} + (z - \beta\gamma)(z - \gamma)\hat{a}_t - (z - \beta\gamma)(z - \gamma)(E_t\hat{\Omega}_{t+1} + \hat{r}_t - E_t\hat{\pi}_{t+1}) \\ = (z^2 + \beta\gamma^2)\hat{y}_t + z\gamma(\hat{x}_{t-1} - \hat{y}_{t-1}) + \beta\gamma z(\hat{x}_{t+1} - \hat{y}_{t+1}) + (\beta\gamma\rho_a - \beta\gamma)(z - \gamma)\hat{a}_t + \gamma z\hat{z}_t \end{aligned}$$

Solving above one gets:

$$\begin{aligned} (z^2 + \beta\gamma^2)\hat{y}_t - z\gamma\hat{y}_{t-1} - \beta\gamma z\hat{y}_{t+1} + \gamma z\hat{z}_t + (\beta\gamma\rho_a - z)(z - \gamma)\hat{a}_t = -(z - \beta\gamma)(z - \gamma)(E_t\hat{\Omega}_{t+1} + \hat{r}_t - E_t\hat{\pi}_{t+1}) - (z^2 + \beta\gamma^2)\hat{y}_t \\ + z\gamma\hat{y}_{t-1} + \beta\gamma z\hat{y}_{t+1} - \gamma z\hat{z}_t - (\beta\gamma\rho_a - z)(z - \gamma)\hat{a}_t \\ = (z - \beta\gamma)(z - \gamma)(E_t\hat{\Omega}_{t+1} + \hat{r}_t - E_t\hat{\pi}_{t+1}) \end{aligned}$$

Now substitute equations (8) and (11):

$$\begin{aligned} -(z^2 + \beta\gamma^2)(G_t - G + \hat{y}_{t-1} - \hat{z}_t) + z\gamma\hat{y}_{t-1} + \beta\gamma z\hat{y}_{t+1} - \gamma z\hat{z}_t - (\beta\gamma\rho_a - z)(z - \gamma)\hat{a}_t \\ = (z - \beta\gamma)(z - \gamma)(E_t\hat{\Omega}_{t+1} + \hat{r}_{t-1} + \rho_\pi(\Pi_t - \Pi) + \rho_g(G_t - G) + \varepsilon_{r,t} - E_t\hat{\pi}_{t+1}) \end{aligned}$$

Now take all the terms with  $t$  in  $d_t$  except  $G_t$ ,  $\Pi_t$ ,  $G$  and  $\Pi$ :

$$(z - \beta\gamma)(z - \gamma)(\rho_\pi(\Pi_t - \Pi) + \rho_g(G_t - G)) = -(z^2 + \beta\gamma^2)(G_t - G) + d_t$$

AD Curve is given by:

$$\Pi_t = \left( \frac{(z - \beta\gamma)(z - \gamma)(\rho_\pi\Pi + \rho_g G) + (z^2 + \beta\gamma^2)G}{(z - \beta\gamma)(z - \gamma)\rho_\pi} \right) - \left( \frac{(z - \beta\gamma)(z - \gamma)\rho_g + (z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)\rho_\pi} \right) G_t + d_t$$

Where slope of AD is  $-\frac{((z - \beta\gamma)(z - \gamma)\rho_g + z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)\rho_\pi} = dd$

$$\frac{\partial dd}{\partial \gamma} = -\frac{\partial \left( \frac{\rho_g}{\rho_\pi} + \frac{(z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)\rho_\pi} \right)}{\partial \gamma}$$

$$\frac{\partial dd}{\partial \gamma} = -\frac{(z - \beta\gamma)(z - \gamma)\rho_\pi \times 2\beta\gamma + (z^2 + \beta\gamma^2)\rho_\pi[(z - \gamma) \times \beta + (z - \beta\gamma)]}{((z - \beta\gamma)(z - \gamma)\rho_\pi)^2} < 0$$

AD slope falls with  $\gamma$  in relevant range while keeping other parameters at estimated level and  $d_t = \frac{-(z - \beta\gamma)(z - \gamma)(E_t\hat{\Omega}_{t+1} + \hat{r}_{t-1} + \varepsilon_{r,t} - E_t\hat{\pi}_{t+1}) + z\gamma(\hat{x}_{t-1} - \hat{y}_{t-1}) - (z^2 + \beta\gamma^2)(\hat{y}_{t-1} - \hat{z}_t) + \beta\gamma z(\hat{x}_{t+1} - \hat{y}_{t+1}) + (z - \beta\gamma\rho_a)(z - \gamma)\hat{a}_t - \gamma z\hat{z}_t}{(z - \beta\gamma)(z - \gamma)\rho_\pi}$

D AD and AS for the Ireland (2004) Model

This is derived by Jones and Kulish (2016) as below:

$$\hat{x}_t = E_t\hat{x}_{t+1} - (\hat{r}_t - E_t\hat{\pi}_{t+1}) + (1 - w)(1 - \rho_a)\hat{a}_t \tag{D.1}$$

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \Psi\hat{x}_t - \hat{\Theta}_t \tag{D.2}$$

$$\hat{r}_t = \hat{r}_{t-1} + \rho_\pi\hat{\pi}_t + \rho_g\hat{g}_t + \rho_x\hat{x}_t + \varepsilon_{r,t} \tag{D.3}$$

$$\hat{x}_t = \hat{y}_t - w\hat{a}_t \tag{D.4}$$

$$\hat{g}_t = \hat{y}_t - \hat{y}_{t-1} + \hat{z}_t \tag{D.5}$$

$$\widehat{a}_t = \rho_a \widehat{a}_{t-1} + \varepsilon_{a,t} \quad (D.6)$$

$$\widehat{\Theta}_t = \rho_\Theta \widehat{\Theta}_{t-1} + \varepsilon_{\Theta,t} \quad (D.7)$$

$$z_t = \varepsilon_{z,t} \quad (D.8)$$

The same data series is used to estimate the model and section B implies:

$$\widehat{x}_t = E_t \widehat{x}_{t+1} - (\widehat{r}_t - E_t \widehat{\pi}_{t+1}) + (1-w)(1-\rho_a) \widehat{a}_t \quad (D.1')$$

$$\Pi_t = \Pi + \beta E_t \widehat{\pi}_{t+1} + \Psi \widehat{x}_t - \widehat{\Theta}_t \quad (D.2')$$

$$\widehat{r}_t = \widehat{r}_{t-1} + \rho_\pi (\Pi_t - \Pi) + \rho_g (G_t - G) + \rho_x \widehat{x}_t + \varepsilon_{r,t} \quad (D.3')$$

$$\widehat{x}_t = \widehat{y}_t - w \widehat{a}_t \quad (D.4')$$

$$G_t = G + \widehat{y}_t - \widehat{y}_{t-1} + \widehat{z}_t \quad (D.5')$$

$$\widehat{a}_t = \rho_a \widehat{a}_{t-1} + \varepsilon_{a,t} \quad (D.6')$$

$$\widehat{\Theta}_t = \rho_\Theta \widehat{\Theta}_{t-1} + \varepsilon_{\Theta,t} \quad (D.7')$$

$$z_t = \varepsilon_{z,t} \quad (D.8')$$

To find the aggregate supply schedule, we do the equivalent of their substitution of equation (D.4) and (D.5) in equation (D.2) and obtain:

$$\Pi_t = \Psi G_t + s_t + (\Pi - \Psi G)$$

Where

$$s_t = \beta E_t \widehat{\pi}_{t+1} + \Psi \widehat{y}_{t-1} - \Psi \widehat{z}_t - w \Psi \widehat{a}_t - \widehat{\Theta}_t$$

Our estimated supply curve is:

$$\Pi_t = \Pi - \left( \frac{\Psi}{\beta\alpha + 1} \right) \left( \frac{(z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)} \right) G + \left( \frac{\Psi}{\beta\alpha + 1} \right) \left( \frac{(z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)} \right) G_t + s_t$$

Which reduces to:

$$\Pi_t = \Pi - \Psi G + \Psi G_t + s_t$$

Once we put  $\gamma = \alpha = 0$  and is same. To obtain the aggregate demand schedule, we follow their process and substitute equation (D.3'–D.5') in equation (D.1') and obtain:

$$\Pi_t = - \left( \frac{1 + \rho_g + \rho_x}{\rho_\pi} \right) G_t + \left( \Pi + \frac{1 + \rho_g + \rho_x}{\rho_\pi} G \right) + \widehat{d}_t$$

Where

$$\widehat{d}_t = - \frac{1}{\rho_\pi} \widehat{r}_{t-1} + \frac{1}{\rho_\pi} E_t \widehat{x}_{t+1} + \frac{1}{\rho_\pi} E_t \widehat{\pi}_{t+1} - \left( \frac{1 + \rho_x}{\rho_\pi} \right) \widehat{y}_{t-1} + \left( \frac{1 + \rho_x}{\rho_\pi} \right) \widehat{z}_t + \frac{w(1 + \rho_x) + (1-w)(1 - \rho_a)}{\rho_\pi} \widehat{a}_t - \frac{1}{\rho_\pi} \varepsilon_{r,t}$$

Our estimated aggregate demand curve is given by:

$$\Pi_t = \left( \frac{(z - \beta\gamma)(z - \gamma)(\rho_\pi \Pi + \rho_g G) + (z^2 + \beta\gamma^2)G}{(z - \beta\gamma)(z - \gamma)\rho_\pi} \right) - \left( \frac{(z - \beta\gamma)(z - \gamma)\rho_g + (z^2 + \beta\gamma^2)}{(z - \beta\gamma)(z - \gamma)\rho_\pi} \right) G_t + d_t$$

Which reduces to:

$$\Pi_t = - \left( \frac{\rho_g + 1}{\rho_\pi} \right) G_t + \left( \Pi + \frac{1 + \rho_g}{\rho_\pi} G \right) + d_t$$

Once we put  $\gamma = \alpha = 0$  and is same as theirs if we put  $\rho_x = 0$  as in our case interest rate does not respond to output gap.

E Impulse responses

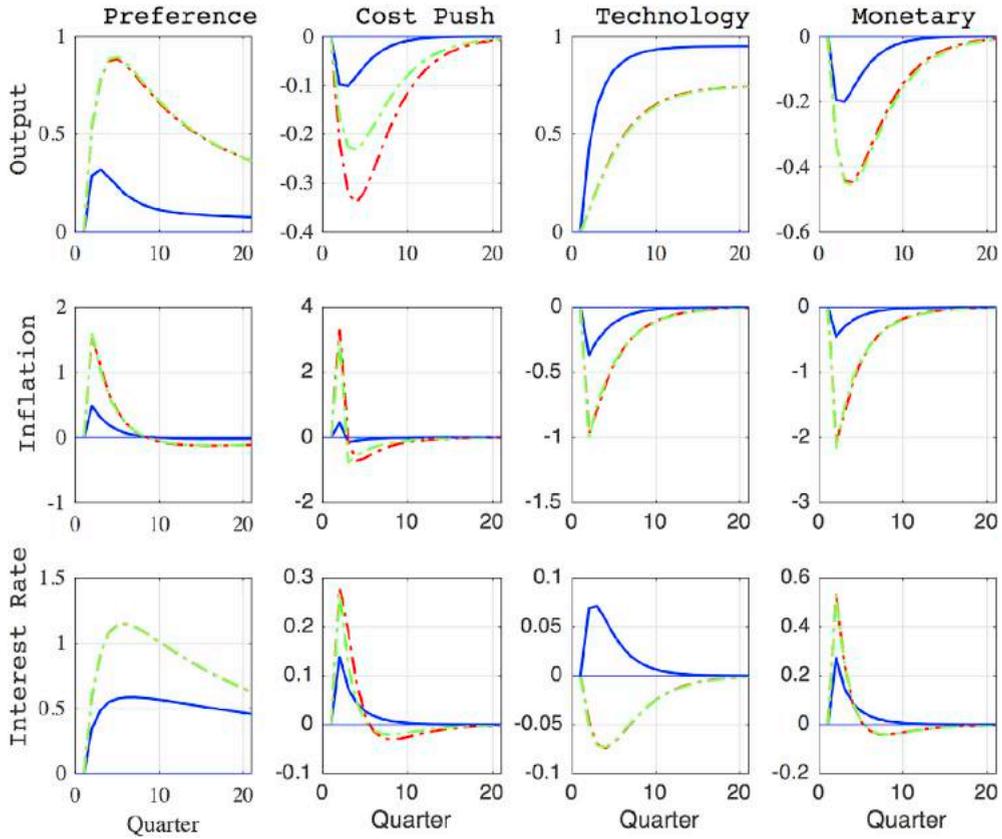


Figure E.1. Impulse Response of variables(LHS) to shocks; solid line (blue) is for US and dotted line (red) is with Indian data. Green line gives impulse response with Indian data with backward looking price-setting  $\alpha = 0$  and persistence of mark-up shock  $\rho_\theta = 0$ .

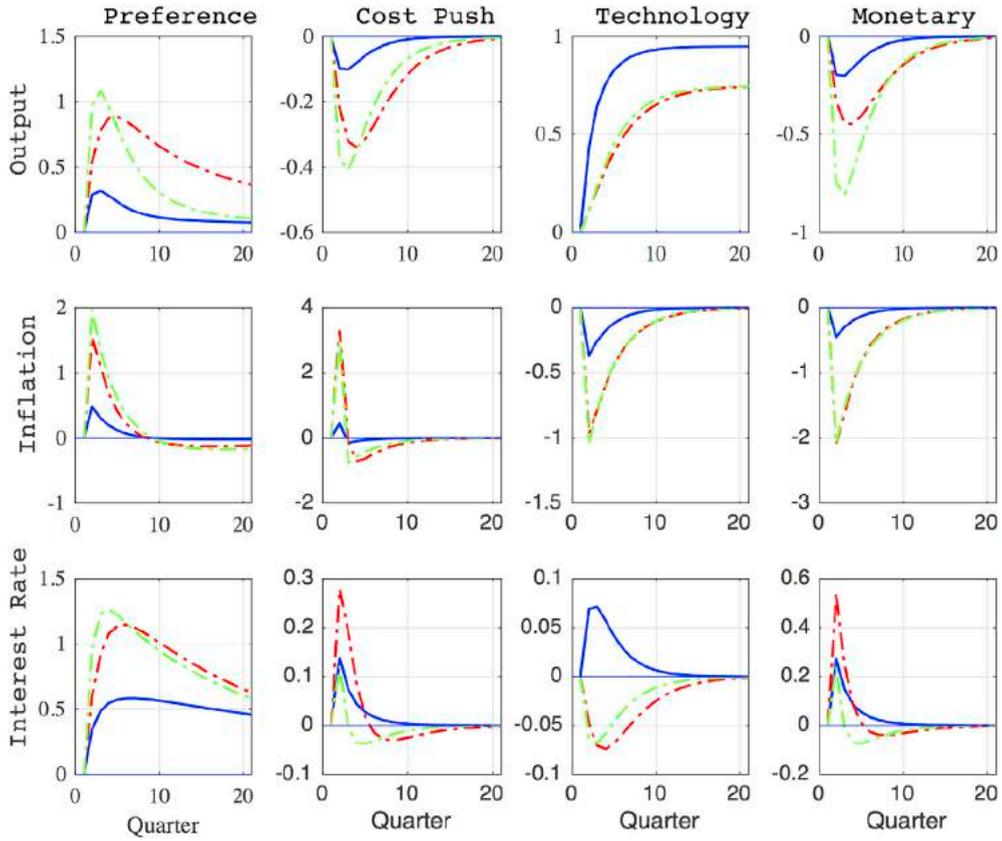


Figure E.2. Impulse Response of variables (LHS) to shocks; solid line (blue) is for US and dotted line (red) is with Indian data. Green line gives impulse response with Indian data with  $\alpha = \rho_\theta = 0$  and habit persistence  $\gamma$  constrained to values as in Ireland (2011).

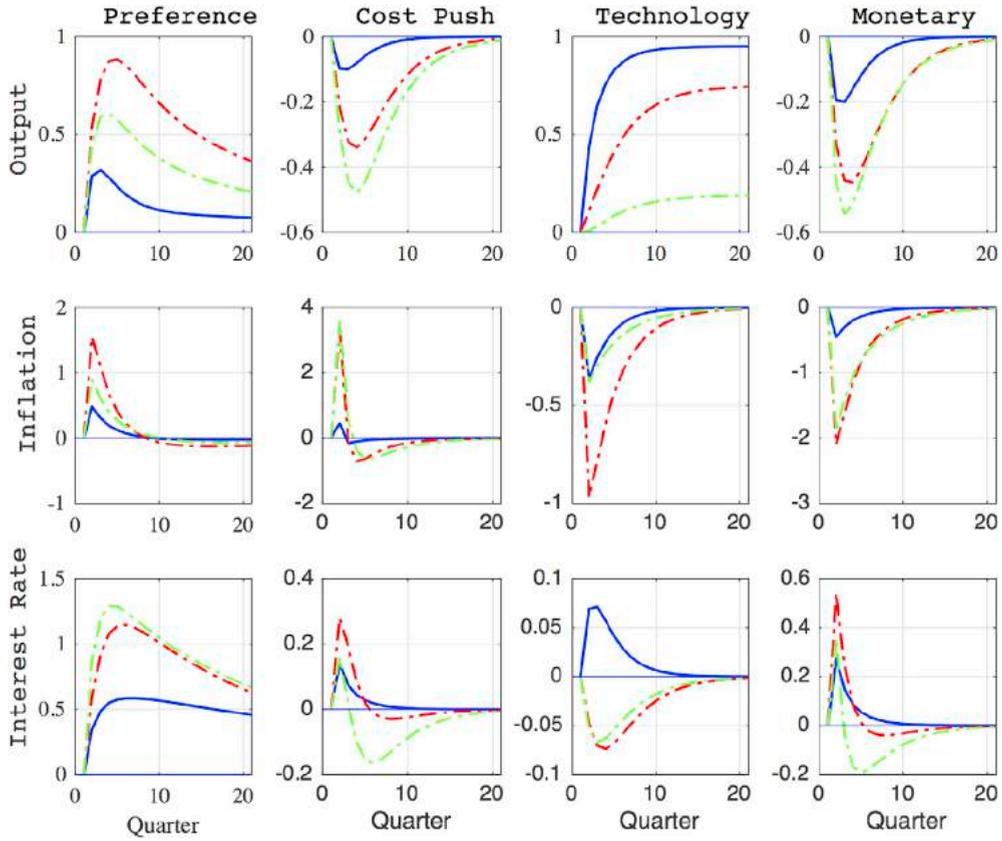


Figure E.3. Impulse Response of variables (LHS) to shocks; solid line (blue) is for US and dotted line (red) is with Indian data. Green line gives impulse responses for India using three regimes as explained in the paper.

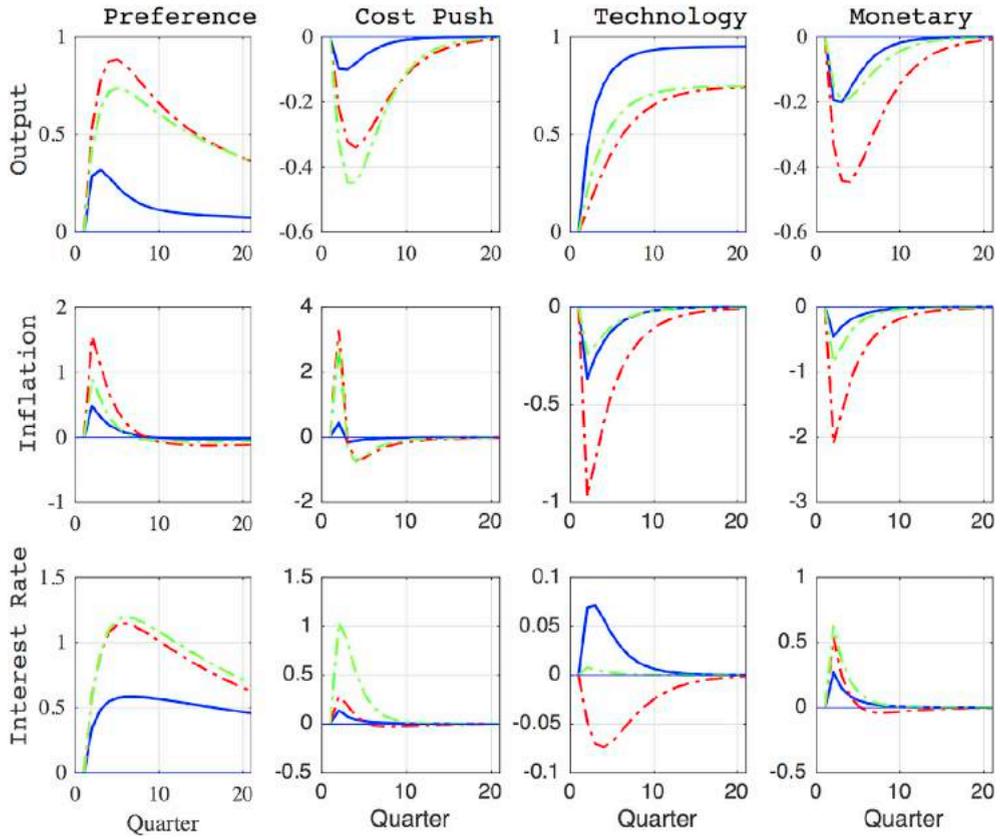


Figure E.4. Impulse Response of variables (LHS) to shocks; solid line (blue) is for US and dotted line (red) is with Indian data. Green line gives impulse responses for India using the same interest rate setting rule weights  $\rho_\pi$  and  $\rho_g$  as in US.

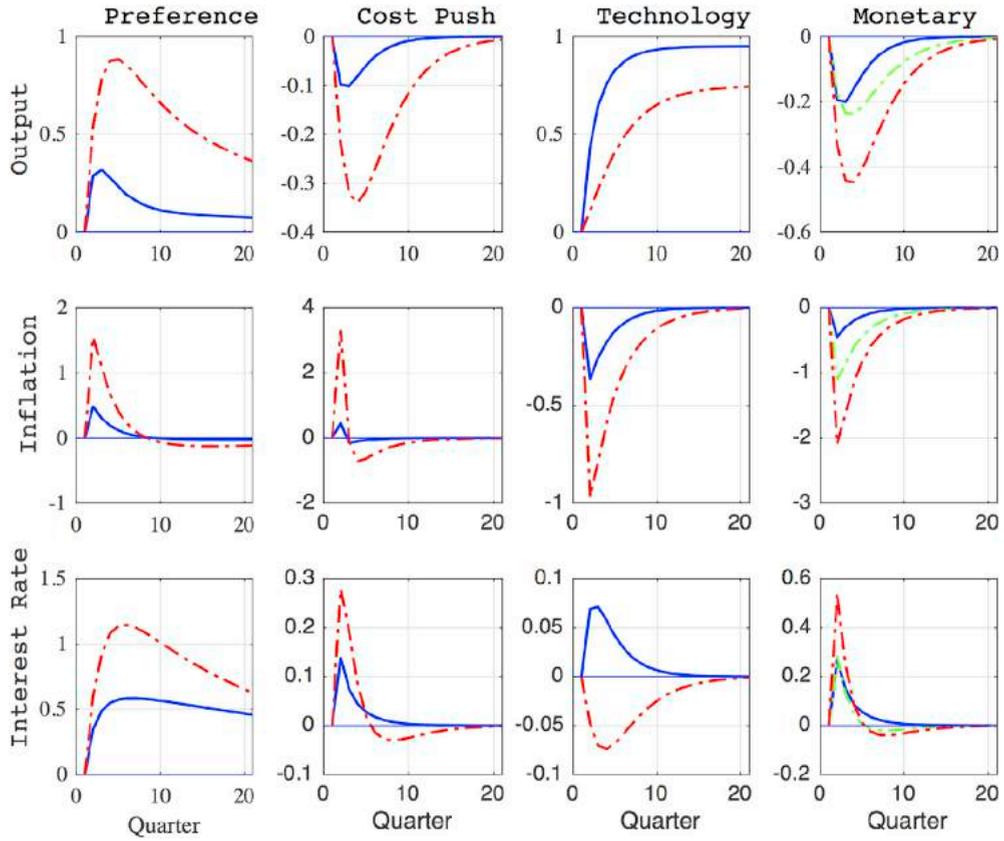


Figure E.5. Impulse Response of variables (LHS) to shocks; solid line (blue) is for US and dotted line (red) is with Indian data. Green line gives impulse responses for India using the same interest rate shock variance  $\sigma_r$  as in US.

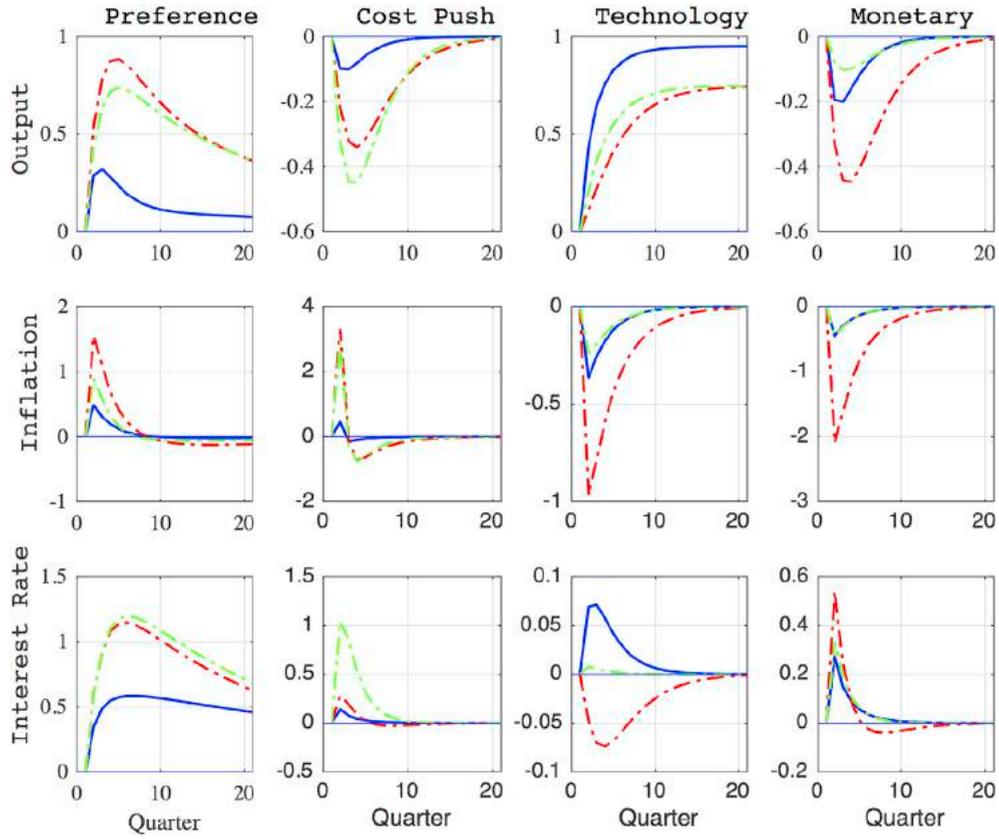


Figure E.6. Impulse Response of variables (LHS) to shocks; solid line (blue) is for US and dotted line (red) is with Indian data. Green line gives impulse responses for India using the same interest rate setting rule  $\rho_\pi$  and  $\rho_z$  as in US and same interest rate shock variance  $\sigma_r$  as in US.

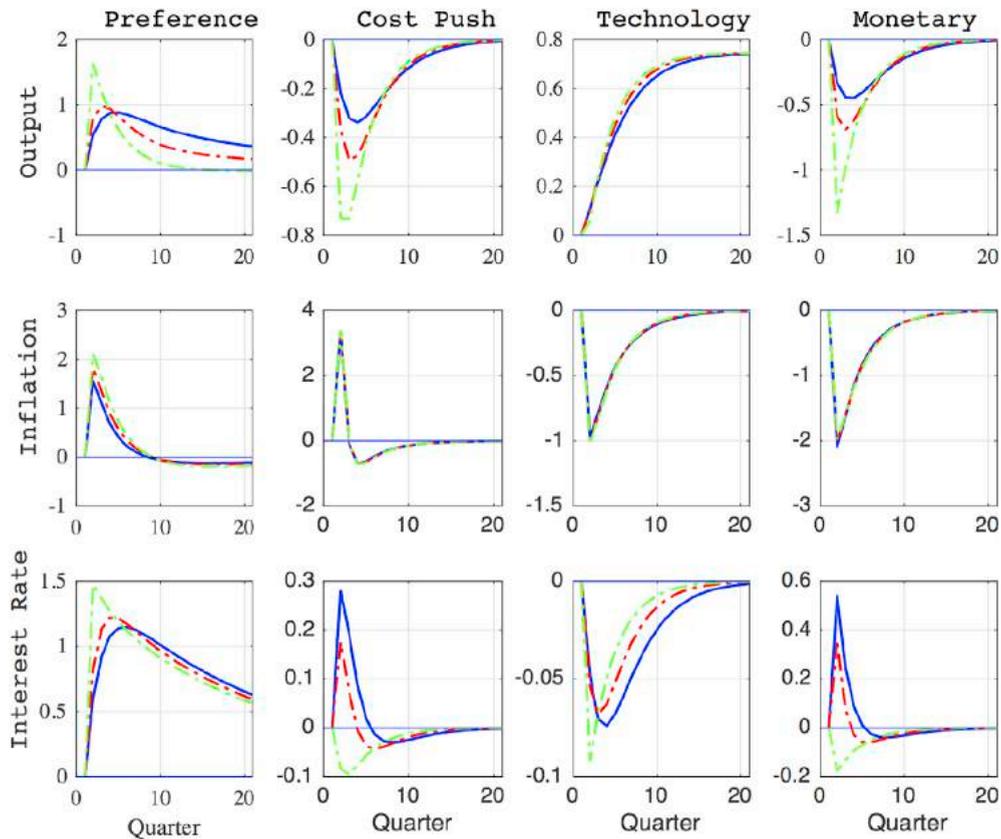


Figure E.7. Impulse Response of variables (LHS) to shocks; solid line (blue) is for habit persistence  $\gamma = 0.67$  and dotted line (red) is with  $\gamma = 0.5$  and green line with  $\gamma = 0$ .

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