



# Testing policy effectiveness during COVID-19: An NK-DSGE analysis

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## ABSTRACT

We examine the effectiveness of fiscal and monetary policy in mitigating the impact of COVID-19 in India using the NK-DSGE framework. In terms of policy effectiveness, our findings imply that expansionary monetary policy is effective in reviving economic growth both from the demand side and supply side. In contrast, expansionary fiscal policy is effective only from the supply side. Our findings recommend the implementation of optimal policy mix in a coordinated and staggered framework for effective mitigation of ill-effects of the COVID-19, such as reviving employment and capacity utilization to its pre-pandemic level with minimal inflationary effects.

## 1. Introduction

The COVID-19 pandemic unfolded in January 2020 and the initial adverse impacts were seen through massive disruptions of global supply chains, pushing the global economy into recession (Acemoglu & Tahbaz-Salehi, 2020; Bilbiie & Melitz, 2020; Bonadio, Huo, Levchenko, & Pandalai-Nayar, 2020; Cerdeiro & Komaromi, 2020; Goel, Saunoris, & Goel, 2021; Monitor, 2021; Razin, 2021; Vidya & Prabheesh, 2020). Of note, the overall damage due to COVID-19 was 1.248% to the supply-chain for the initial four months, which was approximately 1.4 times the damage caused during the global financial crisis of 2008 (Yagi & Managi, 2021). As a result, macroeconomic fundamentals in large emerging market economies (EMEs) deteriorated in terms of increased unemployment, adverse supply shocks, muted aggregate demand, and volatile exchange rates along with unfavourable rates of inflation (Eichenbaum, Rebelo, & Trabandt, 2020a; Lee & Yang, 2022; Nakamura & Suzuki, 2021; Währungsfonds, 2020). Specifically, the frequent lockdowns restricted the mobility of labour which adversely affected their incomes as well as capacity utilization of the production sector and thereby affecting the output capacity. However, the impact was less severe in economies where prompt government policies and stimulus packages were undertaken. Based on regional analysis, Asian economies got highly affected as compared to their European counterparts (Topcu & Gulal, 2020). Accumulation of high fiscal deficits combined with public health crisis created deep recessions in EMEs, thereby leading to a tradeoff between mitigation of pandemic and economic recovery (Arellano, Bai, & Mihalache, 2020).

Our study is motivated by the pivotal role that remedial policy prescriptions can play in mitigating the effects of the COVID-19 (Narayan, 2021). We choose India because it was one of the fastest-growing EME in the world before the COVID-19 outbreak. In terms of COVID-19 cases, it is the most severely affected EME with more than 44 million cases so far, only second to the USA globally. However, despite the massive vaccination drives undertaken throughout the country, the second wave that started in

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March 2021 severely affected the Indian economy and served as a major deterrent to economic recovery. Initially, in the first wave, policy analysts forecasted GDP to exhibit a V-shaped recovery from record low levels of  $-23.9\%$  (GOI, 2021). The domestic supply chains, which were in the process of recovery after the first wave again got disturbed; workers started to return to their homes, thereby further escalating unemployment and layoffs. The associated lockdowns resulted in the suspension of economic activities from the manufacturing sector to the services sector. Regarding policy interventions, various fiscal and monetary sops such as direct cash transfers, tax incentives, low-interest rate, moratorium, etc. were provided to combat the economic impact of the pandemic. Thus, we examine the effectiveness of fiscal and monetary policy in mitigating the effects of COVID-19 in India.

The empirical research on the economic impacts of COVID-19 can be classified into various strands<sup>1</sup>. Further, Narayan (2021) points out that majority of the existing pandemic research is based on high-frequency data on financial markets and very few studies have been explored within the framework of general equilibrium modelling. The majority of the studies have focused on developed economies such as the US (Faria-e Castro, 2021; Danieli & Olmstead-Rumsey, 2020; Eichenbaum et al., 2020a; Eichenbaum, Rebelo, & Trabandt, 2020b) and the Euro countries (Busato, Chiarini, Cisco, Ferrara, & Marzano, 2020; Hürtgen, 2020) while in case of EMEs the literature is still burgeoning like China (Fang, Collins, & Yao, 2021; Jiang, Hou, Wang, & Liu, 2021; Liu et al., 2021; Zhang, Zhang, & Zhu, 2021; Zhao & Chen, 2022), Indonesia (Chopra & Mehta, 2022; Lie, 2021; Takeda, Truong, & Sonobe, 2022), Brazil (Chopra & Mehta, 2022; Porsse, de Souza, Carvalho, & Vale, 2020) and Turkey (Can, Can, Bocuoglu, & Dogru, 2021; Ileri, 2022; Mugaloglu, Polat, Tekin, & Kılıç, 2021).

We contribute to the existing literature on COVID-19 in various ways. First, ours is the first study to analyse the effectiveness of policy responses in combating the impact of COVID-19 on the Indian economy. Second, we use a New-Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) framework that goes further in allowing DSGE models to incorporate various market imperfections as well as certain monopoly elements such as nominal price and wage rigidities (Blanchard, 2018). Third, our results can be generalized for large EMEs that are broadly similar to the Indian economy and opens up the scope for examining the policy effectiveness in tackling the negative consequences of the pandemic.

Our empirical approach is as follows. First, we derive a macroeconomic model within the NKDSGE framework to investigate the impact of the COVID-19 shock on the Indian economy. Second, we apply Bayesian techniques to calibrate the parameters. Third, we specify the priors and derive the posteriors<sup>2</sup>. Fourth, we calculate the simulated response of the covid shock along with monetary and fiscal policy shock to check their effectiveness. Finally, as robustness check we estimated the Bayesian impulse response functions (IRFs). Our empirical analyses produce two key findings. First, we find that the COVID-19 pandemic shock negatively affected aggregate demand and aggregate supply. Second, we find evidence that monetary policy is effective in reviving both aggregate demand and aggregate supply, however fiscal policy is effective only in reviving aggregate supply.

The rest of the paper is organized as follows. Section 2 outlines the model. Section 3 discusses the results. Section 4 estimates the Bayesian IRF's. Section 5 concludes with policy implications.

## 2. Model

We utilize the NK-DSGE framework in our simulation analysis. The DSGE model was developed in the seminal works of Kydland and Prescott (1982) and Prescott (1986). Compared to computation general equilibrium (CGE) models, the DSGE models are more efficient in optimization within the stochastic environment since they optimize the behaviour of economic agents (households, firms, central banks, fiscal authorities) in a competitive framework. Notably, the NK-DSGE models are an improvement over standard DSGE models since they allow for various market imperfections.

The NK-DSGE models are very useful in predicting fluctuations in macroeconomic variables due to stochastic shocks like the current COVID-19 pandemic. In our setting up of the NK-DSGE model, we consider different economic agents. First, the model comprises households disaggregated into Ricardian and non-Ricardian types as in Zhang et al. (2021). Next, we consider the behaviour of firms working under imperfect competition and producing differentiated products with the employment of differentiated labour. For equilibrium analysis, we consider investment behaviour under the law of motion of capital incorporated with rigidities in different forms like optimal utilization of maximum installed capacity and investment adjustment costs as in Christiano, Eichenbaum, and Evans (2005). Also, the model features the government policy intervention in fiscal form due to Drygalla, Holtemöller, and Kiesel (2020) and monetary form due to Christiano et al. (2005). We evaluate the effectiveness of fiscal and monetary policy on macroeconomic variables using different policy instruments through the government sector. Finally, the model is closed within the optimized general equilibrium framework through equilibrium identity wherein aggregate demand and aggregate supply are equated.

<sup>1</sup> Most of the burgeoning research is focused on energy markets (Apergis & Apergis, 2020; Devpura, 2020; Fu & Shen, 2020; Iyke, 2020a, 2020b; Narayan, 2020c; Narayan, Iyke, & Sharma, 2021; Prabheesh & Kumar, 2021; Prabheesh, Padhan, & Garg, 2020; Salisu & Adediran, 2020); financial markets (Akhtaruzzaman, Boubaker, & Sensoy, 2021; Gil-Alana & Claudio-Quiroga, 2020; Haroon & Rizvi, 2020; Mishra, Rath, & Dash, 2020; Narayan, Phan, & Liu, 2021; Nguyen, Phan, Ming, et al., 2021; Phan & Narayan, 2020; Prabheesh, 2020; Prabheesh, Garg, Padhan, et al., 2020; Rai & Garg, 2021; Salisu & Sikiru, 2020; Sharma, 2020; Zhang, Hu, & Ji, 2020); foreign exchange market (Chowdhury & Garg, 2022; Devpura, 2020; Devpura & Narayan, 2020; Feng, Yang, Gong, & Chang, 2021; Garg & Prabheesh, 2021; Narayan, 2020a, 2020b; Narayan, Devpura, & Wang, 2020); international trade (Baldwin & Freeman, 2020; Kiyota, 2022; Liu, Sun, & Zhang, 2020; Vidya & Prabheesh, 2020), among many others. For a detailed survey of the COVID-19 literature, please refer to Brodeur, Gray, Islam, and Bhuiyan (2020) and Padhan and Prabheesh (2021).

**Table 1**

Variables and description.

Source: Author's synthesis.

Variables	Description
$Y_t$	Gross domestic product or output
$W_t$	Return on labour
$C_t$	Aggregate consumption both Ricardian and non-Ricardian households
$U_t$	Utilization of maximum installed capacity
$L_t$	Aggregate employment both Ricardian and non-Ricardian households
$P_t$	Average price level
$C_R$	Consumption due to Ricardian households
$MC_t$	Marginal cost
$C_{NR}$	Consumption due to non-Ricardian households
$R^B$	Return on bonds Issued
$I^P$	Private investment
$\pi_t$	Gross inflation rate
$L_R$	Employment of Ricardian households
$G_t$	Government expenditure
$L_{NR}$	Employment of non-Ricardian households
$T_t$	Amount of taxation
$K^P$	Private capital stock
$I^G$	Government investment
$R_t$	Return on capital
$K^G$	Government capital stock
$A_t$	Total factor productivity

Notes: This table presents the list of variables that are included in the NK-DSGE model.

### 2.1. The household sector

The households maximize their welfare through the following utility function:

$$U_t = f(C_t, L_t) \tag{1}$$

where  $U_c > 0$  and  $U_L < 0$  thereby inferring a positive effect of consumption on the one hand and a negative effect in the form of dis-utility on the other hand when supplying labour for work. Additionally, the second derivative for consumption and labour viz.  $U_{cc} < 0$  and  $U_{LL} < 0$  infers that because of an increase in consumption, the utility should fall, thereby tracing the concave nature of the utility function. To maximize the utility function, we assume that households' own factors of production in the form of labour and capital, and they receive their returns in terms of wages and rents after being employed by production units. Further, we assume the existence of a continuum of infinitely lived representative households indexed as  $j \in [0, 1]$ , with a fraction among this continuum having access to formal finance indexed as  $R \in [0, \omega_R)$ . These households are categorized as Ricardian households due to their easy access to credit from formal financial institutions. The rest of the households are indexed as  $NR(\omega_R, 1]$  and categorized as non-Ricardian because of their limited access to formal finance.

#### 2.1.1. Ricardian households

Ricardian households try to maximize their welfare by optimizing the following utility function:

$$\max_{C_{R,t}, K_{t+1}^P, U_t, I_t^P, B_{t+1}} E_t \sum_{t=0}^{\infty} \beta_t^R \left[ \frac{(C_{R,t} - \phi_t C_{R,t-1})^{1-\sigma_t}}{1-\sigma_t} - \frac{L_{R,t}^{1+\varphi_t}}{1+\varphi_t} \right] \tag{2}$$

subject to the following budget constraint

$$P_t(1 + \tau_t^c)(C_{R,t} + I_t^P) + \frac{B_{t+1}}{R_t^B} = W_t L_{R,t}(1 - \tau_t^l) + R_t U_t K_t^P(1 - \tau_t^k) - \lambda \tag{3}$$

where  $\lambda = R_t U_t K_t^P(1 - \tau_t^k) - P_t K_t^P \left[ \Psi_1(U_t - 1) + \frac{\Psi_2}{2}(U_t - 1)^2 \right]$ . The variables in Eq. (2) and Eq. (3) are defined in Table 1.

From Eq. (2),  $E_t$  denotes the expectation operator;  $\beta_t^R$  is the intertemporal discounting factor;  $C_{R,t}$  is the consumption of Ricardian households;  $\phi_c$  is the habit persistence parameter;  $L_{R,t}$  is the quantity of labour supplied by the Ricardian households;  $\sigma_t$  is the coefficient of relative risk aversion (CRRA);  $\varphi_t$  is the Inverse of Frisch elasticity due to labour supply;  $P_t$  is the general price level;  $\tau_t^c, \tau_t^l, \tau_t^k$  is the rate of taxation on consumption, labour and capital respectively;  $I_t^P$  is the private investment;  $\frac{B_{t+1}}{R_t^B}$  represents the bonds issued discounted at the prevailing rate;  $W_t$  is the wage rate;  $R_t$  is the rate of return on capital;  $U_t$  is the level of utilization of maximum installed capacity available with the firm as in Junior (2016);  $K_t^P$  is the capital stock of the private sector;  $B_t$  represents the real quantity of bonds issued by the households;  $\omega_R$  is the coefficient associated with nominal revenue realized by the Ricardian households due to direct transfers,  $TRANS_t$ , from the fiscal authority.

Expression  $R_t U_t K_t^P (1 - \tau_t^k) - P_t K_t^P \left[ \Psi_1 (U_t - 1) + \frac{\Psi_2}{2} (U_t - 1)^2 \right]$  in Eq. (3) represents the net returns associated with utilization of installed capacity,<sup>2</sup> wherein  $R_t U_t K_t^P (1 - \tau_t^k)$  reflects the profitability due to capital utilized in production and  $P_t K_t^P \left[ \Psi_1 (U_t - 1) + \frac{\Psi_2}{2} (U_t - 1)^2 \right]$  reflects the costs due to variation in the degree of utilization of installed capacity  $U_t$ .

$$K_{t+1}^P = (1 - \delta) K_t^P + I_t^P \left[ 1 - \frac{\chi}{2} \left( \frac{I_t^P}{I_{t-1}^P - 1} \right)^2 \right] \tag{4}$$

where  $I^P$  is gross private investment, and  $\left[ 1 - \frac{\chi}{2} \left( \frac{I_t^P}{I_{t-1}^P - 1} \right)^2 \right]$  is the investment adjustment cost. In the NK-DSGE model, under imperfect competition, households possess differentiated labour, thereby exerting a monopoly power in the determination of wages defined as per the following Calvo (1983) nominal wage aggregator rule:

$$W_t = \left[ \theta_w W_{t-1}^{1-\psi_w} + (1 - \theta_w) W_t^{*1-\psi_w} \right]^{\frac{1}{1-\psi_w}} \tag{5}$$

where  $W_t^*$  is the optimal wage. The differentiated labour  $L_j$  when supplied by the households are aggregated by the firms into a single labour input  $L_t$ , as per the following Dixit and Stiglitz (1977) aggregator function:

$$L_t = \left( \int_0^1 L_{j,t}^{\frac{\psi_w-1}{\psi_w}} dj \right)^{\frac{\psi_w}{\psi_w-1}} \tag{6}$$

where  $\psi_w$  is the elasticity of substitution between differentiated jobs, with household  $j$  supplying differentiated labour,  $L_{j,t}$ , at a wage rate,  $W_{j,t}$ .

In order to optimize the given objective function, we apply the Lagrangian multiplier principle followed by partial differentiation to Eq. (2) and Eq. (3)<sup>3</sup>. We arrive at an optimal level of consumption of Ricardian households,  $C_R$ , along with the optimal labour supply. Additionally, optimal capital stock,  $K^P$ , private investment,  $I^P$ , and installed capacity utilization,  $U_t$ , are also obtained.

### 2.1.2. Non-ricardian households

Analogous to the Ricardian households, non-Ricardian households also tries to optimize the following utility function

$$\max_{C_{NR,t}} E_t \sum_{t=0}^{\infty} \beta_t \left[ \frac{(C_{NR,t} - \phi_t C_{NR,t-1})^{1-\sigma_t}}{1-\sigma_t} - \frac{L_{NR,t}^{1+\varphi_t}}{1+\varphi_t} \right] \tag{7}$$

subject to budget constraint

$$P_t (1 + \tau_t^c) (C_{NR,t}) = W_t L_{NR,t} (1 - \tau_t^l) + (1 - \omega_R) P_t TRANS_t \tag{8}$$

where  $C_{NR}$  represents the consumption of non-Ricardian households. Therefore,  $C_t$  and  $L_t$  in composite function are given as:

$$C_t = \omega_R C_{R,t} + (1 - \omega_R) C_{NR,t} \tag{9}$$

$$L_t = \omega_R L_{R,t} + (1 - \omega_R) L_{NR,t} \tag{10}$$

### 2.2. Firms

The NK-DSGE models assume that monopolistic competitive firms realize their short-run profits through production and sale of final output either to households for consumption or to firms for further processing. Following Dixit and Stiglitz (1977) output aggregator, the operation of retail firms producing final goods are given as:

$$Y_t = \left( \int_0^1 Y_{j,t}^{\frac{\psi_t-1}{\psi_t}} dj \right)^{\frac{\psi_t}{\psi_t-1}} \tag{11}$$

where  $Y_t$  represent the retail output in period  $t$ ;  $Y_{j,t}$  for all  $j \in (0, 1)$  represents the wholesale goods; and parameter  $\psi_t > 1$  is the elasticity of substitution between differentiated goods. The representative retail firm tries to maximize the following profit function:

$$\max_{Y_{j,t}} P_t Y_t - \int_0^1 P_{j,t} Y_{j,t} dj \tag{12}$$

where  $P_t$  is the nominal price for a retail product, and  $P_{j,t}$  as the nominal price for the wholesale product  $j$ . The retail firms which purchase intermediate goods from the wholesale firms realize their profits either due to efficient utilization of inputs during the

<sup>2</sup> Level of utilization of installed capacity expresses the relation between the actual output and potential output a particular firm can produce given its available resources.

<sup>3</sup> For more on derivations see Junior (2016).

processing of intermediate goods into final goods or due to change in the prices of final goods. In the first case retail firm tries to optimize the following cost function:

$$\min_{L_{j,t}, K_{j,t}} W_t L_{j,t} + R_t K_{j,t} \tag{13}$$

subject to the following Cobb–Douglas production function as given among others by [Bajo-Rubio \(2000\)](#), [Barro and Sala-i Martin \(1992\)](#), [Cashin \(1995\)](#), [Finn \(1993\)](#), [Glomm and Ravikumar \(1994\)](#) after incorporating public capital:

$$Y_{j,t} = A_t K^{P\alpha_1} L_{j,t}^{\alpha_2} K_{j,t}^{G\alpha_3} \tag{14}$$

where  $A_t$  in Eq. (14) denotes the total factor productivity (TFP) due to technology having spillover effects. It also measures expertise of human capital through available skills for realizing the potential benefits due to increasing returns to scale from the production process,  $Y_{j,t}$  is the output of a particular monopolistic firm;  $\alpha_1$  measures output elasticity in relation to private capital  $K^P$ ;  $\alpha_2$  denotes output elasticity per unit employment of labour; and  $\alpha_3$  measures output elasticity in relation to public capital,  $K^G$ , under constant return to scale. The TFP follows first order auto-regressive process AR (1) process written in a logarithmic form as:

$$\log A_t = (1 - \rho_a) \log A_{ss} + \rho_a \log A_{t-1} + \varepsilon_t \tag{15}$$

where  $A_{ss}$  in Eq. (15) represents the steady-state value of TFP;  $\rho_a$  denotes the auto-regressive parameter of the TFP satisfying the condition that  $|\rho_a| < 1$  thereby ensuring its stationary property;  $\varepsilon_t$  is the stochastic exogenous COVID-19 shock to the TFP and is assumed to be normally distributed, i.e.  $\varepsilon_t \sim N(0, \sigma_a)$ .

In case second few retail firms retain their prices sticky while as others change their final product price as per the [Calvo \(1983\)](#) sticky pricing rule:

$$P_t = \left[ \theta_t P_{t-1}^{1-\psi_t} + (1 - \theta_t) P_t^{*1-\psi_t} \right]^{\frac{1}{1-\psi_t}} \tag{16}$$

In Eq. (16),  $\theta_t$  is the proportion of firms with sticky prices and  $(1 - \theta_t)$  as the proportion among the given continuum which alters their prices.

### 2.2.1. New Keynesian Phillip curve (NKPC)

In the New Keynesian models, market imperfections due to price stickiness and product differentiation create a markup, generating an inflationary situation. This inflationary situation  $\bar{\pi}_t$  within the contour of New Keynesian Phillip curve (NKPC) is given as:

$$\bar{\pi}_t = \beta_t E_t \bar{\pi}_{t+1} + \left[ \frac{(1-\theta_t)(1-\beta_t\theta_t)}{\theta_t} \right] (\bar{M}C_t - \bar{P}_t) \tag{17}$$

where  $\beta_t$  the discounting factor measures the expected inflation rate over successive periods,  $\bar{P}_t$  is the average prevailing price and  $\bar{M}C_t$  is the average marginal cost given as:

$$\bar{M}C_t = \alpha_1 \bar{R}_t + \alpha_2 \bar{W}_t + \alpha_3 \bar{G}_t - \bar{A}_t \tag{18}$$

where  $\bar{R}_t$  and  $\bar{W}_t$  represents the average return on capital and labour, respectively;  $\alpha_1, \alpha_2, \alpha_3$  represents the respective elasticities and  $\bar{A}_t$  is the TFP.

### 2.3. Fiscal authority

Fiscal policy under the optimization principle relies on revenue maximization subject to a given expenditure constraint. Revenue realization happens through different sources, primarily through taxation,  $T_t$ , issuance of government bonds,  $B_t$ , or through currency issue by a seignorage process. On the expenditure side, accumulated income is disposed either in purchasing goods and services,  $G_t$ , or undertaking public investment,  $I^G$ . In addition, the fiscal authority disposes its accumulated revenue through direct transfer to the individuals known as transfer payments  $TRANS_t$ . Ignoring the assumption of revenue realization through seignorage, the budget constraint of the fiscal authority is given as:

$$\frac{B_{t+1}}{R_t^B} - B_t + T_t = P_t G_t + P_t I_t^G + P_t TRANS_t \tag{19}$$

where  $\frac{B_{t+1}}{R_t^B} - B_t$  represents the net debt issued, and  $T_t$  is the amount of tax revenue. The instruments available with the fiscal authority are either from the expenditure side like  $(G_t, I_t^G, TRANS_t)$  or from the revenue side like  $\tau_t^c, \tau_t^l$  and  $\tau_t^k$ . In the steady state, fiscal policy rule is expressed as:

$$\frac{Z_t}{Z_{ss}} = \left( \frac{Z_{t-1}}{Z_{ss}} \right)^{\gamma_z} \left( \frac{B_t}{Y_{t-1} P_{t-1}} \frac{Y_{ss} P_{ss}}{B_{ss}} \right)^{(1-\gamma_z)\phi_z} S_t^z \tag{20}$$

where  $\gamma_z$  represents the smoothing parameter for fiscal policy instruments with  $Z_t$  a vector of instruments viz.  $[G_t, I_t^G, TRANS_t, \tau_t^c, \tau_t^l, \tau_t^k]$  and  $S_t^z$  which is a fiscal policy shock follows an AR(1) process:

$$\log S_t^z = (1 - \rho_z) \log S_{ss}^z + \rho_z \log S_{t-1}^z + \varepsilon_{z,t} \tag{21}$$

where  $\rho_z$  is the persistence parameter associated with the fiscal policy shock with  $\varepsilon_{z,t} \sim N(0, \sigma_z)$ .

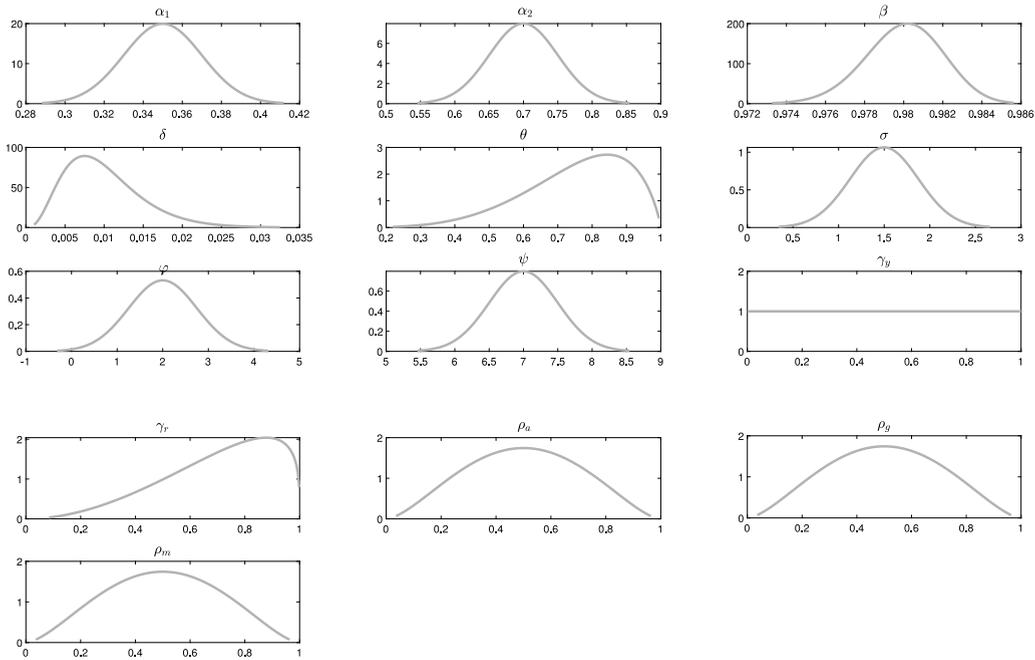


Fig. 1. Distribution plots of specified priors.

Notes: This figure reports the priori plots for the model parameters as specified in Table 3 with parameters following either Normal, Beta or Gamma distributions respectively.

Source: Authors' calculation.

### 2.4. Monetary authority

The monetary policy is entrusted with a twofold objective of price stability and economic growth under the following Taylor (1993) rule:

$$r_t = \theta_t + \beta_t \pi_t + \varphi x_t \tag{22}$$

where  $r_t$  is the interest rate target,  $\pi_t$  is the average gross inflation rate,  $\theta_t = r^* + (1 - \beta_t)\pi_t^*$  in which  $r_t^*$  represents the equilibrium rate of interest,  $\pi_t^*$  is the target inflation rate,  $x_t$  is the output gap. Taylor rule contends that for monetary policy to have a stabilizing effect, it should minimize the inflation and output gaps that diverge from their equilibrium targets. Monetary policy alters the interest rate for maintaining the target inflation rate at a threshold level of output. Monetary policy rule in steady-state is represented as:

$$\frac{R_t^B}{R_{SS}^B} = \left( \frac{R_{t-1}^B}{R_{SS}^B} \right)^{\gamma_r} \left[ \left( \frac{\pi_t}{\pi_{SS}} \right)^{\gamma_\pi} \left( \frac{Y_t}{Y_{SS}} \right)^{\gamma_y} \right]^{(1-\gamma_r)} S_t^m \tag{23}$$

where  $\gamma_y$  and  $\gamma_\pi$  are the sensitivity parameters in relation to potential output and inflation,  $\gamma_r$  is the smoothing parameter for the interest rate, and  $S_t^m$  the monetary policy shock that follows an AR(1) process:

$$\log S_t^m = (1 - \rho_m) \log S_{SS}^m + \rho_m \log S_{t-1}^m + \varepsilon_{m,t} \tag{24}$$

where  $\rho_m$  represents the persistence parameter for AR associated with monetary policy shock with  $\varepsilon_{m,t} \sim N(0, \sigma_m)$ .

### 2.5. Equilibrium identity

The equilibrium output identity in the NK-DSGE model determines the market clearing condition wherein aggregate demand is equal to aggregate supply. Under the general equilibrium framework, on the one hand, firms decide the quantity of output,  $Y_t$ , that they can produce with available resources and a given technology. On the other hand, households and fiscal authority determine the actual aggregate demand. The equilibrium identity is given as:

$$Y_t \equiv C_t + I_t^P + I_t^G + G_t \tag{25}$$

Eq. (25) represents the competitive general equilibrium condition under a balanced growth path (BGP) where all macroeconomic variables and economic agents attain the point of stable equilibrium.

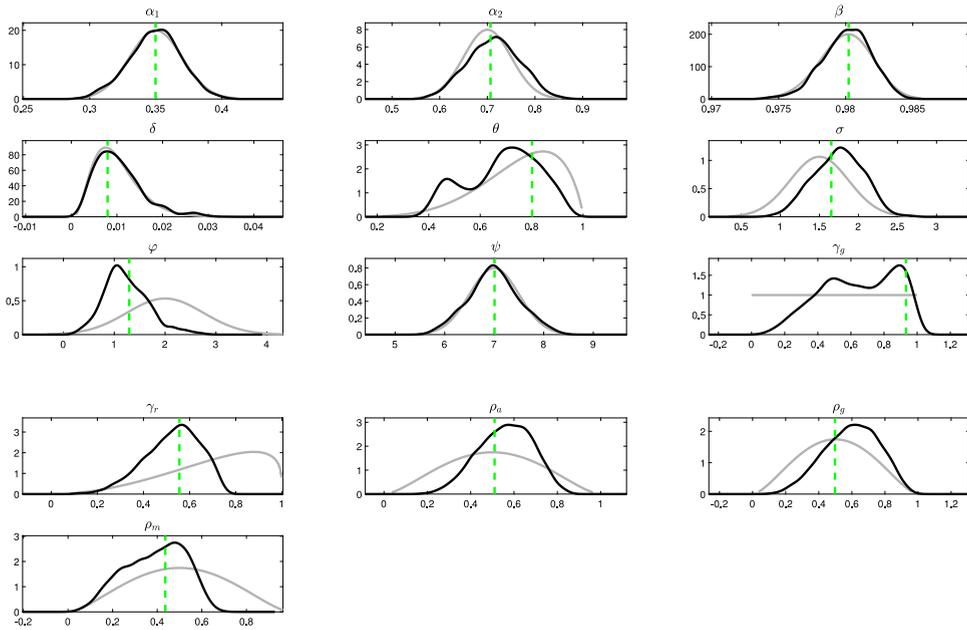


Fig. 2. Priori and posteriori distribution of parameters.

Notes: This figure reports the priori and posteriori plots for the model parameters. It depicts that data is more informative given that most of the posteriori estimates diverge from their priori counterparts after following standard distributions based on the empirical evidence.

Source: Authors' calculation.

Table 2

Calibrated specification of model parameters.

Source: Compiled from empirical studies.

Parameters	Calibrated values	Source	Description
$\alpha_1$	0.30	Elasticity of output in relation to capital	Banerjee and Basu (2019)
$\alpha_2$	0.70	Elasticity of output in relation to labour	Bhattacharya and Patnaik (2013)
$\alpha_3$	0.18	Elasticity of output in relation to public capital	Sahoo and Dash (2012)
$\beta_t$	0.98	Discounting factor	Levine, Pearlman, Perendia, and Yang (2012)
$\delta_t$	0.02	Depreciation rate	Banerjee and Basu (2019)
$\theta_t$	0.07	Price stickiness parameter	Goyal (2011)
$\theta_w$	0.50	Wage stickiness parameter	Smets and Wouters (2003)
$\sigma_t$	2.00	Relative risk aversion coefficient	Levine et al. (2012)
$\varphi_t$	3.00	Inverse of Frisch elasticity of labour supply	Anand and Prasad (2010) as in Ghatge, Gupta, and Mallick (2018)
$\psi_t$	7.02	Substitution elasticity among intermediate goods	Levine et al. (2012)
$\phi_t$	0.67	Habit persistence	Goyal and Kumar (2018)
$\omega_R$	0.40	Proportion of consumption and labour due to Ricardian households	Nandi (2019)
$\Psi_t$	2.00	Cost sensitivity in relation to under-utilization of maximum installed capacity	Gabriel, Levine, Pearlman, Yang, et al. (2010)
$\chi_t$	2.00	Sensitivity of investment in relation to adjustment cost	Banerjee and Basu (2019) as in Banerjee, Basu, and Ghatge (2020)
$\gamma_g$	0.59	Public spending persistence parameter	Banerjee et al. (2020)
$\gamma_r$	0.00	Persistence due to interest rate smoothing	Ghatge et al. (2018)
$\gamma_y$	0.50	Interest rate sensitivity in relation to GDP	Taylor (1993)
$\gamma_\pi$	1.50	Interest rate sensitivity in relation to inflation	Taylor (1993)
$\rho_a$	0.82	Persistence due to technology shock	Banerjee et al. (2020)
$\rho_g$	0.75	Persistence due to public expenditure shock	Banerjee, Basu, et al. (2015)
$\rho_m$	0.32	Persistence due to monetary policy shock	Banerjee et al. (2020)

Notes: This table reports the calibrated specification of the parameters with their respective sources.

### 3. Results and discussion

We apply the Bayesian analysis, which is the modern workhorse technique used to estimate dynamic macro general equilibrium models. Its main advantage over other estimation methods is that Bayesian method uses prior information, i.e. *priori*, to identify the key structural parameters, i.e. *posteriori*. In other words, Bayesian analysis pertains to derivation of the posterior distribution for the

**Table 3**  
 Priori specification of parameters.  
 Source: Compiled from empirical studies.

Parameters	Density	Prior mean	Prior SD	Source
$\alpha_1$	Normal	0.35	0.02	Herbst and Schorfheide (2015)
$\alpha_2$	Normal	0.70	0.05	Gabriel et al. (2010)
$\beta_i$	Beta	0.98	0.00	Schorfheide (2000)
$\delta_i$	Beta	0.01	0.00	Schorfheide (2000)
$\theta_i$	Beta	0.07	0.15	Gabriel, Levine, and Yang (2016)
$\sigma_i$	Normal	1.50	0.37	Gabriel et al. (2010)
$\phi_i$	Normal	2.00	0.75	Smets and Wouters (2003)
$\psi_i$	Normal	7.00	0.50	Gabriel et al. (2010)
$\gamma_g$	Gamma	0.40	0.20	Leeper, Plante, and Traum (2010) as in Herbst and Schorfheide (2015)
$\gamma_r$	Beta	0.70	0.20	Mohanty and Klau (2005)
$\rho_a$	Beta	0.50	0.20	Gabriel et al. (2010)
$\rho_g$	Beta	0.50	0.20	Gabriel et al. (2010)
$\rho_m$	Beta	0.50	0.20	An and Schorfheide (2007)

Notes: The table shows specified priori mean and standard deviation (SD) for the parameters with  $\alpha_1, \alpha_2, \sigma_i, \phi_i, \psi_i$  follow normal distribution,  $\beta_i, \delta_i, \theta_i, \gamma_r, \rho_a, \rho_g, \rho_m$  follow beta distribution and finally the parameter  $\gamma_g$  follow gamma distribution respectively.

**Table 4**  
 Posterior estimation.  
 Source: Author's calculation.

Parameters	Density	Priori		Posteriori		90% HPD interval	
		Mean	Standard deviation	Mean	Standard deviation		
$\alpha_1$	Normal	0.35	0.02	0.34	0.02	0.31	0.38
$\alpha_2$	Normal	0.70	0.05	0.71	0.04	0.62	0.79
$\beta_i$	Beta	0.98	0.00	0.98	0.00	0.97	0.98
$\delta_i$	Beta	0.01	0.00	0.01	0.00	0.00	0.01
$\theta_i$	Beta	0.75	0.15	0.68	0.14	0.43	0.88
$\sigma_i$	Normal	1.50	0.37	1.73	0.32	1.22	2.24
$\phi_i$	Normal	2.00	0.75	1.23	0.40	0.52	1.91
$\psi_i$	Normal	7.00	0.50	6.98	0.49	6.09	7.82
$\gamma_g$	Gamma	0.40	0.20	0.64	0.14	0.32	0.99
$\gamma_r$	Beta	0.70	0.20	0.52	0.15	0.34	0.72
$\rho_a$	Beta	0.50	0.20	0.55	0.13	0.35	0.75
$\rho_g$	Beta	0.50	0.20	0.59	0.23	0.33	0.86
$\rho_m$	Beta	0.50	0.20	0.38	0.16	0.16	0.59

Notes: This table reports the posteriori estimates for various parameters. Parameters  $\alpha_1$  and  $\alpha_2$  represent output elasticity in relation to capital and labour, respectively.  $\beta_i$  and  $\delta_i$  are discounting factor and depreciation rate while as  $\phi_i$  and  $\psi_i$  represents dis-utility due to labour supply and substitution elasticity among intermediate goods, respectively.  $\gamma_g$  and  $\gamma_r$  represents smoothing parameters for fiscal and monetary policies, respectively. Finally,  $\rho_a, \rho_g$  and  $\rho_m$  represent the persistent parameters associated with total factor productivity, fiscal policy and monetary policy shocks, respectively.

parameters conditional upon the already available information. The posteriori are denoted by  $\theta$  that are obtained by the famous Bayes' theorem. The theorem postulates estimating posterior distribution with the following relation:

$$p(\theta|Y^T) = \frac{L(Y^T|\theta)p(\theta)}{\int L(Y^T|\theta)p(\theta)d\theta} \tag{26}$$

where  $p(\theta)$  represents the prior density associated with the parameter vector  $\theta$ ;  $L(Y^T|\theta)$  represents the likelihood of the sample with  $T$  observations, and  $\int L(Y^T|\theta)p(\theta)d\theta$  is the marginal likelihood.

Next, we solve the model by calibrating<sup>4</sup> the parameters reported in Table 2, wherein the latter are the steady-state values. Then, we estimate impulse response functions based on the simulated shocks. The existing empirical literature on DSGE models does not provide adequate calibrated parameter values for developing economies (Gabriel et al., 2016). Hence, some of the calibrated values are taken from those estimated in the context of developed economies.

We conduct the Bayesian analysis of the posteriori conditional upon the priori as specified in Table 3. For non-negativity constraints, we select the inverse gamma distribution, while the beta distribution is preferred in the case of fractions and probabilities. In the case of a more informative priori, a normal distribution is chosen (see Fig. 1)<sup>5</sup>.

<sup>4</sup> We calibrate using MATLAB with DYNARE interface. For details, see Griffoli (2007).

<sup>5</sup> For more on priori elicitation, see Del Negro and Schorfheide (2008).

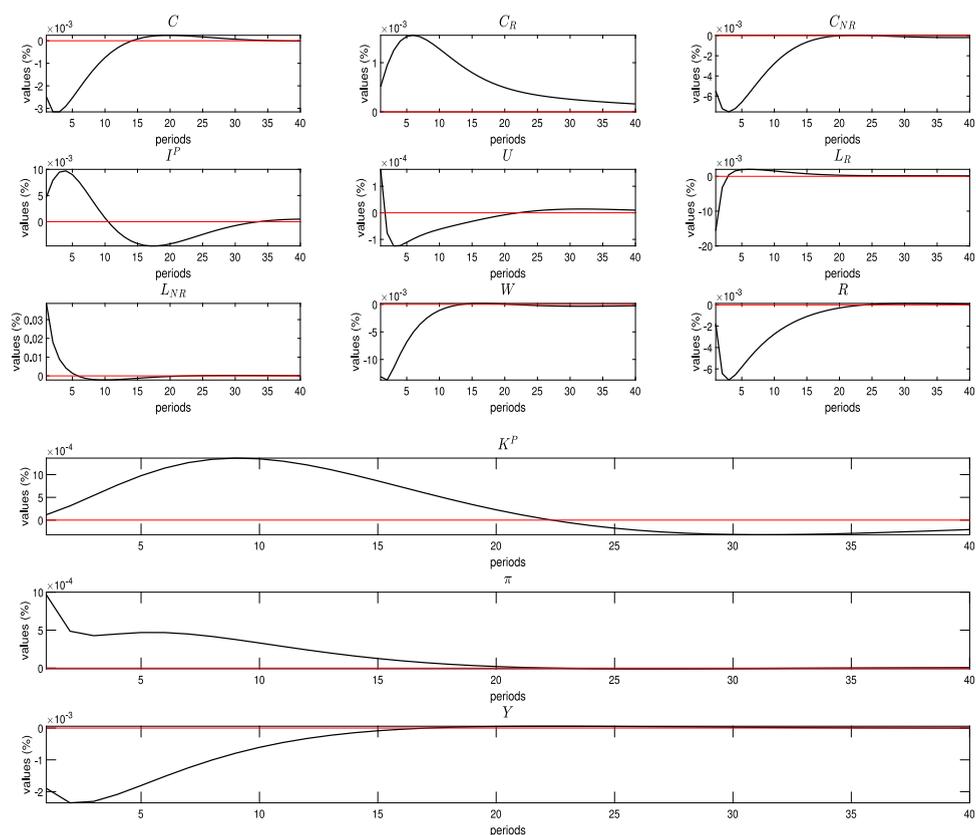


Fig. 3. Simulated responses due to productivity shock.

Notes: This figure reports pandemic shock to total factor productivity in terms of COVID-19. Aggregate consumption responds negatively mainly due to negative response of non-Ricardian consumption. Further, it shows a negative impact on the employment of Ricardian households with a negative return to labour and capital respectively.

Source: Authors' calculation.

### 3.1. Posterior estimates

We find a statistically significant fit for all the model parameters. Specifically, we find that the calculated posteriori mean are close to the already specified priori mean and lie within the 90% high powered density (HPD)<sup>6</sup> interval (see Table 4 and Fig. 2). For instance, the specified priori in case of risk aversion coefficient  $\sigma_t$  is 1.50, and the calculated posterior mean was 1.73. Likewise, the priori for depreciation rate  $\sigma_t$  is 0.01 and its posterior mean is 0.01. The same is true for output elasticities,  $\alpha_1$  and  $\alpha_2$ , wherein the specified priori 0.35 and 0.75 has a posteriori counterpart of 0.34 and 0.71, respectively. With regards to posteriori standard deviation (SD), we find that the calculated values are in line with the priori values. The standard deviation for the parameter  $\sigma_t$  specified as 0.37 in case of priori has a posteriori counterpart of about 0.32. Similarly, the specified priori standard deviation for output elasticities  $\alpha_1$  and  $\alpha_2$  which are 0.02 and 0.05, has a posteriori estimate of 0.02 and 0.04, respectively. Overall, we find that the estimated posteriori fits the specified priori parameters well and the values lie inside the HPD interval bounds. Therefore, estimated results satisfy the criteria of goodness of fit in the case of Bayesian analysis.

### 3.2. Productivity shock

Next, we examine the impact of the COVID-19 shock, as a shock through total factor productivity,  $\varepsilon_t$  and the resultant response of endogenous variables. The simulated responses are reported in Fig. 3. The impulse response function from the figure reveals that a negative productivity shock has negatively impacted the macroeconomic variables. A 1% productivity shock decreases the growth rate of consumption by a maximum of 7% in the case of non-Ricardian,  $C_{NR}$ , households. While we find a positive impact on consumption in case of Ricardian household,  $C_R$ , that are forward-looking in nature, the net impact on total consumption is found to be negative. The results are in line with Eichenbaum et al. (2020b) findings that consumption responds negatively during

<sup>6</sup> High-powered density (HPD) expresses the concentration of maximum values within 90% confidence interval.

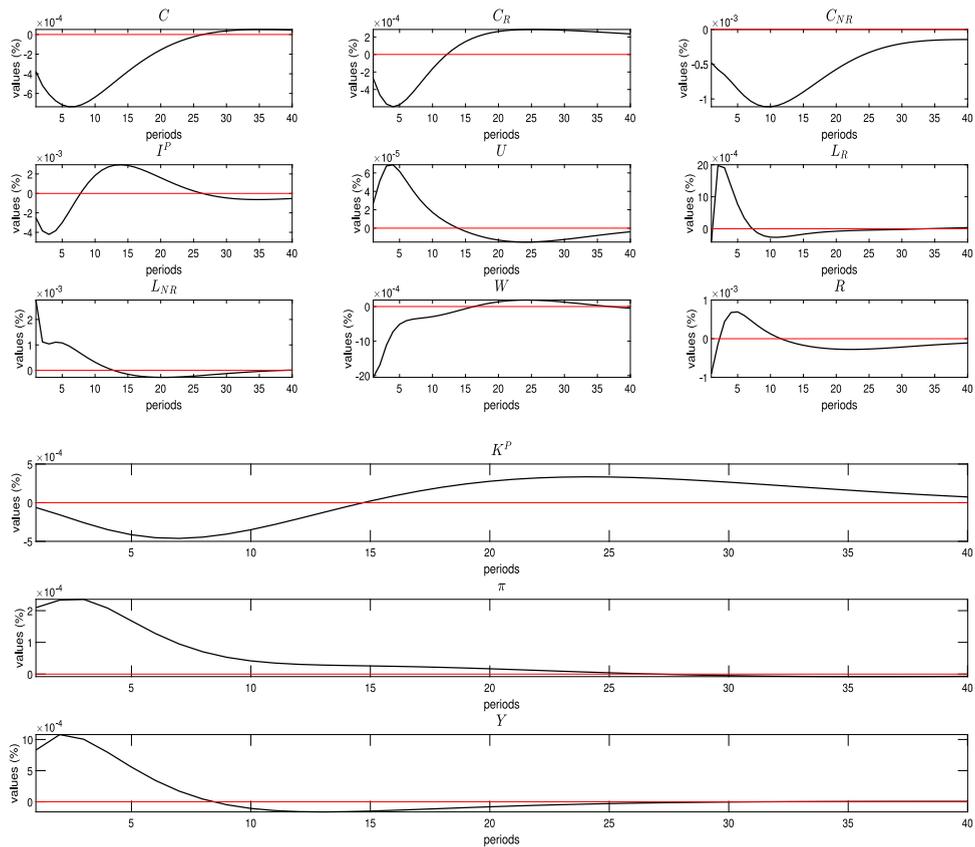


Fig. 4. Simulated responses due to government spending shock.

Notes: This figure reports response of endogenous variables due to government spending shock. It shows that, with increased government spending, consumption responds negatively with a negative impact on private investment during initial periods, possibly due to crowding out effect, hence government spending negatively contributes to the aggregate demand, while as a positive response is perceived from capacity utilization and employment.

Source: Authors' calculation.

the pandemic under the sticky price condition. Similarly, the pandemic negatively affected the employment of  $C_R$  with 15.6% in the first period, and 3.2% percent in the second period. However, the employment of  $C_R$  turned positive in the fourth period with an impact of about 0.1%. Further, capacity utilization,  $U_t$ , steeply falls till the sixth period with negative returns for labour and capital, thereby negatively affecting the growth rate of output  $Y_t$  (see Fig. 3)

### 3.3. Fiscal policy shock

First, we identify the impact of government expenditure shock,  $S_t^G$ , on macroeconomic variables, Fig. 4 presents the simulated responses. We find that a 1% government expenditure shock negatively affected consumption by about 3.75% in the first period, 5.19% in the second period and peaking in the sixth period with a negative impact of about 7.35%. Similarly, the private investment gets negatively affected due to the crowding out effect with 2.5% in the first period, 3.9% in the second period, and then gradually turning positive. Hence, an increase in government expenditure was ineffective in stimulating aggregate demand. However, we find evidence of positive impact on both Ricardian  $L_R$  and non-Ricardian  $L_{NR}$  household's employment and capacity utilization, implying that fiscal policy is effective in reviving aggregate supply with inflationary effect and falling wages,  $W_t$ .

Next, we examine the simulated response of government investment shock,  $S_t^{IG}$ , and the results are reported in Fig. 5. We find the negative impact of government investment on the consumption of both Ricardian and non-Ricardian households, with falling private capital stock,  $K^P$ , and private investment,  $I^P$ . Ricardian households' consumption negatively falls in the first period by about 0.48% and keep falling till the seventh period before turning positive thereafter. Likewise, the consumption of non-Ricardian households falls by about 1.62% in the first period and 2.17% in the second period reaching a maximum decline of 5.53% in the tenth period. However, capacity utilization and employment responded positively to investment shock, which resulted in a positive impact on the growth rate of income.

Finally, we investigate the impact of government transfers,  $S_t^{TRANS}$ , and simulated responses are presented in Fig. 6. We find a negative effect of direct transfers on total consumption and capacity utilization. The total consumption falls by about 3.07% in the first period and 5.19% in the second period, with a maximum fall of about 6.71% in the third period and changing its course

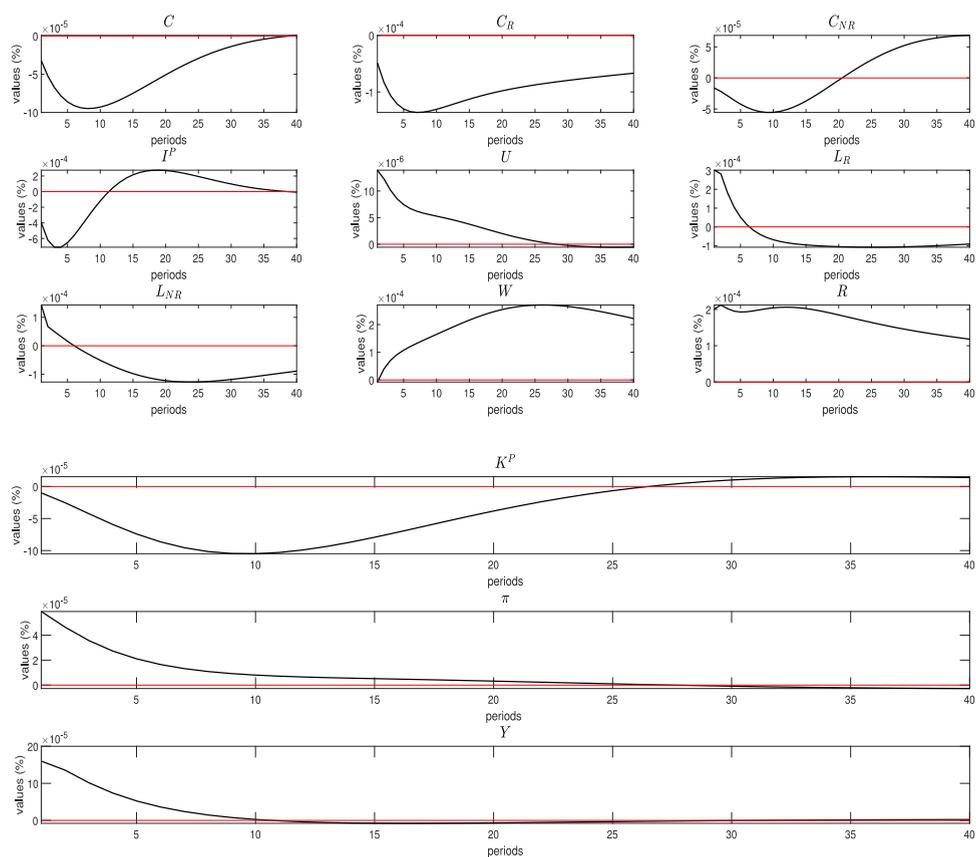


Fig. 5. Simulated responses due to government investment shock.

Notes: This figure reports the response of variables due to government investment shock. Both aggregate consumption and the Ricardian consumption responds negatively with a negative response of private capital and private investment. This infers a weak impact on overall aggregate demand.

Source: Authors' calculation.

afterwards. However, non-Ricardian employment,  $L_{NR}$ , private investment,  $I^P$ , and capital stock,  $K^P$ , responded positively to the government transfers.

Overall, our findings indicate the role of expansionary fiscal policy in positively affecting capacity utilization and employment, which, in turn, helps in reviving aggregate supply. This confirms the role of income-based support from the fiscal authority in employment revival during the pandemic period in the case of India. Further, our results imply that fiscal policy is partially ineffective in reviving aggregate demand during recessionary periods. The results are in line with Guerrieri, Lorenzoni, Straub, and Werning (2020).

### 3.4. Monetary policy shock

The response of macroeconomic variables to an exogenous monetary policy shock,  $S_t^m$ , are presented in Fig. 7. We find that a 1% monetary policy shock positively impacts both aggregate demand variables such as total consumption and private investment, and aggregate supply variables such as capacity utilization and employment. Further, we find that wage rate and return on capital responds positively to the monetary policy shock. This, in turn, augments the private capital stock,  $K^P$ , and growth rate of output,  $Y_t$ .

The results further reveal that a 1% monetary policy shock produces a positive impact of about 1.8% on total consumption in the first period and reaching its peak of about 2.3% in the seventh period. Likewise, private investment responded positively to the monetary policy shock. A 1% shock leads to an increase of about 5.7% in the first period and gradually declining in the subsequent periods. With regards to the supply-side variables, capacity utilization responded positively to the monetary policy shock with 1.21% in the first period, 7.78% in the second period, and 4.43% in the third period, respectively. Further, we find that the employment of non-Ricardian households also responded positively to the monetary policy shock, with an impact of about 6.1%, 1.9%, and 1.54% in the first, second, and third period, respectively. Of note, the response from the growth rate of income due to monetary policy shock reveals a 3.4% positive impact in the first period with a peak impact of 3.5% in the second period before tapering towards the origin in the subsequent periods. Overall, our finding confirms monetary policy's effectiveness in reviving both aggregate demand and aggregate supply in mitigating the recessionary effects of a pandemic on the Indian economy.

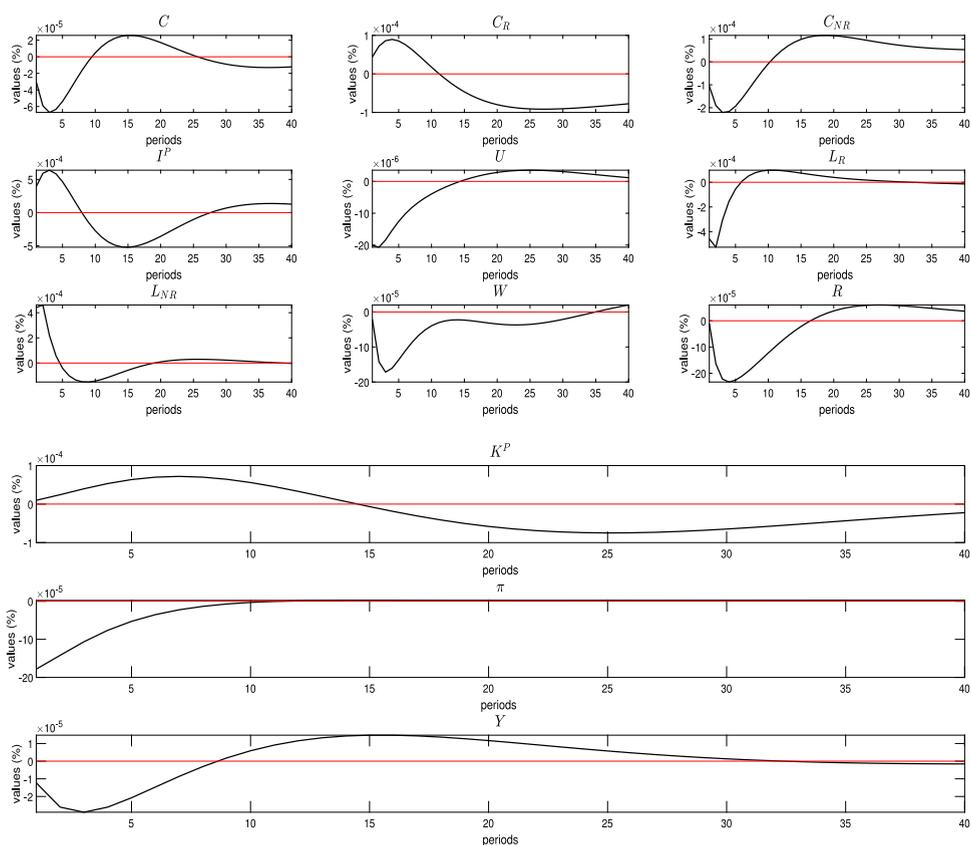


Fig. 6. Simulated responses due to government transfers.

Notes: In terms of government transfers, the figure reveals a negative response of consumption and capacity utilization. Although, non-Ricardian employment, private investment and private capital positively responds to the government transfers.

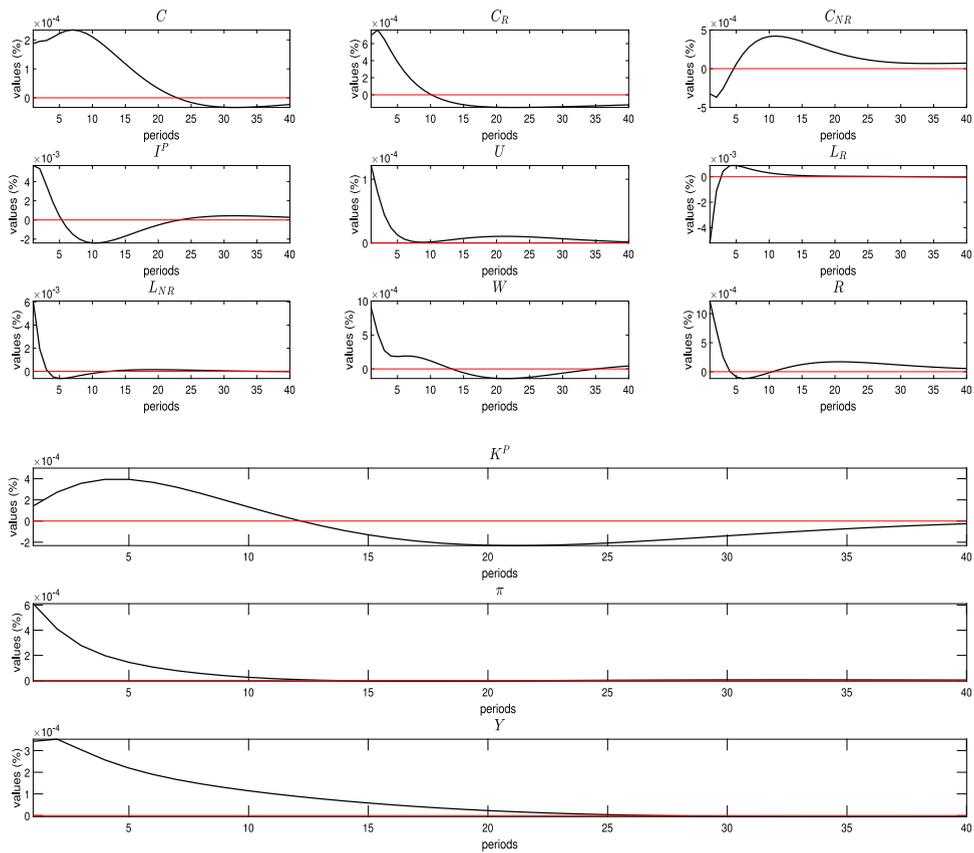
Source: Authors' calculation.

#### 4. Robustness results

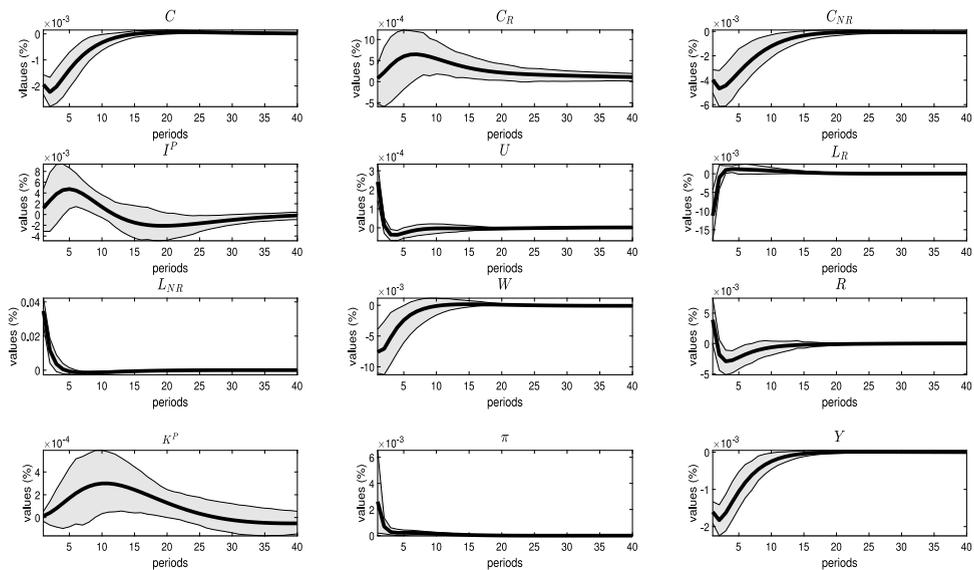
To check robustness of our results, we estimated the Bayesian IRFs based on the posteriori estimates. First, we observe that due to the COVID-19 shock aggregate consumption responds negatively along with a negative response from non-Ricardian households consumption,  $C_{NR}$  (see Fig. 8). Further, employment of Ricardian households,  $L_R$ , depicts a negative response with a fall in the capacity utilization of both labour and capital thereby exerting a negative impact on the growth rate of income. Second, due to positive government spending shock aggregate consumption responds negatively wherein consumption of both Ricardian,  $C_R$ , and non-Ricardian,  $C_{NR}$ , households is negatively impacted. Further government spending shock negatively impacts private investment,  $I^P$  (see Fig. 9), thereby supporting the ineffectiveness of government spending in revival of aggregate demand. However, the positive response from employment of both Ricardian,  $L_R$ , and non-Ricardian households,  $L_{NR}$  as well as from capacity utilization supports the effectiveness of government spending in boosting the aggregate supply.

Third, we investigate the effectiveness of government investment shock and the results are reported in Fig. 10. The results reveals that government investment negatively affects the consumption of both Ricardian,  $C_R$ , and non-Ricardian,  $C_{NR}$ , households along with falling private investment,  $I^P$ , thereby negatively contributing to the aggregate demand. Further, capital stock which responds negatively to the government investment is compensated by the positive response from the capacity utilization,  $U_t$ , and hence contributing favourably to the growth rate of income. Fourth, we analyse the impact of government transfers and the respective impulse responses are reported in Fig. 11. Although the results reveal a negative response from aggregate consumption,  $C_t$ , but employment due to non-Ricardian households,  $C_{NR}$ , and private capital stock responds positively to these shocks hence proving the effectiveness of government transfers in revival of aggregate supply.

Finally, we examine the effectiveness of monetary policy in mitigating the impact of the COVID-19 shock. The results are reported in Fig. 12. We find that monetary policy shock contributes positively to both aggregate demand and aggregate supply. It is evident from Fig. 12 that aggregate consumption,  $C_t$ , responds positively to the expansionary monetary policy shock wherein there is positive response in consumption of Ricardian households,  $C_R$ . Additionally, capacity utilization,  $U_t$ , and private capital stock along with non-Ricardian employment,  $L_{NR}$ , also responds positively. Therefore, expansionary monetary policy shock impacts positively to the growth rate of income, and hence proving its effectiveness.



**Fig. 7.** Simulated responses due to monetary policy shock.  
 Notes: This figure reports the response of endogenous variables due to monetary policy shock. It depicts a positive response of majority of underlying variables. We observe that not only consumption and private investment, but also capacity utilization and employment responds positively. Furthermore, return to capital and labour also respond positively to the monetary policy shock.  
 Source: Authors' calculation.



**Fig. 8.** Robustness checks: Bayesian IRFs due to productivity shock.  
 Notes: The Bayesian impulse response due to the productivity shock in terms of COVID-19 reveals a positive response of consumption with a negative impact on employment possibly due to negative returns from labour and capital.  
 Source: Authors' calculation.

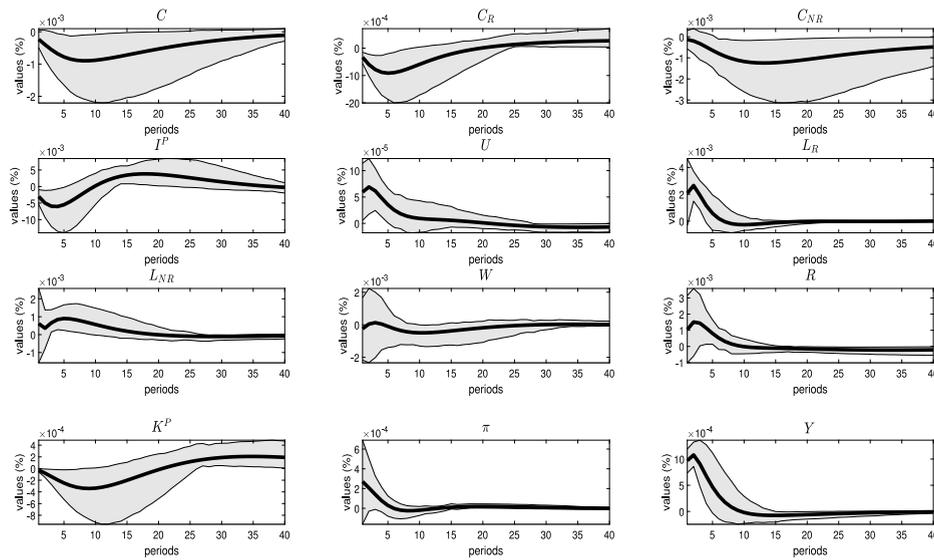


Fig. 9. Robustness checks: Bayesian IRFs due to government spending shock.

Notes: In terms of Bayesian impulse response, the government spending shock depicts a negative impact on consumption and investment. Further, aggregate supply variables especially employment and capacity utilization show a positive response.

Source: Authors' calculation.

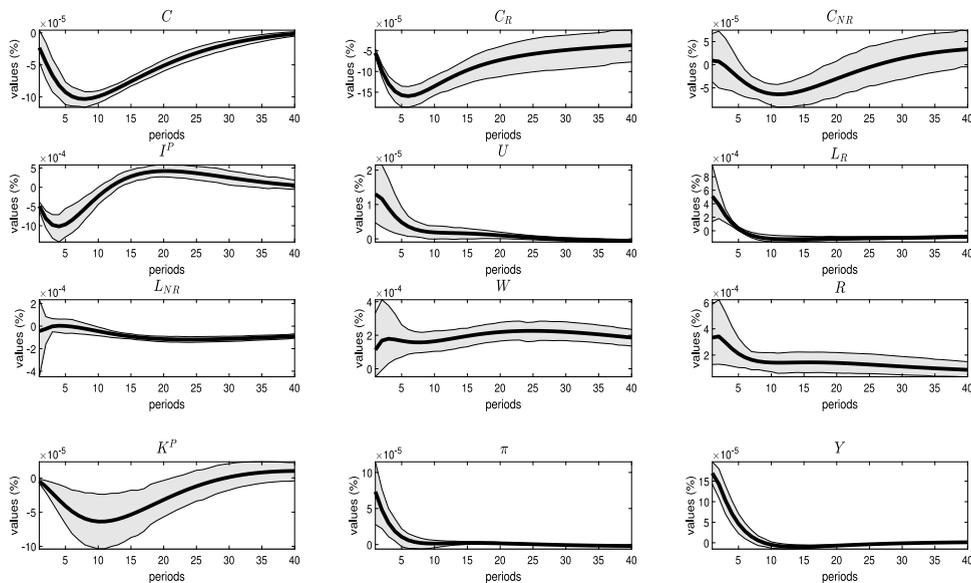


Fig. 10. Robustness checks: Bayesian IRFs due to government investment shock.

Notes: The Bayesian impulse response due to government investment shock depicts a negative consumption effect with a negative response due to private capital and private investment, thereby reflecting a weak impact on the overall aggregate demand.

Source: Authors' calculation.

Overall, our robustness test results are in line with the results from simulated responses. The responses from fiscal and monetary policy analysis proved the role of former in revival of aggregate supply while the latter proved to be effective in revival of both aggregate demand and aggregate supply. Hence, we can confirm robustness of our results.

### 5. Conclusion and policy implications

In this paper, we assess the effectiveness of fiscal policy and monetary policy shocks in combating the COVID-19 impact on the Indian economy. The results revealed that there is a negative impact of the COVID-19 pandemic on macroeconomic variables mainly due to the postponing of current consumption associated with lockdowns and layoffs, which served as the dominant sources of fluctuations

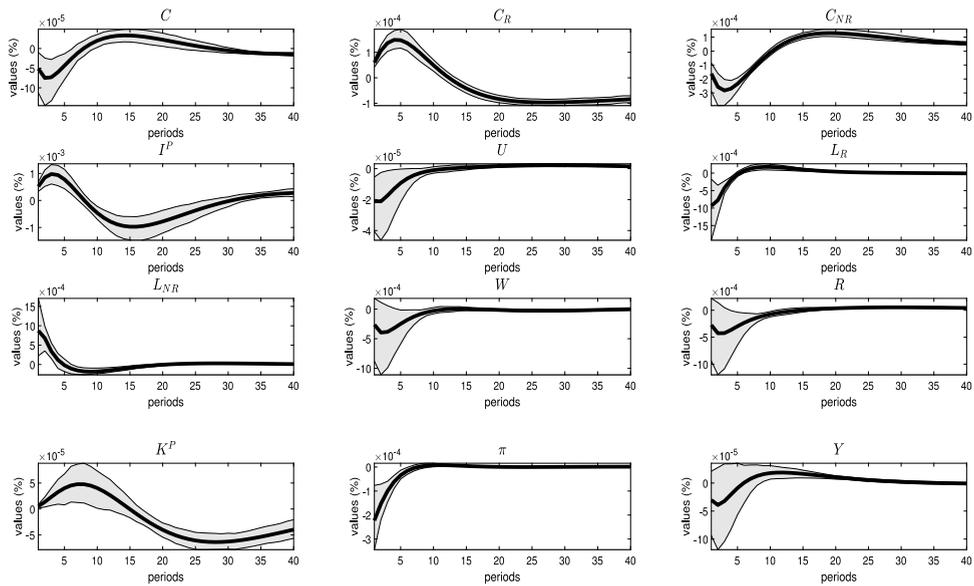


Fig. 11. Robustness checks: Bayesian IRFs due to government transfers.

Notes: This figure reveals that due to government transfers, a negative response of consumption and capacity utilization is observed. Furthermore, the supply side variables viz. non-Ricardian employment, private investment and private capital responds positively to the government transfer shock.

Source: Authors' calculation.

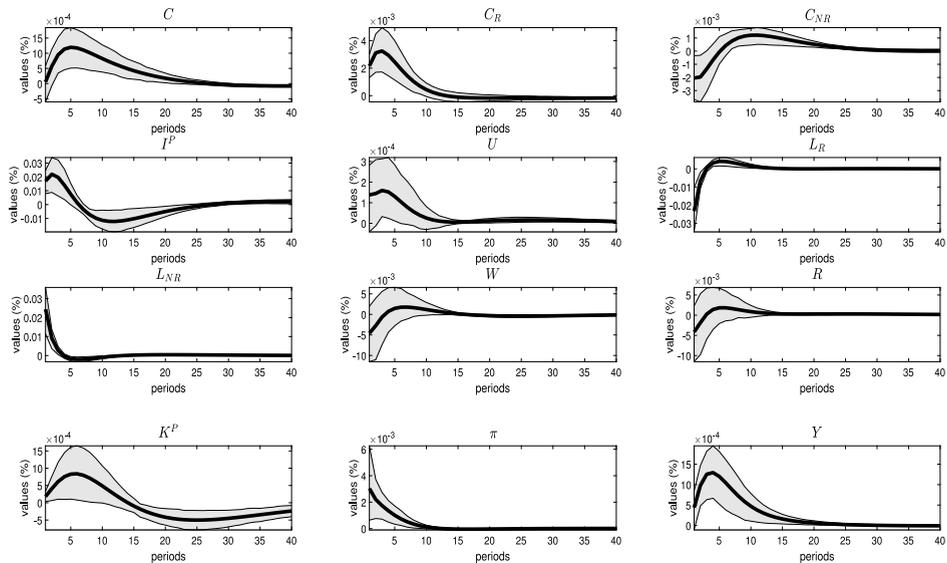


Fig. 12. Robustness checks: Bayesian IRFs due to monetary policy shock.

Notes: Examining the role of monetary policy shock in a Bayesian framework, the figure depicts that not only aggregate demand variables viz. consumption and private investment respond positively, but also the aggregate supply variables viz. capacity utilization, employment, returns to labour as well to the capital also respond positively to the monetary policy shock.

Source: Authors' calculation.

in the Indian economy. We apply the NK-DSGE framework that accounts for heterogeneous households (both Ricardian and non-Ricardian), firms (both retail and wholesale), a monetary authority, and a fiscal authority. We estimate the simulated responses of various macroeconomic variables to fiscal and monetary policy shocks. Further, our results pass the robustness checks.

Our findings have few important policy implications. Overall, we find that monetary policy is more effective in reviving economic growth in recessionary periods as compared to fiscal policy. The fiscal policy is effective only from the supply side, i.e., fiscal policy can boost capacity utilization and employment and thereby increase aggregate supply. Expansionary fiscal policy measures such as providing wage subsidies, expanding employment guarantees, tax relief, and support in financing the working capital of

manufacturing firms to help the production sector, etc. Of note, we find that the monetary policy is highly effective in reviving economic growth both from the supply side and demand-side. Hence, easing monetary policy instruments such as improving the availability of credit, low-interest rates, mortgage payment holidays, etc., is warranted to boost economic activity. While there have been a number of policy interventions after the COVID-19 outbreak, such as moratorium and tax reliefs, there is still a scope for speeding up the recovery both from the demand side and supply side. Our policy prescriptions warrant the use of monetary and fiscal policy in a coordinated mix. Furthermore, we recommend optimal use of policy mix in a staggered fashion, that not only revives the aggregate demand and aggregate supply, but also takes care of inflationary situation, since focusing solely on either policy in an independent context is ill-advised.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data availability

Data will be made available on request.

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