Australian National University

Crawford School of Public Policy

CAMA

Centre for Applied Macroeconomic Analysis

Redistributive Policy Shocks and Monetary Policy with Heterogeneous Agents

---

CAMA Working Paper 59/2024
September 2024

Ojasvita Bahl
Indian Statistical Institute

Chetan Ghate
Institute of Economic Growth
Indian Statistical Institute
Centre for Applied Macroeconomic Analysis, ANU

Debdulal Mallick
Deakin University

Abstract

Governments in EMDEs routinely intervene in agriculture markets to stabilize food prices in the wake of adverse shocks. Such interventions involve a large increase in the procurement and redistribution of agriculture output, which we refer to as a redistributive policy shock. What is the impact of a redistributive policy shock on inflation and the distribution of consumption amongst rich and poor households? We build a two-sector-two-agent NK-DSGE model (2S-TANK) to address these questions. Using Indian data, we estimate the model using a Bayesian approach. We characterize optimal monetary policy. We show that the welfare costs of redistributive policy shocks are substantially higher when non-optimized rules are used to set monetary policy in response to such shocks.

Keywords

TANK models, inflation targeting, emerging market and developing economies, procurement and redistribution, NK-DSGE, welfare costs

JEL Classification

E31, E32, E44, E52, E63

Address for correspondence:

(E) cama.admin@anu.edu.au

ISSN 2206-0332

Redistributive Policy Shocks and Monetary Policy with Heterogeneous Agents

Ojasvita Bahl* Chetan Ghate† Debdulal Mallick‡

September 5, 2024

Abstract

Governments in EMDEs routinely intervene in agriculture markets to stabilize food prices in the wake of adverse shocks. Such interventions involve a large increase in the procurement and redistribution of agriculture output, which we refer to as a redistributive policy shock. What is the impact of a redistributive policy shock on inflation and the distribution of consumption amongst rich and poor households? We build a two-sector-two-agent NK-DSGE model (2S-TANK) to address these questions. Using Indian data, we estimate the model using a Bayesian approach. We characterize optimal monetary policy. We show that the welfare costs of redistributive policy shocks are substantially higher when non-optimized rules are used to set monetary policy in response to such shocks.

Keywords TANK models, Inflation Targeting, Emerging Market and Developing Economies, Procurement and Redistribution, NK-DSGE, Welfare Costs

JEL codes: E31, E32, E44, E52, E63.

*Economics and Planning Unit, Indian Statistical Institute, New Delhi – 110016, India. Tel: 91-11-4149-3938. Fax: 91-11-4149-3981. E-mail: ojasvita18r@isid.ac.in

†Corresponding Author: Institute of Economic Growth, University Enclave, University of Delhi (North Campus), Delhi-110007; Economics and Planning Unit, Indian Statistical Institute, New Delhi – 110016, India. Tel: +91-11-4149-3938. Fax:+91-11-4149-3981. E-mail: cghate@isid.ac.in, cghate@gmail.com

‡Department of Economics, Faculty of Business and Law, Deakin University, 70 Elgar Road, Burwood, Vic 3125, Australia. Phone: (+61 3) 92517808. Email: debdulal.mallick@deakin.edu.au

1 Introduction

Governments in many emerging market and developing economies (EMDEs) routinely intervene in their agricultural markets. Higher food security norms require an increase in the redistribution of agricultural output to the poorest population in a country. Other interventions involve the procurement and redistribution of food to minimize food price volatility in the wake of domestic (e.g., poor rainfall) or external (e.g., global commodity price) shocks.

There are many examples of these types of interventions. In 2013, India enacted a new National Food Security Act (NFSA) under the umbrella of a new ”rights-based” approach to food security. The Act legally entitles ”up to 75% of the rural population and 50% of the urban population to receive subsidized food grains” under a Targeted Public Distribution System. Under the new act, about two thirds of the population is covered to receive highly subsidized food grains. The ostensible goal is to smooth the purchasing power of poor populations that are food insecure. Moreover, in India, the food entitlements under the NFSA were doubled during COVID and made completely free (see Ranade (2023))

In the Philippines, the National Food Authority (NFA) is mandated to purchase and distribute rice and other commodities across the country. In response to the rise in world prices of grains in the last quarter of 2007, the Philippines government provided higher funding support to implement its Economic Resiliency Program part of which involved scaling up a rice production enhancement program called ”Ginintuang Masaganang Ani.” The total fiscal cost of the NFA rice subsidy jumped to 0.6% of GDP in 2008 compared to 0.08% of GDP in 2007 (Balisacan et al. (2010)). In Bangladesh, the government has intervened in food markets for several years in order to reduce price fluctuations and procure rice for safety net programs (Hossain and Deb (2010)). To ensure food security in Indonesia in 2008, the Indonesian government, through its BULOG operational strategy doubled the amount of rice distributed to cover all poor families under the RASKIN program through targeted market operations requested by local governments. Regular rice distribution for the poor was achieved by increasing domestic rice procurement. BULOG's heavy procurement added to demand, helping farmers maintain prices at a profitable level (Saifullah (2010)). The Korean government also motivates its agricultural policy for food security reasons based on self-sufficiency (Beghin et al. (2003)).

Interventions such as the enactment of a new national food security act with wider coverage, the expansion of free or subsidized food entitlements during COVID, or surprise government interventions when there are large price shocks in food commodities such as the world rice price crisis of 2008, have two salient features. First, they typically imply higher procurement and redistribution of food commodities by the government to households. This raises the food subsidy to the household. Second, such interventions are conducted at a relatively high frequency, i.e., several times within a year. We refer to frequent interventions by the government in agriculture markets as redistributive policy shocks. The main research questions that this paper addresses is: how should monetary policy respond to redistributive policy shocks? What is the impact of redistributive policy shocks on the sectoral and aggregate dynamics of inflation and rich and poor consumption? What are the welfare costs of redisributive policy shocks and other shocks emanating from the agriculture sector ? The novel part of our analysis is that we allow for government intervention in the agriculture market that captures the essence of procurement and redistributive style interventions in EMDEs.

We build a two-sector (agriculture and manufacturing) two agent (rich and poor) New Keynesian DSGE model. We refer to this as 2S-TANK. Our theoretical model builds on earlier work by Aoki (2001), Debortoli and Gali (2017), and Ghate et al. (2018). The main methodological contribution of our framework is that we extend the two agent New Keynesian, i.e., TANK DSGE framework of Debortoli and Gali to two sectors (agriculture and manufacturing). On the production side, the agriculture sector is perfectly competitive with flexible prices while the manufacturing sector is characterized by monopolistic competition and sticky prices. As in Debortoli and Gali, we assume that there are two types of agents, rich and poor. Rich agents are Ricardian and buy one period risk free bonds. Poor agents are assumed to be rule of thumb consumers. Both types of households consume both types of goods. To provide the subsidized agriculture good to the poor, the government imposes a lump sum tax on the rich and uses the proceeds to procure agricultural output from the open market. It then redistributes a fraction of the procured agriculture good to the poor. Higher redistribution and procurement, by leading to a higher subsidy of the agriculture good to the poor leads to a larger reduction in the poor's market expenditures on the agriculture good. Further, we assume that rich agents have a higher intertemporal elasticity of substitution of consumption compared to the poor which affects their labor supply decisions deferentially in response to changes in the real wage.[1]

The Indian agriculture sector is subject to frequent government interventions in the agriculture market.[2] Using Indian data, we estimate the model equations using the Bayesian method. Our Bayesian estimation gives us parameter values which allows us to understand the mechanisms through which redistributive policy shocks impact economy wide and distributional variables in an empirically grounded framework.[3] From the impulse response functions (IRFs), we identify the transmission mechanism of agricultural productivity shocks, redistributive policy shocks, and monetary policy shocks to sectoral inflation rates, the econ-

[1]In Debortoli and Gali, all agents have the same inter-temporal elasticity of substitution. Our assumption is driven by estimates of different inter-temporal elasticity of substitution parameters for rich and poor households from Indian household data. See Atkeson and Ogaki (1996). Our assumption is also in line with some of the DSGE literature on the macroeconomic evaluation of LSAPs (large scale asset purchase programs), where the inter-temporal elasticity of substitution across households is assumed to be different. See Chen et al. (2012).

[2]India is an EMDE with a large agriculture sector and has less reliance on imports for meeting its food security needs - closer to our closed economy model.

[3]Ginn and Pourroy (2019)) estimate a Bayesian DSGE model using India data and show that food subsidy policies have large distributional effects. While our model focuses on redisributive policy shocks, they focus on world food price shocks.

omy wide inflation rate, and consumption of rich and poor agents. We compare our results to a variety of benchmarks that emerge as special cases from our framework: a two sector representative agent NK framework along the lines of Aoki, a one sector two agent NK DSGE model along the lines of Debortoli and Gali, and the simple one sector one agent NK model in Gali (2015).[4] This allows us to isolate the impact of demand side factors (consumer heterogeneity) and supply side factors (multiple sectors) in determining sectoral and aggregate inflation rates, and rich and poor consumption in response to these shocks.

We show that a positive agricultural productivity shock leads to a decline in aggregate inflation, a decline in aggregate employment, a negative output gap, and a rise in both poor and rich consumption. In contrast, a procurement and redistributive policy shock leads to higher aggregate inflation, a positive output gap, lower consumption by the rich, higher consumption of the poor, and higher aggregate consumption in the economy. Because of the redistributive effect of the transfer, the rise in poor consumption makes aggregate consumption rise dominating the decline in rich consumption. Compared to the Aoki model, since the poor receive a fraction of their agriculture consumption for free (via the redistributive shock), the market demand for the agriculture good is less, and so the inflationary impact of a procurement and redistributive policy shock is much lower in our model compared to the Aoki model (where there is no redistribution).

In two extensions of the model, we show that the distributional impacts of redistributive policy shocks are robust to assuming i) non-homothetic preferences, and ii) labor immobility across sectors.

[4]Both productivity shock and procurement and redistributive policy shock IRFs are benchmarked only to the Aoki model since Aoki has two production sectors while both Debortoli and Gali and Gali (2015, Chapter 3) have a single sticky price manufacturing sector. In the case of Debortoli and Gali, their framework assumes incomplete markets, ours has complete markets. Parameter restrictions that yield their model can therefore be seen as an approximation of their framework.

It is important to note that in standard NK models the optimal policy design is to perfectly stabilize inflation at the natural level of output. In the presence of a flexible price sector, we would expect that the planner would not be able to smooth the variability in inflation in the flexible price sector and thus not be able to achieve full (headline) inflation stabilization.[5] To evaluate the welfare cost of redistributive policy shocks, we follow Schmitt-Grohe and Uribe (2007). We assume that the monetary authority acts like a utilitarian Ramsey planner and maximizes the weighted average of inter-temporal utility functions of rich and poor households subject to the private sector optimality conditions and the economy's feasibility constraints. This is referred to as Ramsey optimal monetary policy (ROMP) in the literature. To rank alternative policies, we compare (both conditional and unconditional) welfare under optimal simple rules (OSR), and a variety of non-optimized rules, and convert any improvements in welfare to consumption equivalent welfare gains.

Our main welfare results, which are in Section 6, show that while a Ramsey planner is able to achieve close to full *core-inflation* stabilization (or sticky price inflation), *aggregate inflation* variability is lower under OSR compared to Ramsey. This is because under OSR, the monetary authority places a high weight on minimizing the variance of aggregate inflation, and chooses a Taylor parameter for inflation responsiveness to be highest feasible value ($\phi_\pi = 3$). We also find that non-optimized rules (both simple Taylor, and Standard Taylor) lead to consumption equivalents that are of an order of magnitude higher when compared to optimal simple rules. This suggests that redistributive policy shocks are costly to both rich and poor households, especially when monetary policy is not set optimally.[6]

[5] It is well known that optimal policy design is model-dependent (see Woodford (2010)).

[6] When we fix the steady-state amount of agriculture output procured and assess the implication of varying steady-state redistribution on consumption equivalent welfare gains, we show that the volatility of poor consumption rises, when the steady state redistribution in the economy rises. We conduct a similar exercise using optimal simple rules. In both cases, poor agents are risk averse and unable to smooth consumption. They therefore are willing to forego a greater amount of their steady state consumption to avoid fluctuations in consumption because of the redistributive policy shock. These results are described in the Technical Appendix.

1.1 Literature Review

A recent focus in the monetary policy literature explores the impact of monetary policy in the presence of consumer heterogeneity (see McKay et al. (2016); Kaplan et al. (2018); Auclert (2019), and Broer et al. (2020)). As in this research, we ask how heterogeneity matters for whether monetary policy responses to shocks raise aggregate welfare or not? Why is it important to take into account heterogeneity? In our model consumer heterogeneity interacts with rich inter-sectoral dynamics to determine the differential response of rich and poor consumption, and therefore aggregate demand to shocks. We therefore compare our two-sector TANK model under a contractionary monetary policy shock with the simple NK framework in Gali (2015) (Chapter 3), the Aoki model, and Debortoli and Gali. In models with two sectors (our model and Aoki's) the presence of a flexible price sector creates a large deflation in the economy in response to a contractionary monetary policy shock. This is because a rise in the nominal interest rate leads to the inter-temporal substitution of consumption, as in the standard NK model, which causes a reduction in aggregate demand and a decline in the aggregate price level and inflation. This decline becomes more pronounced when there is a flexible price sector in addition to a sticky price sector. Since the shock is of one period, agricultural inflation returns to the steady state in the next period. Manufacturing inflation, however, recovers, gradually, because of the sticky price assumption in all models. Crucially, in our model and Aoki's model, real interest rates increase by less, and therefore rich and poor consumption falls be less compared to Debortoli and Gali and the simple NK model. The decline in aggregate consumption, therefore, is also less in our model and Aoki's model compared to the simple NK model and Debortoli and Gali. In all cases, consumer heterogeneity interacts with rich inter-sectoral dynamics to determine the general equilibrium responses to a variety of shocks.

An interesting insight from our analysis is that when the employment share of the manufacturing sector rises, output adjusts more compared to an economy with a higher share of the agriculture/flexible price sector, and the effectiveness of monetary policy is comparatively more. Our model therefore provides a rationale for why monetary policy is ineffective in economies with a large agriculture sector.

Our two sector-two agent NK framework builds on the seminal work by Gali and Monacelli (2005), Aoki (2001), and Debortoli and Gali (2017). The main difference with respect to these papers is that Gali and Monacelli (2005) consider an open economy framework, whereas we consider a closed economy framework. In Aoki (2001) there are two production sectors, a flexible price agriculture sector that is perfectly competitive, and a sticky price manufacturing sector that is monopolistically competitive. The production side of our model is similar to Aoki's model. However, Aoki's model has a single representative agent. In our model, we allow for two types of agents, rich (Ricardian) and poor (rule of thumb) with different inter-temporal elasticities of substitution in consumption and different budget constraints. Another difference with respect to Aoki (2001) is that the government in our model taxes rich agents, procures grain from the agriculture sector, and redistributes the agriculture good to poor agents. In Aoki's framework there is no government intervention.[7]

Debortoli and Gali (2017) build a DSGE model in which agents are Ricardian/rich and rule of thumb/poor. They show that a TANK model provides a good approximation to study the impact of aggregate shocks to aggregate variables in a baseline HANK (Heterogenous agent New Keynesian) model. In Debortoli and Gali (2017), there is however only one production sector (sticky price sector). The main methodological contribution of our paper is to extend the two agent-one sector framework of Debortoli and Gali to two sectors.

Our paper also builds on previous work in Ghate et al. (2018), or GGM. In GGM, there are three production sectors (grain, vegetables, and manufacturing). In that framework,

[7]Gali et al. (2007) use a two-agent framework (rule of thumb and Ricardian) to account for evidence on government spending shocks, but their focus is on fiscal policy, not monetary policy.

all three sectors are monopolistically competitive, with the agriculture sector having flexible prices. The manufacturing sector is the sticky price sector. In the current framework, there are two production sectors (agriculture, manufacturing). Unlike GGM, the agriculture sector is just characterized by a grain sector which is assumed to be perfectly competitive. Like GGM, the manufacturing sector is the sticky price sector. In GGM, there is a single representative agent, i.e., it is a RANK (Representative Agent New Keynesian) model. Our model has two types of agents.[8] Like GGM however, our model illustrates how the terms of trade between agriculture and manufacturing plays a crucial role in the transmission of monetary policy changes to aggregate outcomes.

In sum, the contribution our paper is both methodological and policy oriented. We merge a two sector production structure along the lines of Aoki with a TANK framework along the lines of Debortoli and Gali to understand the impact of redistributive policy shocks and its implications for monetary policy using a New Keynesian DSGE framework. We characterize optimal monetary policy in this context, and calculate the welfare costs of redistributive policy interventions.[9]

2 The Model

The model has two sectors: agriculture (A) and manufacturing (M). The A-sector is characterized by perfect competition and flexible prices, and produces a single homogeneous good. The M-sector is characterized by monopolistic competition and staggered price setting.[10]

[8] In the current framework, we do not model minimum support prices as we did in GGM. Our focus is to study the impact of redistributive policy shocks on rich-poor consumption and sectoral and aggregate inflation dynamics, and monetary policy setting in this context.

[9] Our paper has relevance for the ongoing protests on the farm laws that were introduced in India in November 2020 (but then repealed a year later in 2021). One of the demands of the farmers is to fix the minimum support price of agriculture products by a committee of stakeholders, which would include farmers. A higher minimum support price would raise the amount of the food subsidy. Our analysis sheds light on the dynamics of food subsidies, their implication for inflation, and a better understanding of their general equilibrium effects.

[10] The manufacturing sector can also be termed as the "non-agriculture" sector. The names are not crucial. What is crucial is that one sector is a flexible price sector, and the other is a sticky price sector.

We assume that there are two types of households: poor (P) and rich (R). The fraction of households which are rich is exogenously given and denoted by μ_R. The rest $(1 - \mu_R)$ are poor. The poor and rich can either work in the A sector or the M sector, i.e., there is perfect mobility of labor across sectors. Poor households are assumed to be rule of thumb (or hand to mouth consumers) and do not have bond holdings. Rich households are forward-looking Ricardian consumers and hold bonds. The rich households own the firms and also supply labor to their own firms, and so they have both dividend and labor income. The poor households only supply labor to the firms owned by the rich, and so their only income is labor income.

Like GGM, the government procures grain in the open market. It does this by imposing a lump-sum tax on the rich and uses the proceeds to procure/buy A-sector output from the market at the market price.[11] It then redistributes a fraction of the procured A good to poor households. Hence redistribution goes to the poor households, rather than any particular sector. The rich households also have higher incomes than the poor since the poor households only have labor income, whereas rich households have labor and dividend income.

Following Atkeson and Ogaki (1996) who show that the intertemporal elasticity of substitution (IES) in consumption rises with wealth in Indian data, we assume that the poor have a lower IES than the rich. This means that the poor are less willing to substitute consumption across time periods. This allows labor responses of the rich and poor to differ for a given change in the real wage (see Chen et al. (2012)).

2.1 Households

All households are assumed to have identical preferences.[12] At time 0, a household of type K $(= R, P)$ maximizes its expected lifetime utility given by

[11]It is important to note that the seller of the A good can be either poor or rich.

[12]All derivations for the model in Section 2 and 3 are in the Technical Appendix.

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[U\left(C_{K,t}\right) - V\left(N_{K,t}\right) \right] \tag{1}$$

where $C_{K,t}$ is a consumption index, and $N_{K,t}$ is labor supply. The subscript $K \in \{R, P\}$ specifies the household type. A household of type K derives utility from consumption, $C_{K,t}$, and disutility from supplying labor, $N_{K,t}$. $\beta \in (0,1)$ is the discount factor. The period utility function is specified as:

$$U\left(C_{K,t}\right) = \frac{C_{K,t}^{1-\sigma_K}}{1-\sigma_K} \tag{2}$$

$$V\left(N_{K,t}\right) = \frac{N_{K,t}^{1+\varphi}}{1+\varphi} \tag{3}$$

where σ_K and φ, respectively, are the inverse of the intertemporal elasticity of substitution for consumer type K, and the inverse of the Frisch labor supply elasticity, which is assumed to be the same for both types of households. Consumption of both rich and poor households depend on goods consumed from both sectors and follow Cobb-Douglas indices of agriculture (A) and manufacturing (M) consumption and is given by:

$$C_{K,t} = \frac{C_{K,A,t}^{\delta_K} C_{K,M,t}^{1-\delta_K}}{\delta_K^{\delta_K}\left(1-\delta_K\right)^{1-\delta_K}}; \qquad \text{for } K = R \text{ and } P \tag{4}$$

where $\delta_K \in [0,1]$ is the share of income spent on agricultural goods by the K^{th} type of agent. Consumption in the manufacturing sector is a CES aggregate of a continuum of differentiated goods indexed by $j \in [0,1]$,where $P_{M,t}(j)$ is the price level of the j^{th} variety of the M-sector good, i.e.,[13] $C_{K,M,t} = \left(\int_0^1 C_{K,M,t}\left(j\right)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \varepsilon > 1$.

Rich households maximize utility given in equation (1) subject to the following intertem-

[13] The demand functions for goods within manufacturing varieties are

$$C_{K,M,t}(j) = \left(\frac{P_{M,t}(j)}{P_{M,t}}\right)^{-\varepsilon} C_{K,M,t}$$

for $K = R$ and P.

poral budget constraint

$$\int_0^1 [P_{M,t}(j)C_{R,M,t}(j)]\, dj + P_{A,t}C_{R,A,t} + E_t\{Q_{t+1}B_{t+1}\} \leq B_t + W_tN_{R,t} - T_{R,t} + Div_t \qquad (5)$$

where Q_{t+1} is the stochastic discount factor, B_{t+1} are the nominal payoffs in period $t+1$ of the bonds held at the end of period t, $T_{R,t}$ is the lump-sum tax paid to the government, and Div_t is the dividend income distributed to households by monopolistically competitive firms. Labor is assumed to be completely mobile across sectors, with the nominal wage rate given by W_t. We assume that the A sector produces a single homogeneous good, whose price is $P_{A,t}$.

To model a procurement-redistribution style intervention in an EMDE, the government in every period procures the agriculture good at the open market price, $P_{A,t}$. Part of the procured agriculture good is rebated back to each poor household as a subsidy, $C^S_{P,A,t}$, while the remaining portion is put into a buffer stock.[14] Of the total consumption of the agriculture good by the poor household, $C_{P,A,t}$, a fraction, λ_t, is subsidized (it is given for free). That is, $C^S_{P,A,t} = \lambda_t C_{P,A,t}$ The remaining fraction, $(1-\lambda_t)$, of $C_{P,A,t}$ is purchased from the open market ($C^O_{P,A,t}$) which implies

$$C^S_{P,A,t} + C^O_{P,A,t} = C_{P,A,t}. \qquad (6)$$

Poor households are assumed to be rule of thumb consumers, and maximize their current utility (1) subject to the following (static) budget constraint

$$\int_0^1 [P_{M,t}(j)C_{P,M,t}(j)]\, dj + P_{A,t}C^O_{P,A,t} \leq W_tN_{P,t} \qquad (7)$$

where $P_{A,t}C^O_{P,A,t}$ denotes the nominal value of open market purchases of the agriculture good done by the poor. The poor agent derives utility from the amount of the agricultural good

[14]An equivalent interpretation is that non-redistributed procured output is wasted, or *thrown into the ocean*. We do not endogenize buffer stock dynamics in this paper.

consumed, while the expenditure depends only on a fraction, $1-\lambda_t$, of the quantity consumed. It is easy to see that equation (7) can be re-written as

$$\int_0^1 [P_{M,t}(j) C_{P,M,t}(j)]\, dj + P_{A,t}(1-\lambda_t) C_{P,A,t} \leq W_t N_{P,t}. \tag{8}$$

Hence the proportional quantity subsidy can be interpreted as a price subsidy. We define: $P^{'}_{A,t} = (1-\lambda_t)P_{A,t}$, which is the effective price of the agriculture good paid by the poor agent.

2.1.1 Optimal allocations

Optimal consumption allocations by the rich for A and M goods are given, respectively, by

$$C_{R,A,t} = \delta_R \left(\frac{P_{A,t}}{P_t}\right)^{-1} C_{R,t} \tag{9}$$

$$C_{R,M,t} = (1-\delta_R) \left(\frac{P_{M,t}}{P_t}\right)^{-1} C_{R,t} \tag{10}$$

where the aggregate price level is given by $P_t = P_{A,t}^{\delta_R} P_{M,t}^{1-\delta_R}$.

For poor households, consumption allocations for the A and M goods are given respectively by

$$C_{P,A,t} = \delta_P \left(\frac{P^{'}_{A,t}}{P^{'}_t}\right)^{-1} C_{P,t} \tag{11}$$

$$C_{P,M,t} = (1-\delta_P) \left(\frac{P_{M,t}}{P^{'}_t}\right)^{-1} C_{P,t} \tag{12}$$

where the price index for the poor is given by: $P^{'}_t = \{(1-\lambda_t)P_{A,t}\}^{\delta_p} P_{M,t}^{1-\delta_p}$. Because of the policy, λ_t, it is important to note that the rich and poor face different price indices.

Using the fact that $C_{R,M,t}(j) = \left(\frac{P_{M,t}(j)}{P_{M,t}}\right)^{-\varepsilon} C_{R,M,t}$ and the demand functions in (9)-(10) implies that the budget constraint for the rich can be rewritten as

$$P_t C_{R,t} + E_t\{Q_{t+1}B_{t+1}\} \leq B_t + W_t N_{R,t} - T_{R,t} + Div_t \tag{13}$$

For the poor, using equations (11)-(12) implies

$$P_t^{'} C_{P,t} \leq W_t N_{P,t} \tag{14}$$

where $C_{R,t}$ and $C_{P,t}$ denote the consumption indices (over the agriculture good and manufacturing good) of the rich and poor households, respectively. As seen in equation (14), the impact of subsidizing the agriculture good for poor households reduces the effective price of the consumption basket to $P_t^{'}$.

The solutions to maximizing equation (1) subject to equation (13) for the rich and equation (14) for the poor yield the following optimality conditions:

$$1 = \beta E_t \left[\left(\frac{C_{R,t+1}}{C_{R,t}} \right)^{-\sigma_R} \frac{P_t}{P_{t+1}} R_t \right] \tag{15}$$

$$\frac{W_t}{P_t} = \frac{N_{R,t}^{\varphi}}{C_{R,t}^{-\sigma_R}} \text{ for the rich} \tag{16}$$

$$\frac{W_t}{P_t^{'}} = \frac{N_{P,t}^{\varphi}}{C_{P,t}^{-\sigma_P}} \text{ for the poor} \tag{17}$$

where $R_t = \frac{1}{E_t\{Q_{t+1}\}}$ is the gross nominal return on the riskless one-period bond.

2.1.2 Terms of trade

Terms of trade (TOT) between the agriculture and the manufacturing sectors is defined as $T_t = \frac{P_{A,t}}{P_{M,t}}$. CPI inflation is given by $\pi_t = \ln P_t - \ln P_{t-1}$, and the sectoral inflation rates are given by as $\pi_{A,t} = \ln P_{A,t} - \ln P_{A,t-1}$ and $\pi_{M,t} = \ln P_{M,t} - \ln P_{M,t-1}$, respectively, for the agriculture and the manufacturing sectors. From the aggregate price index, CPI inflation can also be written in terms of TOT as

$$\pi_t = \delta_R \pi_{A,t} + (1-\delta_R)\pi_{M,t} = \delta_R \Delta T_t + \pi_{M,t}. \tag{18}$$

2.1.3 Sectoral aggregates

We define aggregate agriculture consumption as a weighted average of rich and poor agriculture consumption:

$$C_{A,t} = \mu_R C_{R,A,t} + (1-\mu_R) C_{P,A,t} \tag{19}$$

The total amount of redistributed grain and the consumption subsidy to the poor is given by:

$$(1-\mu_R) C^S_{P,A,t} = \phi_t Y^P_{A,t} \tag{20}$$

where the government redistributes a fraction, $\phi_t \in [0,1]$, of procured goods, $Y^P_{A,t}$, to the poor. Substituting out for $C_{P,A,t}$ from (11) yields

$$\underbrace{C_{A,t}}_{\text{Total Ag. Con}} = \underbrace{\mu_R \delta_R \left(\frac{P_{A,t}}{P_t}\right)^{-1} C_{R,t}}_{\text{Con. by Rich}} + \underbrace{(1-\mu_R)\delta_P \left(\frac{P'_{A,t}}{P'_t}\right)^{-1} C_{P,t}}_{\text{Con. by Poor}} \tag{21}$$

This implies

$$C_{A,t} = \mu_R \delta_R T_t^{-(1-\delta_R)} C_{R,t} + (1-\mu_R)\delta_p \left\{(1-\lambda_t) T_t\right\}^{-(1-\delta_p)} C_{P,t} \tag{22}$$

Likewise, $C_{M,t} = \mu_R C_{R,M,t} + (1-\mu_R) C_{P,M,t}$ which implies

$$C_{M,t} = \mu_R (1-\delta_R) T_t^{\delta_R} C_{R,t} + (1-\mu_R)(1-\delta_P) \left\{(1-\lambda_t) T_t\right\}^{\delta_p} C_{P,t} \tag{23}$$

These two last equation imply that total agriculture and manufacturing consumption depends on rich and poor consumption, and the terms of trade.

2.2 Firms

In the manufacturing sector, there is a continuum of firms indexed by j. Each firm produces a differentiated good with a linear technology given by the production function $Y_{M,t}(j) = A_{M,t}N_{M,t}(j)$. We assume that productivity shocks are the same across firms and follow an AR(1) process,

$$\log A_{M,t} - \log A_M = \rho_M \left(\log A_{M,t-1} - \log A_M\right) + \varepsilon_{M,t}$$

where $\varepsilon_{M,t} \sim i.i.d(0, \sigma_M)$. The nominal marginal costs are common across firms and are given by $MC_{M,t} = (1+\tau_M)\frac{W_t}{A_{M,t}}$ where τ_M is the employment subsidy given to manufacturing production. Real marginal costs is written as

$$mc_{M,t} = \frac{MC_{M,t}}{P_{M,t}} = (1+\tau_M)\frac{W_t}{P_t}T^{\delta_R}\frac{1}{A_{M,t}}. \tag{24}$$

Let $Y_{M,t} = \left(\int_0^1 Y_{M,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}$, where $\varepsilon > 1$. Output demand is given by $Y_{M,t}(j) = \left(\frac{P_{M,t}(j)}{P_{M,t}}\right)^{-\varepsilon} Y_{M,t}$. The labor supply allocation in manufacturing sector is obtained as

$$N_{M,t} = \int_0^1 N_{M,t}(j)\, dj = \frac{Y_{M,t}}{A_{M,t}} Z_{M,t} \tag{25}$$

where $Z_{M,t} = \int_0^1 \left(\frac{P_{M,t}(j)}{P_{M,t}}\right)^{-\varepsilon} dj$ represents the price dispersion term. Equilibrium variations in $\ln \int_0^1 \left(\frac{P_{M,t}(j)}{P_{M,t}}\right)^{-\varepsilon} dj$ around perfect foresight steady state are of second order. Given that the agriculture sector is characterized by flexible price and perfect competition, we can write the sectoral aggregate production as

$$Y_{A,t} = A_{A,t}N_{A,t} \tag{26}$$

where the productivity shock follows an AR(1) process,

$$\log A_{A,t} - \log A_A = \rho_A \left(\log A_{A,t-1} - \log A_A\right) + \varepsilon_{A,t}. \tag{27}$$

where $\varepsilon_{A,t} \sim i.i.d(0, \sigma_A)$. Nominal marginal costs in the agriculture sector are given by $MC_{A,t} = \frac{W_t}{A_{A,t}}$

2.2.1 Price setting in the manufacturing sector

Price setting follows Calvo (1983), and is standard in the literature. Firms adjust prices with probabilities $(1 - \theta)$ independent of the time elapsed since the previous adjustment. The inflation dynamics under such price setting is

$$\pi_{M,t} = \beta E_t\{\pi_{M,t+1}\} + \kappa \widetilde{mc}_{M,t} \tag{28}$$

where $\kappa = \frac{(1-\beta\theta)(1-\theta)}{\theta}$, and $\widetilde{mc}_{M,t}$ is the deviation of the real marginal cost in the manufacturing sector from its natural rate (to be defined later).

2.3 Government procurement

In each period, the government procures $Y^P_{A,t}$ amount of agricultural output at the market price $P_{A,t}$ using the tax receipts from the rich and redistributes a fraction ($\phi_t \in [0, 1]$) of procured goods to the poor.[15] The redistributed amount is given by $\phi_t Y^P_{A,t}$. The agricultural sector output is the sum of consumption and the amount accumulated by the buffer stock

$$Y_{A,t} = C_{A,t} + (1 - \phi_t) Y^P_{A,t} \tag{29}$$

[15]Please note that when P is super-script, it refers to procurement. When it is sub-script, it refers to the poor.

where the total consumption of the agricultural good $C_{A,t}$ consists of the total amount consumed (by both the rich and poor). A procurement shock is given by an AR(1) process,

$$\ln Y_{A,t}^P - \ln Y_A^P = \rho_{Y_A^P}(\ln Y_{A,t-1}^P - \ln Y_A^P) + \varepsilon_{Y_{A,t}^P} \tag{30}$$

where $\rho_{Y_A^P} \in (0,1)$ and $\varepsilon_{Y_{A,t}^P} \sim i.i.d(0, \sigma_{Y_A^P})$. Re-distributive policy shocks, captured by changes in ϕ_t, capture sudden increases in the *fraction* of procured grain re-distributed to the poor, and are given by the following AR(1) process,

$$\ln \phi_t - \ln \phi = \rho_\phi(\ln \phi_{t-1} - \ln \phi) + \varepsilon_\phi \tag{31}$$

where $\rho_\phi \in (0,1)$ and $\varepsilon_\phi \sim i.i.d(0, \sigma_\phi)$. Higher redistribution and procurement, by leading to a higher subsidy of the agriculture good to the poor from equation (20), therefore leads to a larger reduction in the poor's expenditures on the agriculture good.[16]

3 Equilibrium Dynamics

3.1 Market Clearing

Market clearing is given by the following equations:

$$C_t = \mu_R C_{R,t} + (1-\mu_R)C_{P,t}\,(1-\lambda_t)^{-(1-\delta_p)}\,T_t^{\delta_p - \delta_R}\,(1-\lambda_t(1-\delta_p)) \tag{32}$$

$$N_t = N_{A,t} + N_{M,t} \tag{33}$$

$$Y_{M,t} = C_{M,t} \tag{34}$$

[16]See also Technical Appendix 7.3.

$$Y_t = C_t + T_t^{1-\delta_R} Y_{A,t}^P (1-\phi_t) \tag{35}$$

$$Y_t = T_t^{1-\delta_R} Y_{A,t} + T_t^{-\delta_R} Y_{M,t} \tag{36}$$

$$\mu_R T_{R,t} = \left[(1-\phi_t) Y_{A,t}^P + C_{P,A,t}^S (1-\mu_R)\right] P_{A,t} = P_{A,t} Y_{A,t}^P \tag{37}$$

and equation (29). Equation (32) corresponds to aggregate consumption by both rich and poor households obtained by adding nominal values of agriculture and manufacturing consumption, weighted by their respective masses, μ_R, and $1-\mu_R$ in the population (which is normalized to 1), and deflating by the price index. Both the policy, λ_t, and the terms of trade, T_t, are seen to affect aggregate consumption positively.[17] The labor market clearing condition is given by equation (33). The agriculture market clearing condition is given by equation (29). The manufacturing goods market clearing condition is given by equation (34). The aggregate goods market clearing condition is given by equation (35) which can be written in terms of T_t as in equation (36). Equation (37) is the government budget constraint, which equates lump sum taxes collected from the rich to the nominal value of redistribution ($C_{P,A,t}^S P_{A,t}(1-\mu_R)$) and the fraction of procured output that goes towards buffer stock accumulation ($(1-\phi_t) Y_{A,t}^P P_{A,t}$).

3.2 Log-linearization

We relegate a discussion and derivation of the steady state and complete log-linearized model to the Technical Appendix. What is of interest here are the log-linearized expressions for $\widehat{C}_{P,t}$ and $\widehat{C}_{R,t}$, as these give the differential impact on consumption of the poor and rich from a variety of shocks. Log-linearization of the aggregate market clearing condition (equation

[17]Comparative statics suggest that higher redistribution (higher λ, holding T constant) lowers the effective price index of the poor agent. This leads to a positive income effect. Holding λ constant and raising T leads to higher consumption, as a higher terms of trade has a positive impact on output, from equation (36).

(35)) gives

$$\widehat{Y}_t = c\widehat{C}_t + (1-c)\left[(1-\delta_R)\widehat{T}_t + \widehat{Y}^P_{A,t} - \left(\frac{1}{1-\phi}\right)\widehat{\phi}_t\right] \tag{38}$$
$$= \left(\frac{1-\mu_A}{1-\bar{\delta}}\right)\widehat{C}_t + \left(\frac{\mu_A-\bar{\delta}}{1-\bar{\delta}}\right)\left[(1-\delta_R)\widehat{T}_t + \widehat{Y}^P_{A,t} - \left(\frac{1}{1-\phi}\right)\widehat{\phi}_t\right]$$

where c is the steady state consumption share in output and is defined in equation (63). Log linearization of aggregate consumption, C_t, in equation (32) gives

$$\widehat{C}_t = s_R\widehat{C}_{R,t} + (1-s_R)\left\{(1-\lambda_p\tau)\,\widehat{C}_{P,t} + \lambda_p\tau\left(\frac{\widehat{\phi}_t}{\phi} + \widehat{Y}^P_{A,t}\right) + [\delta_p - \delta_R + \lambda_p\tau(1-\delta_p)]\,\widehat{T}_t\right\} \tag{39}$$

where s_R is the steady consumption share of the rich households, , and $\tau = \frac{\lambda(1-\delta_p)}{1-\lambda(1-\delta_p)}$.[18] Log linearization of the first order conditions (equations (16) and (17)) for the rich and poor households give

$$\widehat{W}_t - \widehat{P}_t = \varphi\widehat{N}_{R,t} + \sigma_R\widehat{C}_{R,t} \tag{40}$$

and

$$\widehat{W}_t - \widehat{P}_t = \varphi\widehat{N}_{P,t} + \sigma_P\widehat{C}_{P,t} - \frac{\delta_p}{1-\lambda}\hat{\lambda}_t + (\delta_p - \delta_R)\widehat{T}_t. \tag{41}$$

The log-linearized consumption of the poor, $\widehat{C}_{P,t}$, is given by

$$\widehat{C}_{P,t} = \frac{\sigma_R}{\sigma_P+\lambda_p}\widehat{C}_{R,t} + \frac{\lambda_p}{\sigma_P+\lambda_p}\left[\frac{\widehat{\phi}_t}{\phi} + \widehat{Y}^P_{A,t}\right] - \left\{\frac{\delta_p - \delta_R - \lambda_p(1-\delta_p)}{\sigma_P+\lambda_p}\right\}\widehat{T}_t \tag{42}$$

Note that $\widehat{C}_{P,t}$ is increasing in the redistribution shock, $\widehat{\phi}_t$, the steady state deviation of procurement, $\widehat{Y}^P_{A,t}$, and is affected negatively by the steady state deviation of the terms of

[18] We assume that the share of rich in employment is equal to the share of rich in the population $0 < \mu_R < 1$, i.e., $N_{R,t} = \mu_R N_t$ and $N_{P,t} = (1-\mu_R)N_t$. This implies that $\widehat{N}_{R,t} = \widehat{N}_{P,t} = \widehat{N}_t$ for all t.

trade, $\widehat{T}_t$. An increase in procurement and redistribution induces a "redistribution-effect" which raises consumption of the poor because it provides subsidized goods which raises their consumption. A rise in the consumption of the rich increases consumption of the poor because of our assumption that the labor supply of the rich and poor are constant fractions of total labor supply. The terms of trade exerts a negative impact on consumption as a higher relative price of the agriculture good makes the consumption basket of the poor more expensive. This induces the poor to buy less agricultural output. If both the rich and poor households have the same inter-temporal elasticity of substitution, i.e., $\sigma_R = \sigma_P$, $\delta_p = \delta_R$, and there is no redistributive policy, i.e., $\lambda = 0$, then $\widehat{C}_t = \widehat{C}_{R,t} = \widehat{C}_{P,t}$.

Log linearization of the Euler equation (15) for the rich households around zero inflation in the steady state gives

$$\widehat{C}_{R,t} = E_t\{\widehat{C}_{R,t+1}\} - \frac{1}{\sigma_R}\left[\widehat{R}_t - E_t\{\Pi_{t+1}\}\right] \tag{43}$$

Substituting $\widehat{C}_{P,t}$ in equation (42) into (39), solving for $\widehat{C}_{R,t}$, and substituting the resulting expression for $\widehat{C}_{R,t}$ in equation (43), gives us the Euler equation in terms of aggregate consumption, $\widehat{C}_t$, as

$$\widehat{C}_t = E_t\{\widehat{C}_{t+1}\} - \Phi^{-1}\left[\widehat{R}_t - E_t\{\Pi_{t+1}\}\right] - \Psi E_t\left\{\frac{\Delta\widehat{\phi}_{t+1}}{\phi} + \Delta\widehat{Y}^P_{A,t+1} + \{(1-\delta_p) + (\delta_p - \delta_R)\,z\}\,\Delta\widehat{T}_{t+1}\right\} \tag{44}$$

where

$$\Phi = \frac{\sigma_R(\sigma_P + \lambda_p)}{s_R(\sigma_P + \lambda_p) + (1 - s_R)\sigma_R(1 - \lambda_p\tau)}, \tag{45}$$

$\Psi = \frac{\lambda_p(1-s_R)(1+\sigma_P\tau)}{\sigma_P+\lambda_p}$, and $z = \frac{\sigma_p+\lambda_p-(1-\lambda_p\tau)}{\lambda_p(1+\sigma_p\tau)}$. With $\sigma_R = \sigma_P$, $s_R = 1$, and $\lambda = 0$, equation (44) becomes the standard Euler equation for homogenous households.

3.3 Gap Variables

Define $\widehat{X}_t^N$ as the deviation of $\ln X_t$ under flexible prices from the steady state, i.e., $\widehat{X}_t^N = \ln X_t^N - \ln X$. Also, define the gap of a variable as $\widetilde{X}_t = \widehat{X}_t - \widehat{X}_t^N$. Then, the dynamic IS equation (DIS) is given by

$$\begin{aligned}\widetilde{Y}_t = E_t\left\{\widetilde{Y}_{t+1}\right\} - c\Phi^{-1}\left[\widehat{R}_t - E_t\{\Pi_{t+1}\} - \widehat{R}_t^N\right] \\ - \left[(1-\delta_R)(1-c) + \Psi c\left\{(1-\delta_p) + (\delta_p - \delta_R)z\right\}\right] E_t\left\{\Delta\widetilde{T}_{t+1}\right\}\end{aligned} \tag{46}$$

where $\widehat{R}_t^N$ is the real natural interest rate and is given by

$$\begin{aligned}\widehat{R}_t^N = &- \left[\Psi\Phi(1-\Lambda^{-1}\Phi) + \varphi(1-c)\Lambda^{-1}\Phi\right] E_t\left\{\Delta\widehat{Y}_{PA,t+1}\right\} \\ &- \left[\frac{\Psi\Phi}{\phi}(1-\Lambda^{-1}\Phi) - \Lambda^{-1}\Phi\varphi(1-c)\left(\frac{1}{1-\phi}\right)\right] E_t\left\{\Delta\widehat{\phi}_{t+1}\right\} \\ &+ \Phi\Lambda^{-1}E_t\left[\varphi\Delta\widehat{A}_{t+1} + \Delta\widehat{A}_{M,t+1}\right] \\ &+ \Phi\left[\Psi(1+\Lambda^{-1}\Phi)\left(1-\delta_p + (\delta_p - \delta_R)z\right) + \Lambda^{-1}\left\{(1-s_R)\varphi c(\delta_p\tau + \delta_p - \delta_R) - \delta_R\right\}\right] E_t\left\{\Delta\widehat{T}_{t+1}^N\right\}\end{aligned} \tag{47}$$

The NKPC (New Keynesian Phillips Curve) in terms of manufacturing sector inflation, the consumption gap, and the terms of trade gap is given by,

$$\pi_{M,t} = \beta E_t\{\pi_{M,t+1}\} + \kappa\Lambda\widetilde{C}_t + \kappa\left[\delta_R - (1-s_R)\varphi c(\delta_p\tau + \delta_p - \delta_R) - \Psi\Phi\{1-\delta_p + (\delta_p - \delta_R)z\}\right]\widetilde{T}_t \tag{48}$$

We can also express the NKPC in terms of aggregate inflation and the output gap,

$$\begin{aligned}\pi_t = &\beta E_t\{\pi_{t+1}\} + \frac{\kappa\Lambda}{c}\widetilde{Y}_t \\ &+ \kappa\left[\delta_R - (1-s_R)\varphi c(\delta_p\tau + \delta_p - \delta_R) - \Psi\Phi(1-\delta_p + (\delta_p - \delta_R)z) - (1-\delta_R)\left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right)\right]\widetilde{T}_t \\ &+ \delta_R\Delta\widetilde{T}_t - \beta\delta_R E_t\{\Delta\widetilde{T}_{t+1}\}.\end{aligned} \tag{49}$$

Equations (46), the Dynamic IS curve, and (49), the New Keynesian Phillips curve, summarize the non-policy block of the economy in our two sector two agent framework.

How do these equations differ compare to the simple NK model in Gali (2015) with a single agent and a single sticky price sector? There are three key differences between the current framework and such a benchmark. The first difference is that there are two sectors which implies that the terms of trade, T_t, appears in the NKPC and the DIS. The second difference is that we have two types of agents (i.e., $s_R \neq 1$) who have different IES's ($\sigma_R \neq \sigma_P$), and in general, different shares of agriculture in consumption ($\delta_R \neq \delta_p$). The third difference is that there is (steady state) procurement and redistribution in the current framework, i.e., $\mu_A - \bar{\delta} > 0$, and $\lambda > 0$. When $\mu_A - \bar{\delta} > 0$, this implies that the employment share and consumption share in agriculture diverge i.e., $c = \frac{C}{Y} = \frac{1-\mu_A}{1-\bar{\delta}} < 1$. Hence, $\mu_A - \bar{\delta} > 0$ drives a wedge between consumption and production in the aggregate economy.[19]

3.4 Monetary Policy Rule

Monetary policy follows a simple Taylor rule with the nominal interest rate as a function of aggregate inflation and the economy wide output gap as in Anand et al. (2015) and Ginn and Pourroy (2019). We use a standard generalization of Taylor (1993):

$$R_t = (R_{t-1})^{\phi_r} (\pi_t)^{(1-\phi_r)\phi_\pi} \left(\frac{Y_t}{Y_t^n}\right)^{(1-\phi_r)\phi_y}. \tag{50}$$

[19]Suppose $s_R = 1$, $\mu_A = \delta_R = \delta_p = 0$ (*which implies* $\bar{\delta} = 0$), $\sigma_R = \sigma_P$, and $\lambda = 0$. Then equation (46) is given by

$$\widetilde{Y}_t = E_t\left\{\widetilde{Y}_{t+1}\right\} - \frac{1}{\sigma_R}\left[\widehat{R}_t - E_t\{\Pi_{t+1}\} - \widehat{R}_t^N\right]$$

where $\widehat{R}_t^N = \frac{\sigma_R(1+\varphi)}{\varphi+\sigma_R} E_t\left[\triangle \hat{A}_{M,t+1}\right]$, which is the DIS equation in the simple NK model as in Gali (2015). Further, the New Keynesian Phillips Curve in equation (49) is given by

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa(\varphi + \sigma_R)\widetilde{Y}_t$$

which is the NKPC in the simple NK model where $\pi_t = \pi_{M,t}$ and $\widetilde{Y}_t = \widetilde{Y}_{M,t}$.

The log-linearized version of the Taylor rule shows that

$$\hat{R}_t = \phi_r \hat{R}_{t-1} + (1 - \phi_r)\phi_\pi \pi_t + (1 - \phi_r)\phi_y \widetilde{Y}_t, \tag{51}$$

i.e., the nominal interest rate, $\hat{R}_t$, depends on its lagged value, $\hat{R}_{t-1}$, aggregate inflation's deviation from its target, π_t, and the aggregate output gap, $\widetilde{Y}_t$. This closes the model.

4 Quantitative Analysis

We evaluate the model using a Bayesian approach, as is standard in empirical macro research (see Schorfheide (2000), Fernández-Villaverde and Rubio-Ramırez (2004)). In the Indian context, Bayesian estimation has been used to estimate the structural parameters of a NK DSGE models with an agriculture sector (Ginn and Pourroy (2019)). We supplement the estimated parameters in our analysis with some calibrated parameters, as described below.

4.1 Data

We use Indian time series data for the 1994 (Q2)-2019 (Q4) period. Our variables include Gross Domestic Product at 2011-12 prices, Private Final Consumption Expenditure at 2011-12 prices, average daily wage rates for men (in Rs), persons employed in agriculture and manufacturing, total factor productivity in agriculture and manufacturing, inter-sectoral terms of trade, consumer price inflation, procurement and off-take of rice and wheat.[20] The variable selection, data sources and frequency are described in Table 1.

[20]Sectoral employment data (in 1000s)) are taken from EMP series while sectoral total factor productivity and inter-sectoral terms of trade are computed using $TFPG_{va}$ and VA series from India KLEMS database 2021. The Wage rate is calculated as the weighted average of agricultural and non-agricultural wage rate for men (in Rs) with weights being the employment shares. Data on agricultural and non-agricultural wages are taken from Wage Rates in Rural India downloaded from EPWRF India time series. The CPI (series code: SR3194258) and interest rate (3-month T-bill rate with series code: SR3194258) data have been taken from the CEIC database. Procurement and redistribution of rice and wheat (in Lakh (100,000) tonnes) have been taken from the Table 27: Public Distribution System – Procurement, Off-take and Stocks RBI's Handbook of Statistics on the Indian Economy, 2018-2019

Table 1: Data Sources for Bayesian Estimation

Description	Source	Frequency
GDP at 2011-12 Prices	EPWRF India Time series	Quarterly
PFCE at 2011-12 Prices	EPWRF India Time Series	Annual
Average daily wage rates	EPWRF India Time series	Quarterly
Persons employed in Agriculture	INDIA KLEMS 2021	Annual
Persons employed in Manufacturing	INDIA KLEMS 2021	Annual
TFP in Agriculture	INDIA KLEMS 2021	Annual
TFP in Manufacturing	INDIA KLEMS 2021	Annual
Terms of Trade	INDIA KLEMS 2021	Annual
CPI	CEIC	Monthly
Interest Rate	CEIC	Quarterly
Procurement of rice and wheat	RBI	Annual
Redistribution of rice and wheat	RBI	Annual

4.2 Calibration Parameters

Our analysis includes the following calibrated variables, as shown in Table 2. Following Gabriel et al. (2012), we set the discount factor (β) = 0.9832, the measure of price stickiness for manufacturing goods (θ) = 0.75, and the elasticity of substitution between varieties of manufacturing goods (ϵ) = 7.02. We set the steady state employment share in agriculture (μ_A = 0.48) using data from the 2011-2012 Employment and Unemployment Survey (National Sample Survey (a) 68^{th} round). The population share of the rich is the percentage of the population not receiving food grains under the National Food Security Act 2013. Using population estimates from the Census of India 2011 we find ($\mu_R = 0.3279$). The expenditure share of agriculture for the rich ($\delta_R = 0.3527$), and the poor ($\delta_P = 0.4807$), are determined by the share of cereals and cereal substitutes in total expenditures net of expenditures on services, durable goods, vegetables, fuels (see the Technical Appendix for details).

We use previous literature with two-agent or two-sector model structures to inform our priors. We use the study by Anand and Prasad (2010) to determine the Frisch elasticity of labour supply (φ) to be 3. We follow Anand and Prasad (2010) in calibrating values for persistence and the standard deviation of food and non-food productivity shocks. In particular, we use the prior that the agricultural and manufacturing shocks have persistence

Table 2: Calibrated Parameters

Variable	Notation	Value	Source
Discount factor	β	0.9823	Gabriel et al. (2012)
Population share of rich	μ_R	0.3279	Calculated by Authors
Steady state employment share in agriculture	μ_A	0.48	Calculated by Authors
Expenditure share of agriculture - Rich	δ_R	0.3527	Calculated by Authors
Out of pocket Expenditure share of agriculture - Poor	δ_P	0.4807	Calculated by Authors
Elas. of Subs. between varieties of $M-$good	ε	7.02	Gabriel et al. (2012)
Measure of price stickiness (M)	θ	0.75	Gabriel et al. (2012)

of $\rho_A = 0.25$, $\rho_M = 0.95$, respectively, and standard errors of $\sigma_A = 0.03$ and $\sigma_M = 0.02$, respectively. We use Atkeson and Ogaki (1996) to determine the inter-temporal elasticity of consumption substitution for both agents ($\frac{1}{\sigma_R} = 0.8$ and $\frac{1}{\sigma_P} = 0.5$). Following Banerjee et al. (2012), we fix the interest rate smoothing parameter to be $\phi_r = 0.66$, inflation stabilization coefficient to be $\phi_\pi = 1.2$ and the output gap stabilization coefficient $\phi_y = 0.5$.

4.3 Estimation Method

The annual series are converted to quarterly series using natural cubic spline interpolation. The variables (except interest rate, inflation and productivity shocks) are detrended using the Hodrick-Prescott filter. The Bayesian estimation is based on the adaptive Metropolis–Hastings algorithm. The prior distributions of the estimated parameters are reported in Columns (4)-(5) in Table 3 and the Posterior distributions are summarized in Columns (6)-(9) in the same Table. Table 3 summarizes the prior distributions of the estimated parameters, and the mean and standard deviations of the posterior distributions. We use the means of the posterior distributions to study the impulse response functions (IRFs) of the relevant macroeconomic variables.

4.4 Impulse response analysis

Our main IRF analysis focuses on two shocks emanating from the agriculture sector: (i) a shock to agriculture productivity (supply shock) and (ii) a procurement and redistribution

Table 3: Bayesian Estimation: Prior and Posterior Distributions

	Parameter	Density	Prior Distribution		Posterior Distribution			
			Mean	Std Dev	Mean	Std Dev	95% interval	
s_R	SS Rich cons. share	IG	0.50	0.01	0.417	0.005	0.406	0.427
σ_R	Inverse of IES Rich	IG	1.25	0.14	1.142	0.132	0.897	1.407
σ_P	Inverse of IES Poor	IG	2	0.23	1.888	0.223	1.469	2.343
λ	SS share of subsidy in $C^P_{A,t}$	IG	0.2	0.01	0.259	0.003	0.253	0.264
ϕ	SS share of procured A good redistributed	B	0.8	0.06	0.804	0.056	0.686	0.903
φ	Inverse of Frisch elasticity of labor supply	IG	3	0.73	2.434	0.464	1.674	3.522
	Monetary Policy							
ϕ_r	Interest rate smoothing	IG	0.66	0.09	0.99	0.003	0.994	1.005
ϕ_π	Weight on inflation gap	IG	1.2	0.4	1.051	0.354	0.580	1.966
ϕ_y	Weight on output gap	IG	0.5	0.19	0.510	0.200	0.255	1.025
	Shocks: Persistence							
ρ_{A_A}	Productivity shock in A-sector	B	0.25	0.11	0.255	0.106	0.087	0.490
ρ_{A_M}	Productivity shock in M-sector	B	0.95	0.03	0.951	0.033	0.865	0.994
$\rho_{Y^P_A}$	Procurement shock	B	0.43	0.08	0.474	0.081	0.316	0.634
ρ_ϕ	Redistribution shock	B	0.59	0.09	0.694	0.066	0.561	0.816
	Shocks: Standard Deviations							
σ_A	Productivity shock in A-sector				0.016	0.0003	0.016	0.017
σ_M	Productivity shock in M-sector				0.015	0.0001	0.014	0.015
$\sigma_{Y^P_A}$	Procurement Shock				0.0196	$1.16\text{x}10^{-5}$	0.0196	0.0196
σ_ϕ	Redistribution Shock				0.011	0.001	0.011	0.014
σ_v	Monetary Policy				0.009	0.0001	0.009	0.010

(1) Note: 95% credible interval is reported in Columns (8)-(9)

(2) distributions include Beta (B), Inverse Gamma (I), Std Dev for standard deviation.

(3) Inverse Wishart is used as the conjugate prior for the covariance matrix (identity matrix as scale matrix and d.o.f. = 100) of a multivariate normal distribution with unknown mean and covariance matrix.

(demand side shock). We discuss the estimated mechanisms of these shocks. The IRFs of each shock is bench-marked against a one agent two sector version of our model along the lines of Aoki.[21] This allows us to highlight the importance of having rich and poor agents and redistributive policy shocks to interact in the model. To highlight the transmission mechanism in our 2S-TANK model we also discuss the case of a monetary policy shock.[22] Throughout the IRF analysis, our focus is on understanding how these shocks affect sectoral and aggregate inflation rates, consumption of rich and poor agents, and resource allocation across sectors.

We allow for the procurement wedge to be positive, i.e. $\mu_A - \bar{\delta} > 0$, and $\lambda > 0$, in our model.[23] Also, since $\delta_p > \delta_R$, this implies that the share of agriculture consumption by the poor (out of total poor consumption) exceeds the share of agriculture consumption by the rich (out of total rich consumption) which influences the impact effect of the shock on poor and rich agricultural consumption.

4.4.1 Transmission of a single period positive productivity shock in the A-sector

We first describe what happens in our (2 sector TANK) model. This corresponds to the red dash-dotted line in Figures 1a-1c. A positive productivity shock raises output and a causes deflation in the agriculture sector (P_A falls). The terms of trade, T, falls. The price effect dominates the productivity effect of the shock which leads to a reduction in nominal wages. However, the aggregate price index falls by more than nominal wage, leading to an increase in the real wages on impact. The income effect of real wage dominates the substitution effect leading to an increase in consumption and reduction in labour supply by both agents. As T falls, the manufacturing good becomes expensive relative to the agriculture good. This leads

[21]To generate the Aoki model as a special case of our model, the following parameter restrictions are imposed: $\mu_R = s_R = 1$, $\delta_p = \delta_R$, $\lambda = 0$, $\mu_A = \delta_R$, $\sigma_R = \sigma_P$, and an arbitrarily small value of $\phi = 1.000 * 10^{-25}$. For single agent models in the IRFs (Aoki's model and the simple NK model), we have exogenously imposed that $C_P = 0$ as there is no poor agent in these models.

[22]In this case, we benchmark the IRFs against (i) a simple NK model la Gali (2015, Chapter 3), (ii) Aoki, and (iii) Debortoli and Gali.

[23]We drop subscripts (t) and hats from variables for the following discussion to economize on notation. The IRFs for variables however should be interpreted as their log deviations.

to a decline in the demand for the manufacturing (M) good by both agents. Manufacturing output and employment declines.[24] While aggregate output increases, the output gap falls.[25] There is a deflation in the manufacturing sector consistent with the negative output gap. Aggregate inflation falls because inflation in both sectors fall.

The decline in inflation and output gap induces the monetary authority from the Taylor rule, equation (51), to cut nominal interest rates. Real rates also fall since prices are sticky, which induces a rise in the consumption of rich households, C_R, because of the inter-temporal substitution effect. From equation (42), it is apparent that the impact of poor household consumption, C_P, depends positively on C_R and the terms of trade. Overall, C_P rises leading to aggregate consumption, C, to rise. In sum, a positive agriculture productivity shock leads to a rise in both poor and rich consumption, aggregate consumption, lower sectoral inflation rates, and lower aggregate inflation.

Distributional Impact Both the rich and poor benefit from higher real wages because of a positive productivity shock. This induces both sets of households to increase their consumption of both the manufacturing and agriculture good. However, the decline in the terms of trade (P_A falls relative to P_M) induces both the rich and poor to increase their demand of the agriculture good comparatively more because of the inter-good substitution effect. As can be seen below, the impact effect of a positive productivity shock is to induce rich and poor households to buy the agriculture good comparatively more than the manufacturing good. Agriculture consumption therefore rises strongly on impact. The relative magnitudes of rich-poor consumption however, implies that poor consumption increases less relative to rich consumption suggesting that the rich gain more compared to the poor.

[24]In the case of Aoki, there is a much greater increase in demand for the agricultural good inducing an increase in the employment in the agriculture sector.

[25]This happens because while output increases, the natural level of output increases even more. Under flexible prices, the decline in demand (in response to the agriculture productivity shock) would have resulted in lower manufacturing sector prices and therefore relatively higher manufacturing output.

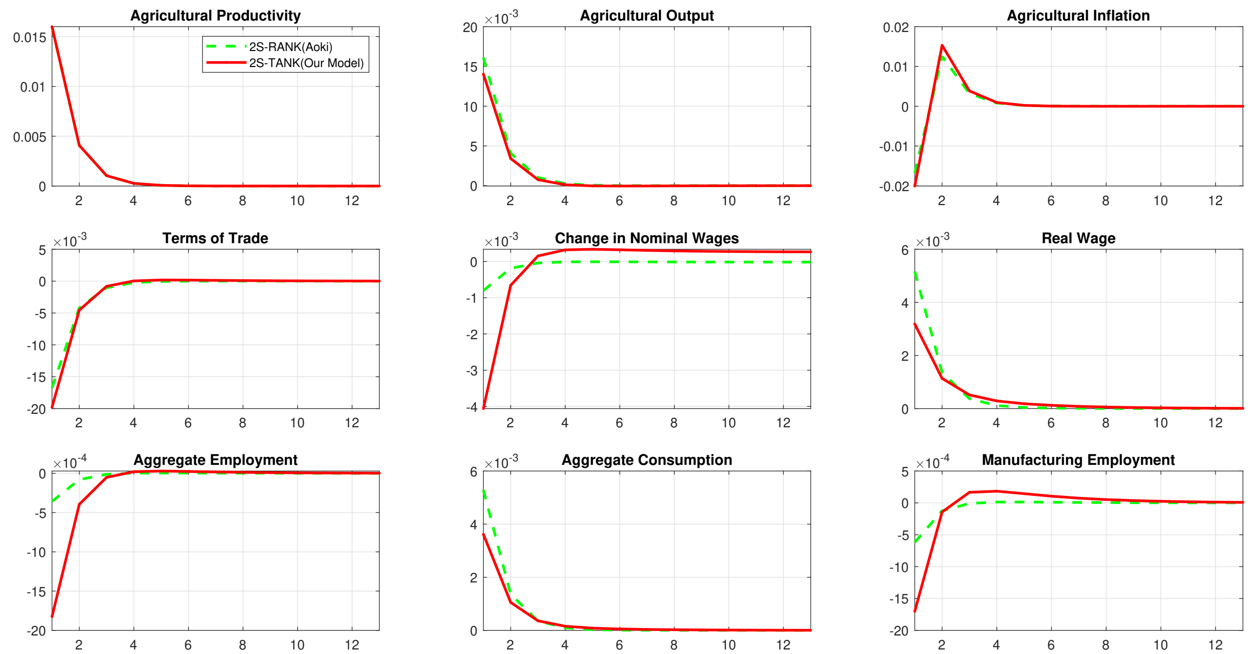

Figure 1a: Impact of single period positive agriculture productivity shock

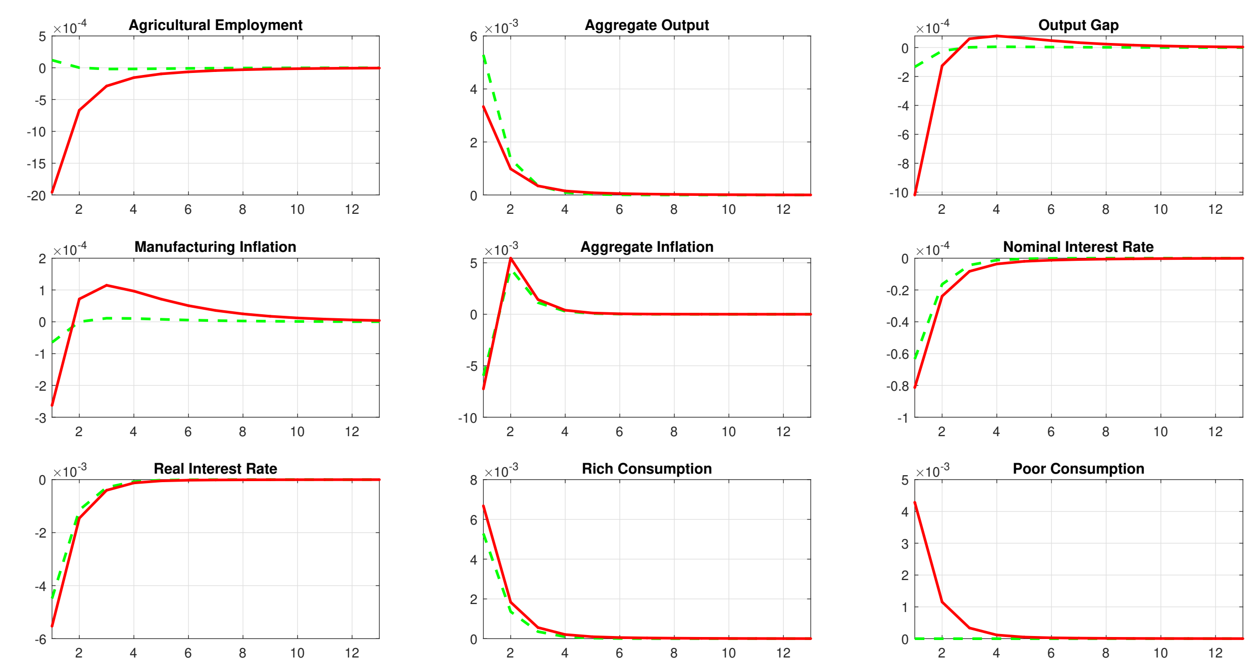

Figure 1b: Impact of single period positive agriculture productivity shock

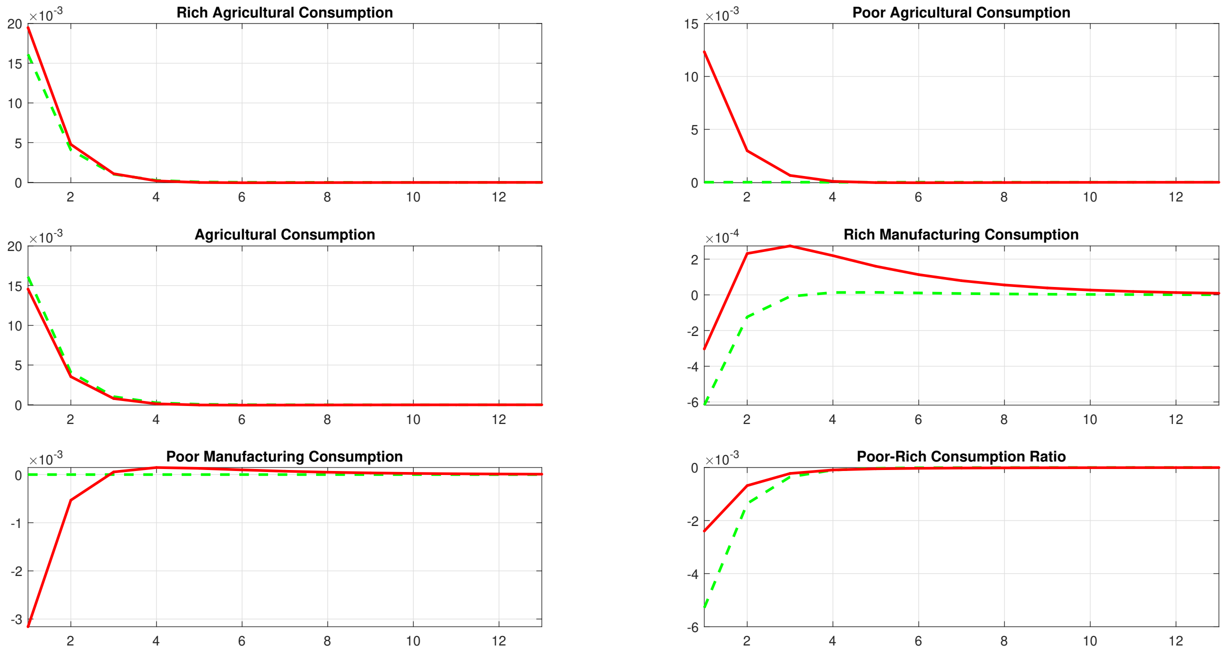

Figure 1c: Impact of single period positive agriculture productivity shock

4.4.2 Transmission of a single period redistributive policy shock

As before, a redistributive policy shocks refers to a procurement and redistributive shock.[26] We first describe what happens in our (2 sector TANK) model. This corresponds to the red dash-dotted line in Figures 2a-2c. A procurement and redistribution (which are orthogonalized) shock acts like a demand shock to the economy.[27] On impact, a procurement and redistributive policy shock leads to higher demand for agricultural output, Y_A, higher P_A and therefore higher π_A. This leads to an *increase* in the terms of trade, T. For the supply of the agriculture good to increase with no change in productivity, employment in the agriculture sector, N_A, must go up on impact. In order to attract labor to the agriculture sector, nominal wages in the agriculture sector must rise. With sticky prices in the manufacturing

[26]We use these terms inter-changably.

[27]The reason why we consider them simultaneously is because the government's desire to increase procurement is driven by its desire for higher redistribution.

sector, equilibrium in labor markets (the same nominal wage in both sectors) means that economy wide real wages rise.[28]

As before, a rise in the real wages has two competing effects: income and substitution effects. The income effect states that a rise in the real wages (income) of an agent would lead to greater consumption of both consumption and leisure (C rises, N falls) while the substitution effect states that a rise in real wages makes leisure relatively more expensive and hence leisure should fall and consumption should rise (C rises, N rises). The rich agent's consumption is governed by a third effect - the inter-temporal consumption substitution effect which states that an increase in the real interest rate will induce agents to save today and consume tomorrow, i.e., substitute today's consumption for future consumption.

As the poor agents don't have access to capital markets - they cannot smooth their consumption over time.[29] The redistributive policy shock lowers the effective price of the poor agent's basket. More precisely it lowers the price of the agricultural good paid by the poor agents to $P_A(1-\lambda)$ which turns out to be lower than P_M. This leads to an increase in C_P, $C_{P,A}$ and a decrease in $C_{P,M}$.[30]

As π_A is positive and current and future marginal costs of production are positive, manufacturing and aggregate inflation are positive on impact. Under flexible prices, manufacturing prices increase in response to higher real wages. This causes a greater reduction in man-

[28]This is broadly in line with research on the Indian National Food Security Act in 2013 which shows that changes in the generosity of the Public Distribution System led to higher wages, suggesting that labor market effects of social transfers bestow important additional effects in terms of benefits for the poor. See Baylis et al. (2019).

[29]Motivated by consumption inequality in India, Lahcen and Gomis-Porqueras (2019) build a monetary model with endogenous credit market participation where the poor, because they don't have access to financial services, smooth their consumption by saving through fiat money. They find that the transmission of monetary policy changes quite a bit with this feature. We hope to take up this extension in a separate paper in the future.

[30]When we only do a procurement shock and set $\lambda = 0$, *both* C_P and C_R fall. Thus, the redistributive effect determines the poor agent's consumption.

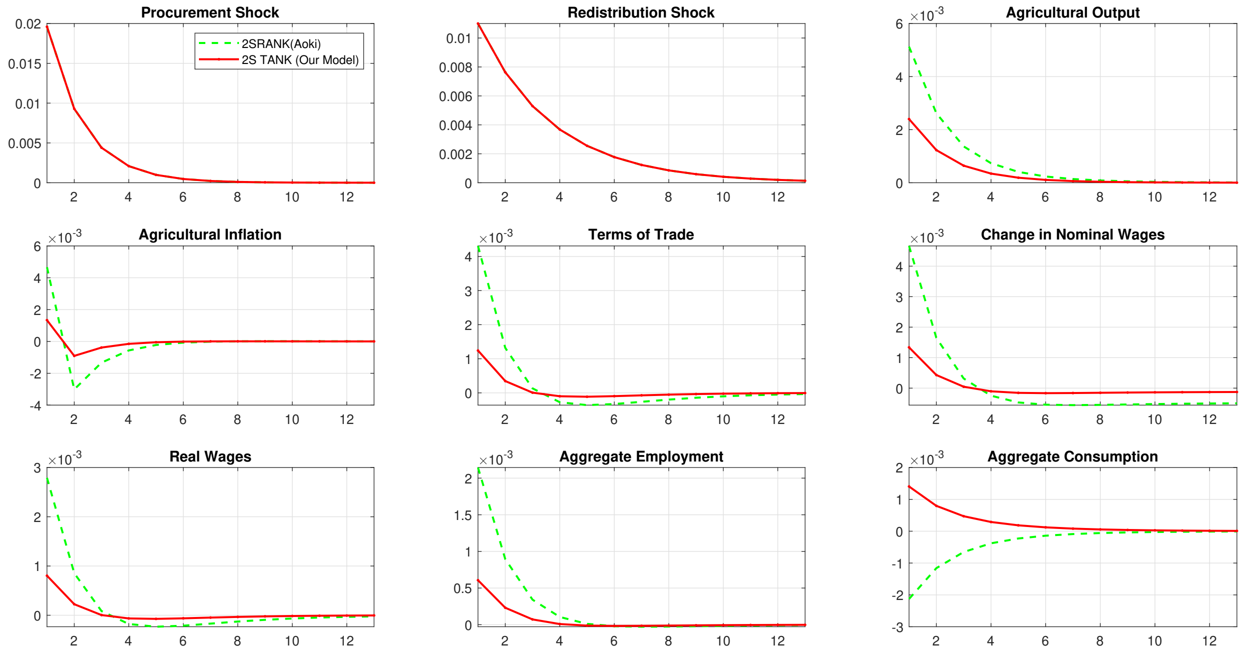

Figure 2a: Impact of single period positive procurement and redistributive policy shock

ufacturing output relative to the flexible price level of output leading to a positive output gap. Given this, central banks must raise nominal interest rates. With sticky prices, real interest rates also rise on impact. Given our parameters, we find that C rises leading to higher welfare, even though monetary policy has tightened the interest rate.

Distributional Impact As can be seen in Figure 2c, consumption of both agriculture and manufacturing goods by the rich fall because of intertemporal substitution. However, a rise in poor agriculture consumption on impact leads to a rise in overall agriculture consumption. Poor manufacturing consumption however also falls because $P_A(1-\lambda)$ is lower than P_M. Unlike the previous case, C_P rises relative to C_R despite the central bank tightening interest rates.

Compared to Aoki's model (green dashed line), there are interesting differences.[31] In the

[31]We have imposed $\mu_A > \delta_R$ to generate these IRFs. Since Aoki's model has a single agent, there is

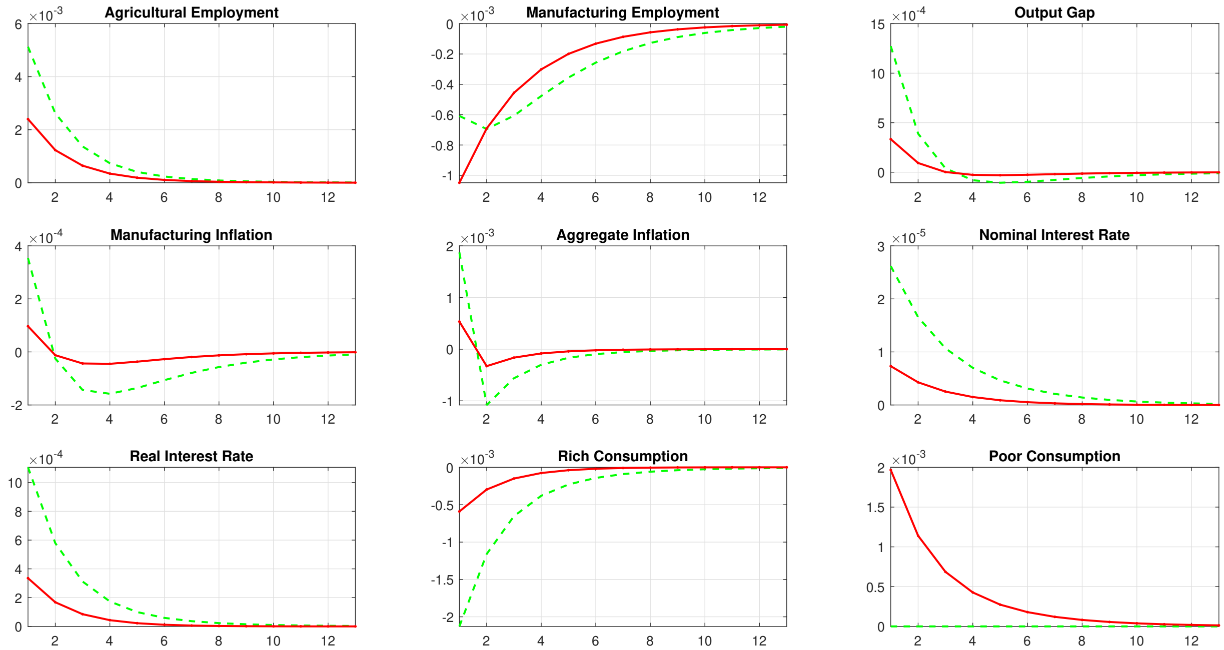

Figure 2b: Impact of single period positive procurement and redistributive policy shock

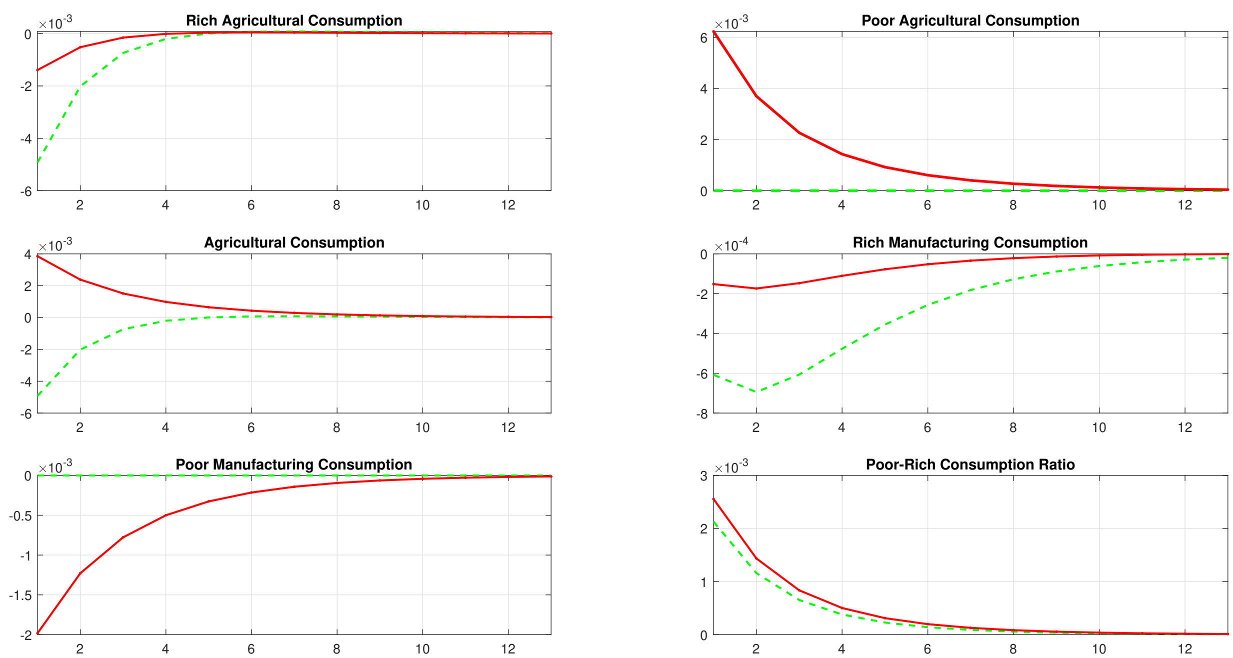

Figure 2c: Impact of single period positive procurement and redistributive policy shock

Aoki model, all agents are rich (Ricardian) and do not have access to subsidized consumption of the agriculture good. Employment in our model, like before, is lower compared to Aoki because of the presence of poor agents who have a lower inter-temporal elasticity of substitution. The difference in the expenditure share of the agriculture good by the poor, δ_p, plays an important role on the rich-poor consumption dynamics. Since the poor receive the redistributed agricultural good for free, their demand for market purchases of the agriculture good are lower (Figure 2a). In addition, $\delta_p > \delta_R$, and so the redistributed agricultural good induces a lower demand for agricultural good consumption by the poor from the market. As a result, aggregate demand for agricultural output is lower, and the impact effect of a procurement and redistributive shock on agricultural output in our model is less compared to the Aoki model. Correspondingly, a procurement and redistributive shock leads to lower inflation on impact in our model compared to Aoki's model. As a result, the corresponding rise in the real interest rate from the Taylor rule is lower in our model which implies that the decline in rich consumption is lower in our model compared to Aoki. Importantly, because of the redistributive shock, poor consumption rises in our model, off-setting the decline in rich consumption, and raising aggregate welfare.

4.4.3 Transmission of a single period monetary policy shock

We consider a single period, contractionary monetary policy shock, which increases the nominal interest rate. This exercise is included to emphasize how our two sector TANK model (red dash-dotted line) leads to a muted impact (less monetary transmission) compared to a variety of benchmarks (the simple NK model (magenta dotted-circle line), Aoki (green-dashed line), and Debortoli and Gali (blue dash-triangle line)).[32] Crucially, we show that

no redistribution, and therefore no redistributive policy shock in his model. The only shock therefore is a procurement shock, which generates the impulses given by the green dashed line.

[32]To generate IRFs for 2 agents and 1 sector along the lines of Debortoli and Gali, we have imposed $\delta_R = \delta_p = \lambda = \mu_A = 0; \phi = 1.0000 * 10^{-25}$; steady state values of $Y_A = C_A = C = Y = Y_M = 1$. Note that the steady state value of $Y_M = 1$ since under the above values, $\bar{\delta} = 0$. We have retained the values of s_R, μ_R, σ_R, and σ_P as in our 2 sector TANK framework listed in Table 1. For the simple NK model, we impose the additional restrictions: $s_R = \mu_R = 1$, and $\sigma_R = \sigma_P = 1.142$, to generate the IRFs for this benchmark. As a preliminary check, we verify that the model dynamics for the simple NK model generated here has IRFs for

monetary policy has both output effects *and* redistributive effects. Our basic insight is that the model dynamics are more influenced by having two sectors, i.e., adding a flexible price sector, rather than the demand side, i.e., having poor agents, when there is a monetary policy shock.

As in the previous cases, we first discuss the effect of a monetary policy shock on our 2 sector TANK model (red dash-dotted line) in Figures 3a-3c. In response to a rise in the nominal interest rate the real interest rate rises, leading to inter-temporal consumption substitution by the rich. The reduction in aggregate demand causes a reduction in prices in both sectors, with the magnitude being greater in the agricultural sector due to flexible prices. As the interest rate shock is for a single period, agricultural inflation returns to its steady state value in the next period, while the manufacturing sector inflation recovers gradually. Thus aggregate inflation falls by more on impact but recovers quickly (owing to the flexible price sector) as compared to the one sector models in this analysis. As a result, the real interest rates rises less in our two sector TANK economy This leads to a reduction in the terms of trade, T, and thus a smaller reduction in C_P relative to C_R.

In the current scenario, where there is no government intervention in the agriculture market, aggregate output is the same as aggregate consumption, and so on impact, Y, must fall from its steady state value. For the supply of the output to decline, less goods must be produced and hence employment, N, should fall on impact. This is ensured by lower real wages, which fall on impact.

In the two sector TANK economy, as the terms of trade falls in response to a contractionary monetary policy shock, the agricultural good is relatively cheaper and hence demand for the agricultural (flexible price) good increases while for the manufacturing (sticky price)

a contractionary monetary policy shock that are consistent with Gali (2015, Chapter 3, page 69).

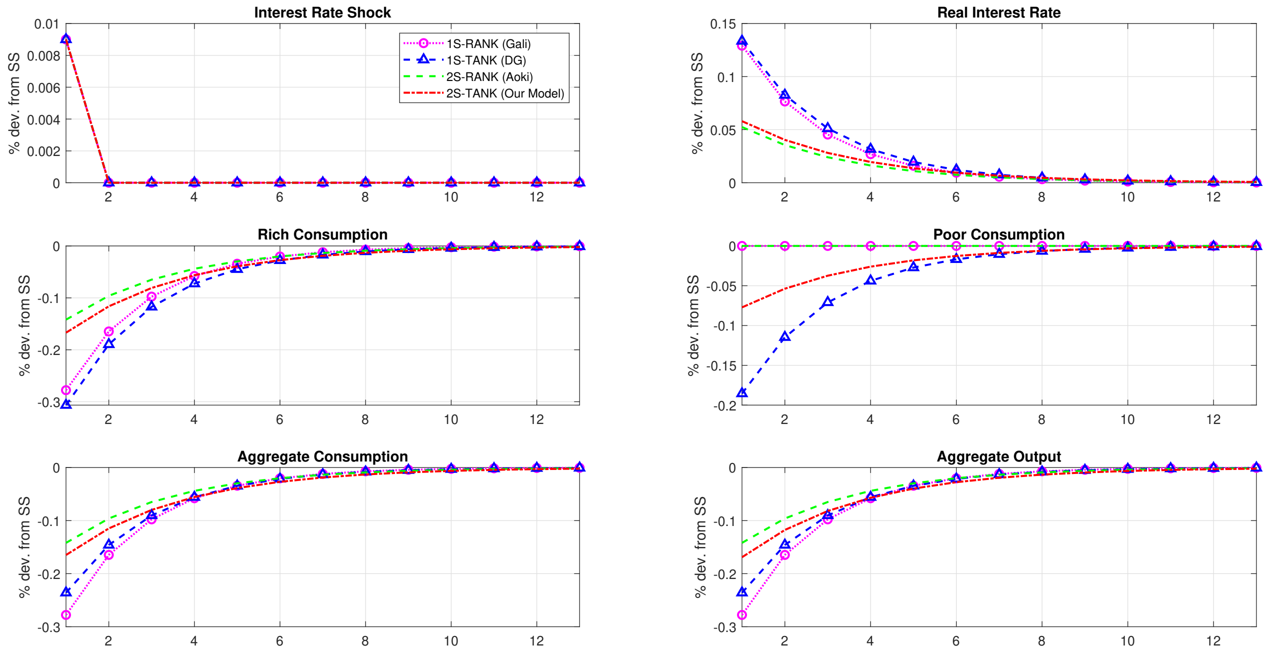

Figure 3a: Impact of single period contractionary monetary policy shock

good falls (inter-good substitution effect). Consequently N_A rises on impact, and therefore, N_M falls.

Distributional Impact A contractionary monetary policy shock leads to a reduction in aggregate consumption in all models, although the magnitude of reduction is smaller in the two sector models (ours and Aoki's model). This happens because of the smaller increase in the real interest rate due to the presence of a flexible price sector.[33] However, as the output gap adjusts more sluggishly, the real interest rate and aggregate consumption take longer to reach their steady state values in the two sector TANK model. Further, in the two agent models (our model and Debortoli and Gali), $C_R < C < C_P < 0$. In the single agent models (Aoki's model and the simple NK model), $C_R = C_P = C < 0$.

[33] We would expect transmission to be weaker in TANK models as a fraction of agents cannot smooth their consumption, but the effect of the negative terms of trade lowers their consumption.

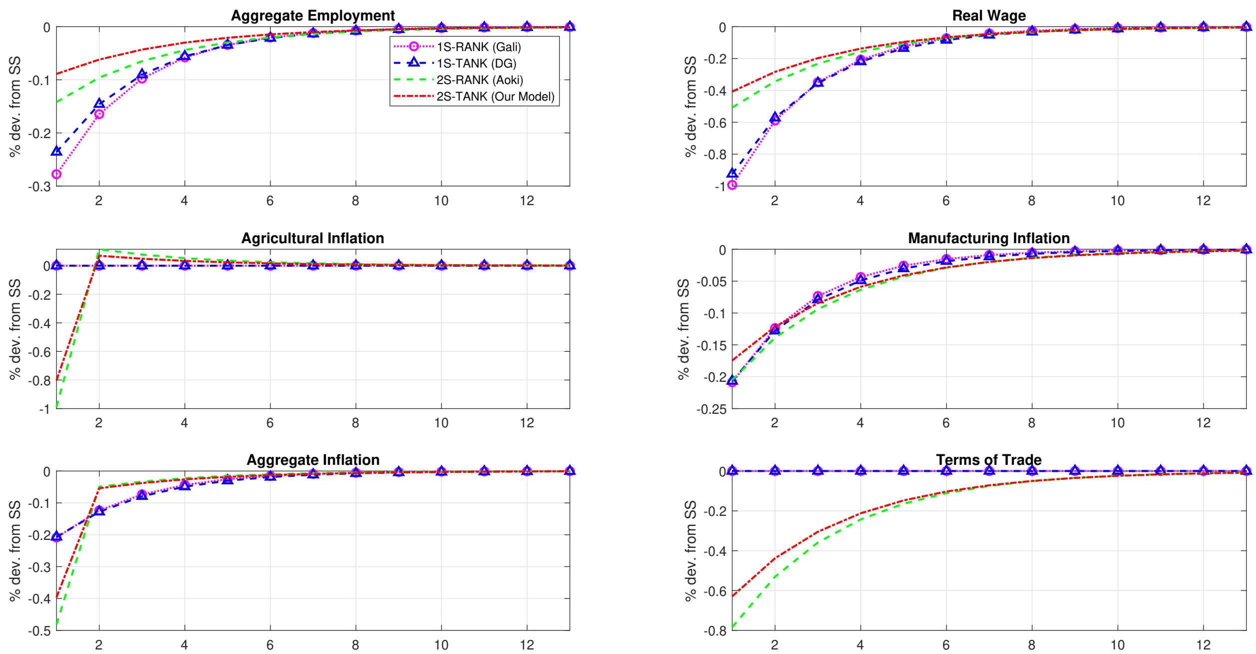

Figure 3b: Impact of single period contractionary monetary policy shock

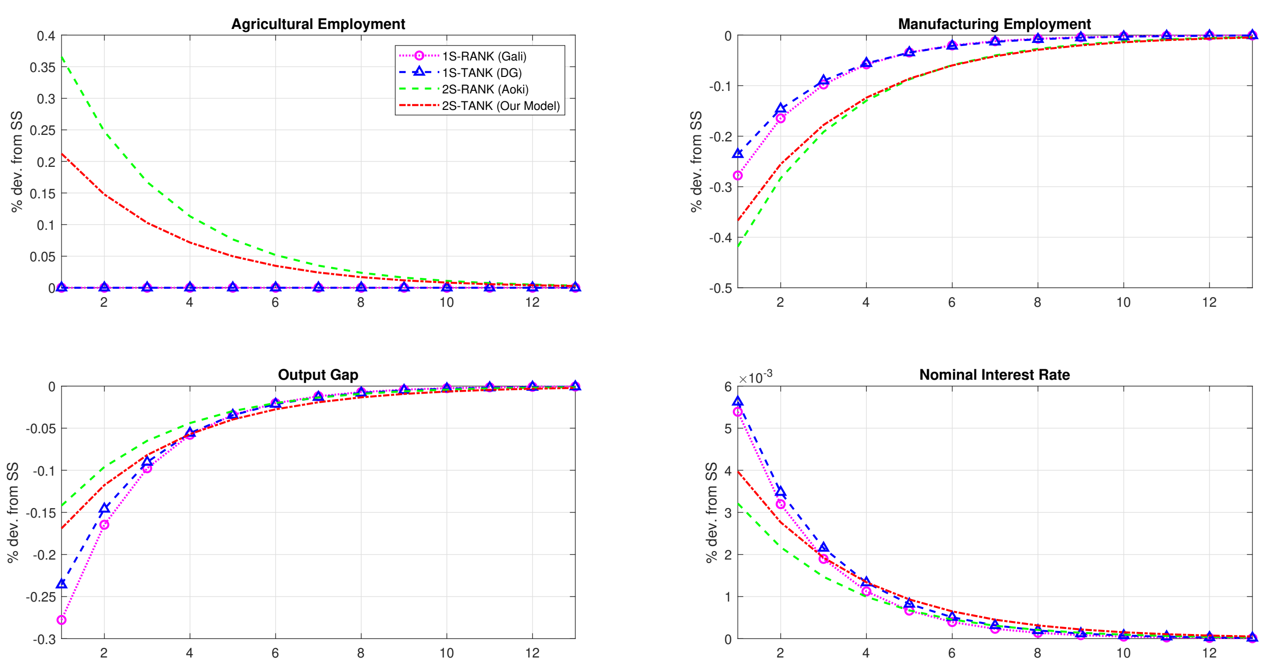

Figure 3c: Impact of single period contractionary monetary policy shock

As mentioned above, the presence of a flexible price sector in our model and Aoki's model creates a large deflation in the economy because of the contractionary monetary policy shock. Since the shock is of one period, aggregate inflation returns to the steady state in the next period in both our model and the Aoki model. Manufacturing inflation, however, recovers, gradually, because of the sticky price sector in all the models. The rise in the nominal interest rate leads to the intertemporal substitution of consumption, as in the standard NK model, which causes a reduction in aggregate demand and a decline in the aggregate price level in all models. However, in our model and Aoki's model, due to the presence of a flexible price sector, real interest rates increase by less, and therefore rich consumption falls by less compared to Debortoli and Gali and the simple NK model. As a result, poor consumption also falls by less from equation (42). The decline in aggregate consumption is also less in our model and Aoki's model.

Since the contractionary monetary policy shock reduces the terms of trade, the agriculture good is relatively cheaper compared to the manufacturing good and hence demand for the agriculture good (flexible price) increases while for the manufacturing good (sticky price) falls. This leads to a rise in agricultural employment, and a decline in manufacturing employment on impact in both our model and Aoki's model.

5 Extensions

To verify the robustness of our results, we consider three extensions. First, to gain insights on the effectiveness of monetary policy in economies with large agriculture sectors, we vary the employment shares to see whether the effectiveness of monetary policy is higher in economies where the employment share in the agriculture sector is smaller.[34] In the second extension we allow for non-homothetic preferences. Finally, we study the implications of redistributive policy shocks in a scenario where labor is immobile across sectors.

[34] For these extensions, we only do comparisons with our baseline 2S-TANK model.

First, we consider the case of a contractionary monetary policy shock, which cools down the economy as in Figure 4. When the employment share in the agriculture sector is high and proxies the value in some poor countries (e.g. Nepal, $\mu_A = 65\%$), compared to an advanced economy, where the share of agricultural employment is much lower (e.g. South Korea, $\mu_A = 5\%$), the impact effect on the output gap is much less (see magenta dotted line versus blue dashed line). This can be seen in Figure 4 in the Technical Appendix. Aggregate output declines by more in the less agriculture-intensive-employment economy when there is a contractionary monetary policy shock. The impact effect on inflation is also more muted when the share of agriculture employment is smaller in the economy. This shows that when the share of the manufacturing sector rises, output adjusts comparatively more, and the effectiveness of monetary policy is comparatively more. This insight applies to all EMDEs with large agriculture sectors, and offers a possible explanation for why monetary policy is ineffective in such economies.

For non-homothetic preferences, we allow for subsistence consumption in agriculture for the poor. In their optimization, this changes the consumption index given in equation (4) to

$$C_{P,t} = \frac{(C_{P,A,t} - C_{P,A}^{subs})^{\delta_P} C_{P,M,t}^{1-\delta_P}}{\delta_P^{\delta_P} \left(1-\delta_P\right)^{1-\delta_P}} \tag{52}$$

where $C_{P,A}^{subs} > 0$ is the subsistence level of agriculture consumption of the poor.[35] Adding subsistence consumption of the agriculture good leads to an increase in the steady state consumption of the agriculture good, and therefore an increase in the total quantity of the agriculture good consumed and produced.[36] The only change in the log-linearized model is in

[35]For simplicity, we assume that the subsidy to the poor is equal to the subsistence level of agriculture consumption.

[36]Non-homothetic preferences implies that the elasticity of substitution between the agriculture good and the manufacturing good is no longer unity. Rather, it depends on $C_{P,A}^{subs}$. Also changes in income lead to changes in expenditure shares of the agriculture and the manufacturing good even with a constant terms of trade.

the steady state values. In fact, model simulations show that log deviations from the steady state are qualitatively similar, although the impact effect from the shocks are higher in the model with the standard index (given in equation (4)) because of lower steady state values.[37]

Finally, we allow labor to be completely immobile. The results are in Figures 5a-5c in the Appendix. We assume that the poor work in the agriculture sector, and the rich in the manufacturing sector. This leads to sector specific real wages, $\frac{W_M}{P}$ in the manufacturing (M) sector, and $\frac{W_A}{P'}$ in the agriculture (A) sector. Figures 5a-5c in the Technical Appendix show the IRFs benchmarked against the case (Figures 2a-2c) when labor is mobile and when labor is immobile (blue dashed line). When there is a procurement and redistributive policy shock, in order to increase the supply of the agriculture good, the real wage in the agriculture sector must increase. Because the mass of population in the agriculture sector is limited by the mass of the population who are poor (because labor is not mobile), the real wage in the agriculture sector must rise by more. Hence a procurement and redistributive policy shock leads to a greater impact on agriculture inflation, the terms of trade, and aggregate inflation. Higher inflation with immobile labour induces the monetary authority to respond more aggressively leading to higher real interest rates. The rich agents in turn respond by increasing saving and reducing consumption of both goods (C_R falls). In contrast, the poor increase their consumption of both goods (C_P rises) and supply less labour as they gain from higher real wages and lower prices of the agricultural good on account of the subsidy. Thus agricultural employment declines. Higher demand for the manufacturing good by the poor agents dominates the reduction in demand by the rich. This causes wages in the manufacturing sector to rise (with sticky prices, real wages $\frac{W_M}{P}$ also rise) thereby leading to higher manufacturing employment[38] thereby creating a positive output gap. Aggregate output rises more compared to the baseline model.

[37]These results are available from the authors on request.

[38]This would have induced higher manufacturing prices and a relatively lower manufacturing output in a flexible price regime.

6 Welfare

Following Schmitt-Grohe and Uribe (2007), we characterize optimal monetary policy in the 2S-TANK model with the procurement and redistribution shock by using two approaches (i) we assume that the monetary authority acts like a utilitarian Ramsey Planner and maximizes the weighted average of rich and poor welfare functions (53) subject to the private sector optimality conditions and the economy's feasibility constraints, (ii) by computing optimal values of Taylor Rule parameters (or optimal simple rules) that maximize economy-wide welfare via minimizing variances of inflation and the output gap. We compare the optimized simple rules with the planner's solution to see how well a monetary authority following OSR can implement the planner's solution.

The Ramsey-monetary authority maximizes, W_t, given by

$$W_t = \Omega W_{R,t} + (1-\Omega) W_{P,t} \tag{53}$$

where $W_{R,t}$ is the lifetime welfare of the Ricardian agent and $W_{P,t}$ is the lifetime welfare of poor agents.[39]. The parameter $\Omega \in [0,1]$ is the weight given to rich agents by the planner. This yields Ramsey Optimal Monetary Policy (ROMP).

6.1 Criterion

For each agent $K \in \{R, P\}$, we define the welfare measure under a monetary policy regime a to be its expected lifetime utility at time 0 as $V^a_{K,0}$:

$$V^a_{K,0} \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{{C^a_{K,t}}^{1-\sigma_K}}{1-\sigma_K} - \frac{{N^a_{K,t}}^{1+\varphi}}{1+\varphi} \right] \tag{54}$$

[39]The parameter $\Omega \in [0,1]$ is the weight given to rich agents by the planner. Note that $W_{K,t} = U(C_{K,t}, N_{K,t}) + \beta E_t W_{K,t+1}$ for each $K \in \{R, P\}$

To compare welfare across regimes, we compute the *percentage* of steady state consumption that agent K would like to give up to avoid the volatility from a shock under regime a.[40] Improvements in welfare are converted into consumption equivalent welfare gains (see Lucas (1987), Schmitt-Grohe and Uribe (2007) and Lubik and Teo (2009)).[41].

Thus, the consumption equivalent χ_K can be computed from:

$$\sum_{t=0}^{\infty} \beta^t \left[\frac{\left[(1-\frac{\chi_K}{100})C_K\right]^{1-\sigma_K}}{1-\sigma_K} - \frac{{N_K}^{1+\varphi}}{1+\varphi} \right] = V_{K,0}^a \tag{55}$$

This definition captures the notion that business cycles are costly and risk averse agents would be willing to pay (in consumption units) to avoid fluctuations in consumption.

6.2 Analysis

As the focus of our paper is on interventions in the agriculture sector, we focus on optimal monetary policy under redistributive policy shocks. We quantify consumption equivalents with respect to agriculture productivity shocks for comparison (See Section 11 in the Technical Appendix for details).

Our main results are presented in Table 4. We find that the optimized simple rule features a no-smoothing interest-rate, an aggressive response to inflation and a muted response to output. The inflation coefficient of the optimized rule takes the largest value allowed in our search, namely $\phi_\pi = 3$.[42] We also find that the optimized rule is quite effective as it delivers welfare levels remarkably close to those achieved under the Ramsey policy as evi-

[40] We compute expected lifetime utility conditional on the initial state being the deterministic steady state using the non-linear version of the model with Dynare 5.2.0.

[41] Rubio and Carrasco-Gallego (2014) also compute consumption equivalents separately in terms of borrowers and savers to assess the importance of macro-prudential policy on financial stability.

[42] As the optimized rule features no interest-rate inertia, there is no difference in long run impact of monetary policy. This is a result of the Taylor Rule specification and no persistence of the monetary policy shock. Relaxing these two allows for significant long run impact of inflation on interest rates as in Schmitt-Grohe and Uribe (2007).

Table 4: Optimal Monetary Policy for a Procurement & Redistribution Shock

	Optimized Parameters	Conditional Welfare Cost χ^cx100	Unconditional Welfare Cost χ^ux100	σ_π (%)	σ_{π_M}(%)	σ_R(%)	$\sigma_{\tilde{Y}}$(%)
Ramsey	ϕ_r : −	χ_R : 0	χ_R : 0	0.241	0.038	0.224	0.155
	ϕ_π : −	χ_P : 0	χ_P : 0				
	ϕ_y : −						
Optimized	ϕ_r : 0	χ_R : 0.0035	χ_R : 0.0037	0.169	0.122	0.517	0.128
	ϕ_π : 3	χ_P : 0.0024	χ_P : 0.0027				
	ϕ_y : 0						
Non-Optimized Rules							
Bayesian	ϕ_r : 0.9	χ_R : 0.5140	χ_R : 0.1105	0.944	0.405	0.083	0.701
	ϕ_π : 1.051	χ_P : −0.248	χ_P : −0.006				
	ϕ_y : 0.51						
Simple Taylor Rule	ϕ_r : 0	χ_R : 0.0177	χ_R : 0.0185	0.384	0.261	0.586	0.298
	ϕ_π : 1.5	χ_P : 0.0106	χ_P : 0.0120				
	ϕ_y : 0						
Standard Taylor Rule	ϕ_r : 0	χ_R : 0.0879	χ_R : 0.0929	0.712	0.568	0.880	0.498
	ϕ_π : 1.5	χ_P : 0.0514	χ_P : 0.0587				
	ϕ_y : 0.5						

* Conditional and unconditional welfare costs χ^cx100 and χ^ux100, are defined as the percentage decrease in the Ramsey-optimal consumption process necessary to make the level of welfare under the Ramsey policy identical to that under the evaluated policy. Thus, a positive figure indicates that welfare is higher under the Ramsey policy than under the alternative policy.

dent by the low values of χ. While the planner is able to achieve lower sticky price inflation ($\sigma_{\pi_M} = 0.038\%$), which is close to full core-inflation stabilization, under OSR, aggregate inflation variability, σ_π, is lower. This is because under OSR, the monetary authority places a high weight on minimizing the variance of inflation. The planner is able to achieve lower volatility in the interest rates via commitment. Compared to the estimated Taylor Rule parameters in equation 50 from the Bayesian exercise in Section 4.3, we find that under OSR, the monetary authority is able to stabilize inflation (0.944% versus 0.169%) and the output gap (0.701% versus 0.128%) better.

The positive consumption equivalents suggest that conditional and unconditional welfare are higher under Ramsey than in alternative regimes (optimized rules, simple Taylor rule, and the standard Taylor rule). Compared to OSR, both standard and simple Taylor rules yield higher consumption equivalents for the rich and poor households when both conditional and unconditional welfare are used. In general, we find that consumption equivalents are substantially higher under non-optimized rules for both rich and poor households compared to OSR, implying high welfare costs associated with redistributive policy shocks when non-optimized rules are used in setting monetary policy.[43]

In order to assess the impact of redistribution on welfare-costs, we fix the steady-state amount of agriculture output procured and vary steady-state redistribution ($\phi = 0.40$ and $\phi = 0.80$). These results are described in the Technical (Welfare) Appendix. We show that the volatility of poor consumption rises, when the steady state redistribution in the economy rises.[44] We conduct a similar exercise using OSR. As poor agents are risk averse and unable to smooth consumption, they have higher consumption equivalents across both regime. They

[43]The negative consumption equivalent estimated using the Bayesian method for both conditional and unconditional welfare for the poor reflects the high steady state consumption of poor households in the Bayesian regime. This result is independent of the weights given by the planner in equation 53. Bayesian estimated rules lead to the most aggregate inflation volatility.

[44]This is on account of higher variability of subsidy (λ_t) with higher steady state redistribution.

therefore are willing to forego a greater amount of their steady state consumption to avoid fluctuations in consumption because of the redistributive policy shock.

6.3 Sensitivity Analysis

We check for the robustness of our results by altering the weights in the social planner's objective function. These results are reported in Table 8 in the Appendix. We contrast the case of a Ramsey planner (i) who only values the Ricardian agents' welfare (i.e., sets $\Omega = 1$ in 53) and (ii) with a planner who only values the poor (i.e., sets $\Omega = 0$ in 53). We find that placing a zero-weight on the utility of financially-constrained agents makes the planner come closer to full inflation stabilization ($\sigma_\pi = 0.129\%$) which is a superior to a monetary authority following Optimal Simple Rules (see Table 4, $\sigma_\pi = 0.169\%$). Hence the planner weights on utility of rich and poor matters for the incidence of full inflation stabilization.

We also reverse the weights on aggregate inflation and output gap in the loss function under OSR to be 0.1 and 0.9 respectively (see Table 9 in the Appendix). We find that the Taylor rule parameters under OSR don't change for a procurement and redistribution shock. Hence, the welfare-costs in Table 6 and Table 9 are identical. However, the welfare costs are significantly lower for both shocks when the monetary authority places a higher weight on the variance of the output-gap term in the objective function indicating that it is closer to the deterministic steady state. As expected, the variance of sectoral and aggregate inflation exceeds their counterparts in Table 6, but, the output gap is significantly less volatile.

7 Conclusion

Governments in many EMDEs routinely intervene in their agricultural markets because of changing food security norms or to minimize food price volatility. Such interventions typically involve higher procurement and redistribution of food commodities, and higher food subsidies by the government to households. This paper asks: what is the impact of a procurement and redistributive policy shock on the sectoral and aggregate dynamics of inflation, and the distribution of consumption amongst rich and poor households?

To address this, we build a two-sector (agriculture and manufacturing) two-agent (rich and poor) New Keynesian DSGE model with redistributive policy shocks. There are two novel aspects of our framework. First, we extend the framework of Debortoli and Gali to two sectors. Second, we allow for government intervention in the agriculture market in a way that captures the essence of procurement and redistribution style interventions in EMDEs. Our framework allows us to understand how redistributive policy shocks affect the economy, and the role of consumer heterogeneity on the welfare implications of a variety of shocks. Our paper contributes to a growing literature on understanding the role of consumer heterogeneity in analyzing the effect of monetary policy.

Using Indian data, we estimate the model using a Bayesian approach. We show that a redistributive policy shock leads to higher sectoral and aggregate inflation and higher aggregate consumption in the economy, even though there is a decline in the consumption of the rich. We compare our results to a variety of benchmarks to isolate the effect of adding a flexible price production sector or adding rule of thumb agents on the model's dynamics. We also show that our main results are robust to two major extensions: non-homothetic preferences, and immobile labor.

Our welfare analysis allows us to quantify the welfare costs of redistributive policy shocks under alternative regimes when compared to Ramsey optimal monetary policy. In general, we show that when non-optimized simple rules characterize monetary policy, the consumption equivalents are larger for both rich and poor households when benchmarked against optimal simple rules.

Although our paper is set in the Indian context, it has general implications for EMDEs that are characterized by a relatively large agriculture sector and periodic government intervention to support the poor. While procurement and redistributive policies are often enacted to improve the welfare of the poor, our analysis sheds light on the general equilibrium effects of such policies, the welfare costs of such policies, and how a monetary authority should respond to them.

8 Acknowledgements

We are grateful to V. Chari, Kosuke Aoki, Etienne Wasmer, Jean Imbs, Pawan Gopalakrishnan, Charles Engle, Bo Yang, Pedro Gomis-Porqueras, Tim Robinson, Srigopal, and seminar participants at the 2019 Computing in Economics and Finance (CEF) Conference, the 2019 Delhi Macroeconomics Workshop (DMW), the 15^{th}ACEGD at ISI-Delhi, the 2020 Workshop on Labor, Human and Social Capital, and Development at NYU - Abu Dhabi, the 95^{th} WEA Annual Conference, the 2020 CIMS-Surrey DSGE Workshop, IMF, CAFRAL-RBI, the EGROW Foundation, the 2021 Philippine Economic Society (PES) Meetings, Ashoka University, Shiv Nadar University, Ateneo de Manila University, the Delhi School of Economics, the '100 Years of Economic Development Conference' at Cornell University (2022), and the Institute of Economic Growth for generous comments. The usual disclaimer applies.

References

Anand, R., Prasad, E.S., 2010. Optimal Price Indices for Targeting Inflation under Incomplete Markets. IMF Working Paper, 10/2000. International Monetary Fund, Washington, D.C.

Anand, R., Prasad, E.S., Zhang, B., 2015. What measure of inflation should a developing country central bank target? Journal of Monetary Economics 74, 102–116.

Aoki, K., 2001. Optimal Monetary Policy Responses to Relative-Price Changes. Journal of Monetary Economics 48, 55–80.

Atkeson, A., Ogaki, M., 1996. Wealth Varying intertemporal Elasticities of Substitution: Evidence from Panel and Aggregate Data. Journal of Monetary Economics 38, 507–534.

Auclert, A., 2019. Monetary Policy and the Redistribution Channel. Journal of Monetary Economics 119, 2333–2367.

Balisacan, A.M., Sombilla, M.A., Dikitanan, R.C., 2010. Rice Crisis in the Philippines: Why did it occur and What Are its Policy Implications?, in: The Rice Crisis: Markets, Policies, and Food Security, pp. 123–142.

Banerjee, S., Basu, P., Ghate, C., 2012. A Monetary Business Cycle Model For India. Economic Enquiry 58, 1362–1386.

Baylis, K., Crost, B., Shrinivas, A., 2019. Labor Market E¤ects of Social Transfers: Evidence from India's Public Distribution System.

Beghin, J.C., Bureau, J.C., Park, S.J., 2003. Food Security and Agricultural Protection in South Korea. American Journal of Agriculture Economics 85, 618–632.

Broer, T., Hansen, N.J.H., Krussel, P., Öberg, E., 2020. The New Keynesian Transmission Mechanism: A Heterogeneous-Agent Perspective. Review of Economic Studies 87(1), 77–101.

Calvo, G.A., 1983. Staggered Prices in a Utility-Maximizing Framework. Journal of Monetary Economics 12, 383–398.

Census of India 2011, . Census of India 2011-Rural Urban Distribution of Population.pdf. URL: `https://censusindia.gov.in/nada/index.php/catalog/42617`.

Chen, H., Curdia, V., Ferrero, A., 2012. The Macroeconomic Effects of Large Scale Asset Purchase Programs. The Economic Journal 122, F289–F315.

Debortoli, D., Gali, J., 2017. Monetary Policy with Heterogeneous Agents: Insights from TANK models.

Fernández-Villaverde, J., Rubio-Ramırez, J.F., 2004. Comparing Dynamic Equilibrium Models to Data: a Bayesian Approach. Journal of Econometrics 123, 153–187.

Gabriel, J.V., Paul, L., Joseph, P., Yang, B., 2012. An Estimated DSGE Model of the Indian Economy, in: The Oxford Handbook of the Indian Economy. Oxford University Press, New York, pp. 835–890.

Gali, J., 2015. The Basic New Keynesian Model, in: Monetary Policy, Inflation, and the Business Cycle (2nd Edition). Princeton University Press. chapter 3, pp. 52–97.

Gali, J., Monacelli, T., 2005. Monetary Policy and Exchange Rate Volatility in a Small Open Economy. Review of Economic Studies 72, 707–734.

Gali, J., Vallés, J., López-Salido, J.D., 2007. Understanding the Effects of Government Spending on Consumption. Journal of the European Economic Association 5, 227–270.

Ghate, C., Gupta, S., Mallick, D., 2018. Terms of Trade Shocks and Monetary Policy in India. Computational Economics 51, 75–121.

Ginn, W., Pourroy, M., 2019. Optimal monetary policy in the presence of food price subsidies. Economic Modelling 81, 551–575.

Hossain, M., Deb, U., 2010. Volatility in Rice Prices and Policy Responses in Bangladesh, in: The Rice Crisis: Markets, Policies, and Food Security, pp. 91–108.

Kaplan, G., Moll, B., Violante, G., 2018. Monetary Policy According to HANK. American Economic Review 108, 697–743.

Lahcen, M.A., Gomis-Porqueras, P., . A model of endogenous financial inclusion: implications for inequality and monetary policy. Working Paper apers 310, Department of Economics - University of Zurich.

Lubik, T.A., Teo, W.L., 2009. Inventories and Optimal Monetary Policy. Economic Quarterly 95, 357–382.

Lucas, R., 1987. Models of business cycles, in: Yrjö Johansson Lectures Series. London: Blackwell.

McKay, A., Nakamura, E., Steinsson, J., 2016. The Power of Forward Guidance. American Economic Review 106, 3133–3158.

National Sample Survey, a. Report 554 -Employment and Unemployment Situation in India 2011-12. URL: https://cse.azimpremjiuniversity.edu.in/wpcontent/uploads/2019/06/NSS_68_Emp_Unemp_2011-2012.pdf.

National Sample Survey, b. Report 555-Level and Pattern of Consumer Expenditure 20ll-12. URL: https://www.mospi.gov.in/sites/default/files/publication_reports/nss_rep_555.pdf.

National Sample Survey, c. Report 565 -Public Distribution System and Other Sources of Household Consumption 2011-12. URL: https://mospi.gov.in/sites/default/files/publication_reports/report_565_26june2015.pdf.

Ranade, A., 2023. Free grains, Election Promises, Market Distortions. Deccan Herald URL: https://www.deccanherald.com/opinion/free-grains-election-promises-market-distortions-2768983.

RBI's Handbook of Statistics on the Indian Economy, 2018-2019, . Table 27: Public Distribution System – Procurement, Off-take and Stocks. URL: https://rbidocs.rbi.org.in/rdocs/Publications/PDFs/TABLE27A68593E6722446029CA014620E0EA3D3.PDF.

Rubio, M., Carrasco-Gallego, J.A., 2014. Macroprudential and Monetary Policies: Implications for Financial Stability and Welfare. Journal of Banking and Finance 49, 326–336.

Saifullah, A., 2010. Indonesia's Rice Policy and Price Stabilization Program: Managing Domestic Prices During the 2008 Crisis, in: The Rice Crisis: Markets, Policies, and Food Security, pp. 109–122.

Schmitt-Grohe, S., Uribe, M., 2007. Optimal, Simple and Implementable Monetary and Fiscal Rules. Journal of Monetary Economics 54, 1702—1725.

Schorfheide, F., 2000. Loss function-based Evaluation of DSGE models. Journal of Applied Econometrics 15, 645–670.

Taylor, J., 1993. Discretion versus policy rules in practice. Carnegie-Rochester Conference Series on Public Policy 35, 195–214.

Woodford, M., 2010. Optimal Monetary Stabilization Policy, in: Handbook of Monetary Economics. chapter 14, pp. 723–828.

9 Technical Appendix (For Referees)

9.1 The Model

Derivation of Equation (15): In the first stage, rich agents maximize equation (4) for a given level of expenditure, X_t subject to the period budget constraint given by: $P_{A,t}C_{R,A,t} + P_{M,t}C_{R,M,t} = X_{t,}$ This yields equations (9) and (10) In the second stage, rich household maximize (1) subject to the intertemporal budget constraint (5) choosing $C_{R.t}$, $N_{R,t}$, and B_{t+1} optimally. This yields the following first order conditions:

$$C_{R,t}^{-\sigma_R} = \mu_t P_t$$

$$N_{R,t}^{\varphi} = \mu_t W_t$$

and

$$-E_t\{Q_{t+1}\}\beta^t \mu_t + \beta^{t+1} E_t\{\mu_{t+1}\} = 0$$

where μ_t is the Lagrangian multiplier. Using $\frac{1}{E_t\{Q_{t+1}\}} = R_t$, this yields equation (15).

Derivation of Equation (17): Poor agents maximize (4) subject to: $P_{A,t}C^O_{P,A,t} + P_{M,t}C_{P,M,t} = M_t$, where M_t corresponds to the income of the poor, by choosing $C_{P,A,t}$ and $C_{P,M,t}$ optimally. Note that $C^O_{P,A,t} = (1-\lambda_t)C_{P,A,t}$ given equation (6). This yields equation (11) and (12). Substituting equations (11) and (12) into equation (7) implies

$$P_{A,t}(1-\lambda_t)C_{P,A,t} + P_{M,t}C_{P,M,t} \leq W_t N_{P,t}$$

which can be simplified to

$$P_t^{'} C_{P,t} = W_t N_{P,t}.$$

In the second stage, poor households maximize (1) subject to the above equation

9.2 Steady State

We drop subscripts from variables to denote their steady state counterparts. Define X (without t subscript) as the steady state value of the variable, X_t. We assume no trend growth in productivity, $A_s = 1$ for $s = A, M$. Since $A_M = A_A = 1$, nominal marginal costs are given by: $MC_M = MC_A = W$. Given that the agricultural sector is characterized by perfect competition and flexible prices, price equals nominal marginal cost, so $P_A = W$, while in the manufacturing sector the price is a markup over nominal marginal cost $P_M = \frac{\varepsilon}{\varepsilon-1}W$. Therefore, the steady state term of trade is $T = \frac{P_A}{P_M} = \frac{\varepsilon-1}{\varepsilon}$. With the employment subsidy in the manufacturing sector in place,

$$T = 1.$$

Define the steady state consumption share of the rich, s_R, as

$$s_R = \frac{\mu_R C_R}{C} \tag{56}$$

Then using equation (32),

$$\begin{aligned} C &= \mu_R C_R + (1-\mu_R)(1-\lambda)^{-(1-\delta_P)} C_P \left(1-\lambda(1-\delta_p)\right) \\ 1 &= \frac{\mu_R C_R}{C} + \frac{(1-\mu_R)(1-\lambda)^{-(1-\delta_P)} C_P \left(1-\lambda(1-\delta_p)\right)}{C}. \end{aligned}$$

we get the steady state consumption share of the poor as

$$1 - s_R = \frac{(1-\mu_R) C_P (1-\lambda)^{-(1-\delta_p)} (1-\lambda(1-\delta_p))}{C}. \tag{57}$$

We define the steady state employment share of the rich, N_R

$$N_R = \mu_R N \tag{58}$$

and the employment share of the poor as N_P

$$N_P = (1 - \mu_R)N. \tag{59}$$

From the FOCs for the rich and poor (equations (16) and (17)) the steady state condition is

$$\frac{N_R^{\varphi}}{C_R^{-\sigma_R}} = \frac{N_P^{\varphi}}{C_P^{-\sigma_P}}.\frac{P'}{P}$$

where $\frac{P'}{P} = (1-\lambda)^{\delta_P} T^{\delta_P - \delta_R} = (1-\lambda)^{\delta_P}$ (since $T = 1$). Since $N_R = \mu_R N$ and $N_P = (1-\mu_R)N$, we have

$$\begin{aligned}
\mu_R^{\varphi} C_R^{\sigma_R} &= (1-\mu_R)^{\varphi} C_P^{\sigma_P} (1-\lambda)^{\delta_P} \\
\mu_R^{\varphi} \left(\frac{s_R}{\mu_R} C \right)^{\sigma_R} &= (1-\mu_R)^{\varphi} \left[\frac{(1-s_R)}{(1-\mu_R)(1-\lambda)^{-(1-\delta_P)}(1-\lambda(1-\delta_P))} C \right]^{\sigma_P} (1-\lambda)^{\delta_P} \\
C^{\sigma_R - \sigma_P} &= \frac{(1-\mu_R)}{\mu_R^{\varphi-\sigma_R}}^{\varphi-\sigma_P} \frac{(1-s_R)}{s_R^{\sigma_R}}^{\sigma_P} \frac{(1-\lambda)^{\delta_P + \sigma_P(1-\delta_P)}}{(1-\lambda(1-\delta_p))^{\sigma_P}} \\
&= \Gamma
\end{aligned}$$

The steady state aggregate consumption is therefore,

$$C = \Gamma^{\frac{1}{\sigma_R - \sigma_P}} \tag{60}$$

where Γ is a constant. Once we know the expression for C, equations (56) and (57) yield C_R and C_P, respectively. From the market clearing condition (equation ((34)), the production function for manufacturing, and the optimal demand (equation (23)) for manufacturing goods, we have

$$N_M = Y_M = C_M = (1-\bar{\delta})C = (1-\bar{\delta})\Gamma^{\frac{1}{\sigma_R - \sigma_P}}.$$

where $\bar{\delta} = s_R \delta_R + \frac{(1-s_R)\delta_P}{1-\lambda(1-\delta_P)}$.

Using optimal consumption demand for the agricultural good from equation (22), we have $C_A = \bar{\delta}C$

Denoting μ_A as the steady state employment share in agricultural sector, then, using $N_M = (1-\mu_A)N$, we can write aggregate employment, N, as

$$N = \frac{N_M}{1-\mu_A} = \frac{1-\bar{\delta}}{1-\mu_A}C. \tag{61}$$

And using $N_A = \mu_A N$ and the market clearing condition for the agriculture sector (equation (29)),

$$N = \frac{N_A}{\mu_A} = \frac{Y_A}{\mu_A} = \frac{1}{\mu_A}\left[\bar{\delta}C + Y_A^P(1-\phi)\right]. \tag{62}$$

Equating (61) and (62), we obtain

$$Y_A^P = \frac{C}{1-\phi}\left[\frac{\mu_A - \bar{\delta}}{1-\mu_A}.\right]$$

This is the steady state level of agricultural output procured. For $Y_A^P > 0$, it needs to be that $\mu_A > \bar{\delta}$, which implies that the steady state labor share in agriculture is greater than its consumption share since a fraction of agricultural output is not consumed. Note that in the absence of procurement ($Y_A^P = 0$), and these two steady state shares are equal as $C\left(\frac{\mu_A-\bar{\delta}}{1-\mu_A}\right) = 0 \Longrightarrow \mu_A = \bar{\delta}$. The steady state relation in the agricultural sector then becomes

$$N_A = Y_A = C_A + (1-\phi)Y_A^P = C\frac{\mu_A}{1-\mu_A}(1-\bar{\delta})$$

From the aggregate market clearing condition (equation (35)), $Y = C + (1-\phi)Y_A^P = C\left(\frac{1-\bar{\delta}}{1-\mu_A}\right)$. The steady state share of consumption in output $\left(c = \frac{C}{Y}\right)$ equals

$$c = \frac{1-\mu_A}{1-\bar{\delta}}. \tag{63}$$

Note that as a fraction of the agriculture good is not consumed ($\mu_A > \bar{\delta}$), $c < 1$.

We now relate c with the steady state share of consumption in output in the agricultural sector $\left(c_A = \frac{C_A}{Y_A}\right)$. We already have $Y_A = C\left(\frac{\mu_A}{1-\mu_A}\right)(1-\bar{\delta})$, and $C_A = \bar{\delta}C$. Therefore,

$$c_A = \frac{\bar{\delta}(1-\mu_A)}{\mu_A(1-\bar{\delta})} = \frac{\bar{\delta}}{\mu_A}c. \tag{64}$$

Note that $c_A < c$ given that $\mu_A > \bar{\delta}$.

We next derive the steady state value of λ. Note that $\lambda = \frac{\phi Y_A^P}{(1-\mu_R)C_{PA}}$. From (11), $C_{PA} = \delta_P C_P (1-\lambda)^{-(1-\delta_P)}$ (as $T = 1$) and using the relation between C_P and C from.(57). Therefore,

$$\lambda = \frac{\phi Y_A^P (1-\lambda)^{(1-\delta_P)}}{(1-\mu_R)\delta_P C_P} = \frac{\phi Y_A^P (1-\lambda(1-\delta_P))}{\delta_P(1-s_R)C}.$$

Using $Y_A^P = \frac{1}{(1-\phi)}\frac{(\mu_A-\bar{\delta})}{(1-\mu_A)}C$, this implies

$$\lambda = \frac{(\mu_A-\bar{\delta})\phi(1-\lambda(1-\delta_P))}{\delta_P(1-\mu_A)(1-\phi)(1-s_R)} \tag{65}$$

Solving for λ, we obtain

$$\lambda = \frac{\phi(\mu_A-\bar{\delta})}{(1-\delta_P)\phi(\mu_A-\bar{\delta}) + \delta_P(1-\mu_A)(1-s_R)(1-\phi)}. \tag{66}$$

Solving for ϕ,this implies

$$\phi = \frac{\lambda\delta_P(1-\mu_A)(1-s_R)}{\lambda\delta_P(1-\mu_A)(1-s_R) + (\mu_A-\bar{\delta})(1-\lambda(1-\delta_P))}. \tag{67}$$

Given the other parameter restrictions in the model ($\mu_A - \bar{\delta} > 0, \mu_A < 1, s_R < 1, \delta_P > 0, \lambda \geq 0,$), this implies that $\phi \geq 0$. Since $\phi < 1$, this is equivalent to

$$\lambda < \frac{1}{1-\delta_P}$$

9.3 The Log-Linearized Model

Given the steady state, we log-linearize the key relationships of the model. Define $\hat{X}_t = \ln X_t - \ln X$ as the log of deviation of X, where X is the steady state value of X. For variables that are in fractions or have a percentage interpretation, we define $\hat{X}_t = X_t - X$.

Derivation of Equation (42): To derive an expression for the log-linearized consumption for the poor, using the definition of $\lambda_t = \frac{\phi_t Y^P_{A,t}}{C_{P,A,t}(1-\mu_R)}$, and using equation (11), we have

$$\lambda_t = \frac{\phi_t Y^P_{A,t}}{(1-\mu_R)\delta_P C_P (1-\lambda_t)^{-(1-\delta_p)} T_t^{-(1-\delta_P)}}.$$

Log linearization of this equation gives

$$\hat{\lambda}_t = \left[\frac{\lambda(1-\lambda)}{1-\delta_P\lambda}\right]\left[\frac{\widehat{\phi}_t}{\phi} + \widehat{Y}^P_{A,t} - \widehat{C}_{P,t} + (1-\delta_P)\widehat{T}_t\right]$$

The log-linearized first order condition (equation (17)) for the poor is given by

$$\widehat{W}_t - \widehat{P}_t = \varphi \widehat{N}_{P,t} + (\sigma_P + \lambda_p)\,\widehat{C}_{P,t} - \lambda_p\left[\frac{\widehat{\phi}_t}{\phi} + \widehat{Y}^P_{A,t}\right] + \{\delta_P - \delta_R - \lambda_P(1-\delta_P)\}\,\widehat{T}_t$$

Using $\widehat{N}_{R,t} = \widehat{N}_{P,t} = \widehat{N}_t$. for all t and combining this with equation (40) we get equation (42).

Derivation of Equation (68): To derive an expression for $\widehat{C}_{R,t}$,substituting equation (42) for $\widehat{C}_{P,t}$ into equation (39), the log-linearized consumption of the rich is given by,

$$\widehat{C}_{R,t} = \left[s_R + \frac{(1-s_R)\sigma_R(1-\lambda_p\tau)}{\sigma_P + \lambda_p}\right]^{-1} \qquad (68)$$
$$\left[\widehat{C}_t - \Psi\left[\frac{\widehat{\phi}_t}{\phi} + \widehat{Y}^P_{A,t}\right] - \left\{\Psi(1-\delta_P) + (1-s_R)(\delta_P - \delta_R)\left(\frac{\sigma_P + \lambda_P - (1-\lambda_P\tau)}{\sigma_P + \lambda_P}\right)\right\}\widehat{T}_t\right]$$

where $\Psi = \frac{\lambda_p(1-s_R)(1+\tau\sigma_P)}{\sigma_P+\lambda_p}$and $\tau = \frac{\lambda(1-\delta_P)}{1-\lambda(1-\delta_P)}$

Let $x = 1 - \lambda(1-\delta_p)$. Combining equations (44) and (38), we obtain the Euler equation in terms of aggregate output

$$
\begin{aligned}
\widehat{Y}_t = {} & E_t\{\widehat{Y}_{t+1}\} - c\Phi^{-1}\left[\widehat{R}_t - E_t\{\Pi_{t+1}\}\right] \\
& - c\left[(1-\delta_R)\left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right) + \Psi\left\{(1-\delta_p) + (\delta_p - \delta_R)z\right\}\right] E_t\left\{\Delta\widehat{T}_{t+1}\right\} \\
& - c\left[\left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right) + \Psi\right] E_t\left\{\Delta\widehat{Y}^P_{A,t+1}\right\} - c\left[\frac{\Psi}{\phi} - \left(\frac{1}{1-\phi}\right)\left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right)\right] E_t\left\{\Delta\widehat{\phi}_{t+1}\right\}
\end{aligned} \tag{69}
$$

Log-linearization of the market clearing condition in the agricultural sector (equation (29)) gives

$$
\begin{aligned}
\widehat{Y}_{A,t} = {} & \frac{c}{\mu_A}\left[s_R\delta_R\widehat{C}_{R,t} + (1-s_R)\frac{\lambda_p}{x\lambda_s}\widehat{C}_{P,t} + \left\{\frac{(1-s_R)\lambda_p(1-\delta_p)}{x} + \left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right)\right\}\widehat{Y}^P_{A,t}\right] \\
& + \frac{c}{\mu_A}\left[\frac{(1-s_R)\lambda_p(1-\delta_p)}{x\phi} - \left(\frac{1}{1-\phi}\right)\left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right)\right]\widehat{\phi}_t \\
& - \frac{c}{\mu_A}\left[s_R\delta_R(1-\delta_R) + \frac{(1-s_R)\lambda_p(1-\delta_p)}{x\lambda_s}\right]\widehat{T}_t
\end{aligned} \tag{70}
$$

where $\lambda_s = \frac{\lambda}{1-\lambda}$. Log-linearization of the optimal demand for manufacturing output (equation (23)) gives

$$
\begin{aligned}
\widehat{Y}_{M,t} = {} & \frac{1}{1-\bar{\delta}}\left[s_R(1-\delta_R)\widehat{C}_{R,t} + \frac{(1-s_R)(1-\delta_P)(1-\lambda)(1+\lambda_p)}{x}\right]\widehat{C}_{P,t} \\
& + \frac{1}{1-\bar{\delta}}\left[s_R(1-\delta_R)\delta_R + \frac{(1-s_R)(1-\delta_P)(1-\lambda)(\delta_p - \lambda_p(1-\delta_p))}{x}\right]\widehat{T}_t \\
& - \frac{1}{1-\bar{\delta}}\left[\frac{\lambda_p(1-s_R)(1-\lambda)(1-\delta_p)}{x}\right]\left(\frac{\widehat{\phi}_t}{\phi} + \widehat{Y}^P_{A,t}\right)
\end{aligned} \tag{71}
$$

Log-linearization of the labor market clearing condition (33) gives

$$
\widehat{N}_t = \mu_A\widehat{N}_{A,t} + (1-\mu_A)\widehat{N}_{M,t} = \mu_A\widehat{Y}_{A,t} + (1-\mu_A)\widehat{Y}_{M,t} - \widehat{A}_t \tag{72}
$$

where $\widehat{A}_t = \mu_A \widehat{A}_{A,t} + (1-\mu_A)\widehat{A}_{M,t}$, and $\mu_A = \frac{N_A}{N}$ is the steady state employment share in agriculture. The last line uses log linearization of the sectoral production functions.

From equations (40) and (68) and noting that $\widehat{N}_{R,t} = \widehat{N}_t$, we can write equation (16) as

$$\widehat{W}_t - \widehat{P}_t = \varphi \widehat{N}_t + \Phi \widehat{C}_t - \Psi\Phi \left[\frac{\widehat{\phi}_t}{\phi} + \widehat{Y}^P_{A,t} + \{(1-\delta_p) + (\delta_p - \delta_R)z\} \widehat{T}_t \right] \tag{73}$$

Substituting equations (70) and (71) into (72), and the resulting equation into (73), we get

$$\begin{aligned} \widehat{W}_t - \widehat{P}_t = \Lambda \widehat{C}_t + \{\varphi(1-c) - \Psi\Phi\} \widehat{Y}^P_{A,t} - \left\{ \varphi(1-c)\left(\frac{1}{1-\phi}\right) + \frac{\Psi\Phi}{\phi} \right\} \widehat{\phi}_t \\ - \left[\varphi c(1-s_R)\{\delta_p \tau + \delta_P - \delta_R\} + \Psi\Phi\{1-\delta_P + (\delta_P - \delta_R)z\}\right] \widehat{T}_t - \varphi \widehat{A}_t \end{aligned} \tag{74}$$

where $\Lambda = \{\varphi c + \Phi\}$.

Finally, the log linearized real marginal cost in the manufacturing sector is given by

$$\widehat{mc}_{M,t} = \widehat{W}_t - \widehat{P}_t + \delta_R \widehat{T}_t - \widehat{A}_{M,t} \tag{75}$$

9.4 Flexible price equilibrium and the natural rate

Derivation of DIS in Equation (46): Given that under flexible prices, real marginal cost is a constant, so that $\widehat{mc}^N_{M,t} = 0$, equation (75) becomes $0 = \widehat{W}^N_t - \widehat{P}^N_t + \delta_R \widehat{T}^N_t - \widehat{A}_{M,t}$. Combining this with the flexible price counterpart of equation (74), we get

$$\begin{aligned} \widehat{C}^N_t = {} & \Lambda^{-1} \left\{ \varphi(1-c)\left(\frac{1}{1-\phi}\right) + \frac{\Psi\Phi}{\phi} \right\} \widehat{\phi}_t \\ & - \Lambda^{-1}\{\varphi(1-c) - \Psi\Phi\} \widehat{Y}^P_{A,t} + \Lambda^{-1}\left(\varphi \widehat{A}_t + \widehat{A}_{M,t}\right) \\ & + \Lambda^{-1}\left[\varphi c(1-s_R)\{\delta_p \tau + \delta_P - \delta_R\} + \Psi\Phi\{1-\delta_P + (\delta_P - \delta_R)z\} - \delta_R\right] \widehat{T}^N_t \end{aligned} \tag{76}$$

Note that procurement is the same under both sticky and flexible prices. Thus, the flexible price counterpart of equation (38) is

$$\begin{aligned}\widehat{Y}_t^N &= c\widehat{C}_t^N + (1-c)\left[(1-\delta_R)\widehat{T}_t^N + \widehat{Y}_{A,t}^P - \left(\frac{1}{1-\phi}\right)\widehat{\phi}_t\right] \\ &= \left(\frac{1-\mu_A}{1-\bar{\delta}}\right)\widehat{C}_t^N + \left(\frac{\mu_A-\bar{\delta}}{1-\bar{\delta}}\right)\left[(1-\delta_R)\widehat{T}_t^N + \widehat{Y}_{A,t}^P - \left(\frac{1}{1-\phi}\right)\widehat{\phi}_t\right]\end{aligned} \tag{77}$$

Substituting equation (76) into equation (77), forwarding one period and then subtracting from each other, we obtain

$$\begin{aligned}\widehat{Y}_t^N &= E_t\left\{\widehat{Y}_{t+1}^N\right\} - (1-\delta_R)\{1-c\}E_t\left\{\Delta\widehat{T}_{t+1}^N\right\} \\ &- [c\Lambda^{-1}\{(1-s_R)\varphi c\left((\delta_p-\delta_R)+\delta_p\tau\right) + \Psi\Phi\left\{1-\delta_p+(\delta_p-\delta_R)z\right\} - \delta_R\}]E_t\left\{\Delta\widehat{T}_{t+1}^N\right\} \\ &- [c\Lambda^{-1}\{\Psi\Phi\} + (1-c)(1-\Lambda^{-1}\varphi c)]E_t\left\{\Delta\widehat{Y}_{PA,t+1}\right\} \\ &- \left\{c\Lambda^{-1}\left[\frac{\Psi\Phi}{\phi}\right] - \left(\frac{1}{1-\phi}\right)(1-c)(1-\Lambda^{-1}\varphi c)\right\}E_t\{\Delta\widehat{\phi}_{t+1}\} \\ &- c\Lambda^{-1}E_t\left\{\varphi\Delta\widehat{A}_{t+1} + \Delta\widehat{A}_{M,t+1}\right\}\end{aligned} \tag{78}$$

Finally, substituting (44) into (38) and then subtracting equation (78) we obtain the dynamic IS (DIS) curve given by equation (46).

Derivation of NKPC in Equation (49): From equation (38), the consumption gap is written as

$$\widetilde{C}_t = \frac{1}{c}\left[\widetilde{Y}_t - (1-c)(1-\delta_R)\widetilde{T}_t\right] \tag{79}$$

From equation (75) and given that $\widehat{mc}_{M,t}^N = 0$,

$$\widetilde{mc}_{M,t} = \widetilde{W}_t - \widetilde{P}_t + \delta_R\widetilde{T}_t. \tag{80}$$

And from equation (74),

$$\widetilde{W}_t - \widetilde{P}_t = \Lambda \widetilde{C}_t - \left[\varphi c(1-s_R)\left\{\delta_p \tau + (\delta_p - \delta_R)\right\} + \Psi\Phi\left\{1 - \delta_p + (\delta_p - \delta_R)z\right\}\right]\widetilde{T}_t \tag{81}$$

Substituting equation (81) in equation (80) yields the manufacturing sector real marginal cost gap in terms of the aggregate consumption gap and the terms of trade gap.

$$\widetilde{mc}_{M,t} = \Lambda \widetilde{C}_t + \left[\delta_R - \varphi c(1-s_R)\left\{\delta_p \tau + (\delta_p - \delta_R)\right\} - \Psi\Phi\left\{1 - \delta_p + (\delta_p - \delta_R)z\right\}\right]\widetilde{T}_t \tag{82}$$

We also have the relationship that connects CPI inflation with sectoral inflation and TOT as

$$\pi_t = \pi_{M,t} + \delta_R \Delta \widetilde{T}_t \tag{83}$$

Substituting equations (79) and (83) into equation (28) yields equation (49).

9.5 IRF for Monetary Policy Shock with Variable Employment Share

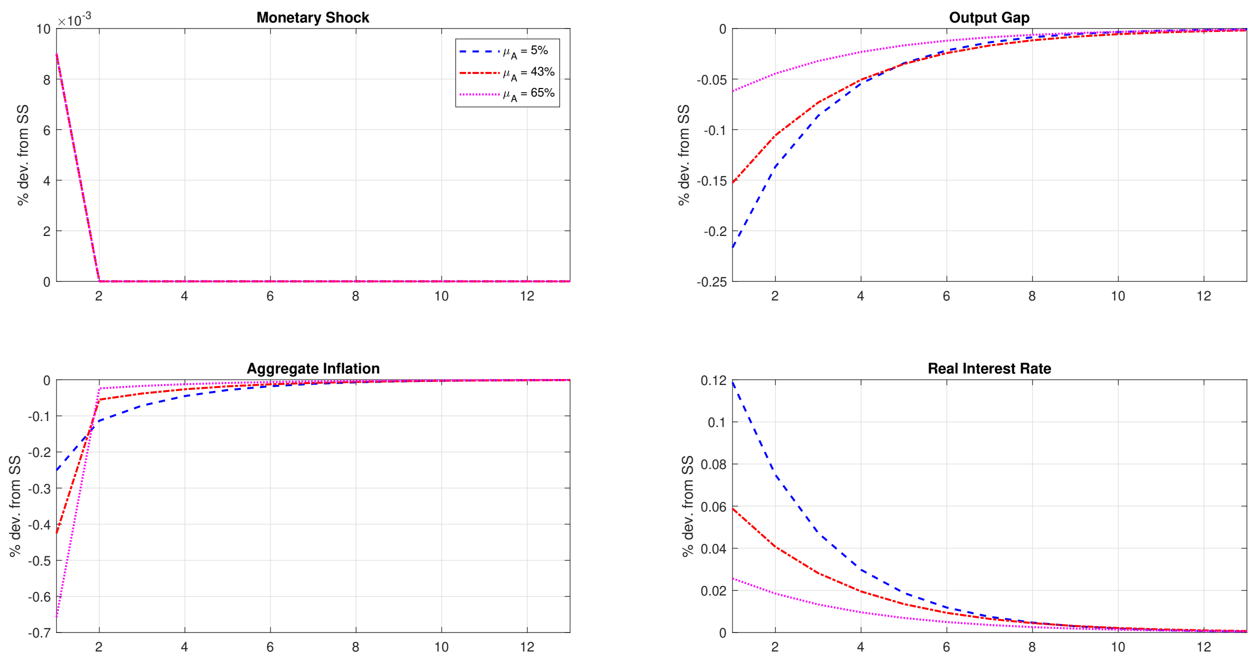

Figure 4: Impact of monetary policy shock when $\mu_A = 5\%$; $\mu_A = 43\%$; $\mu_A = 65\%$,

9.6 IRFs for Immobile Labor

Figures 5a-5c depict the IRFs for a single period positive procurement and redistributive policy shock for the model with immobile labor compared to the benchmark 2S-TANK model.

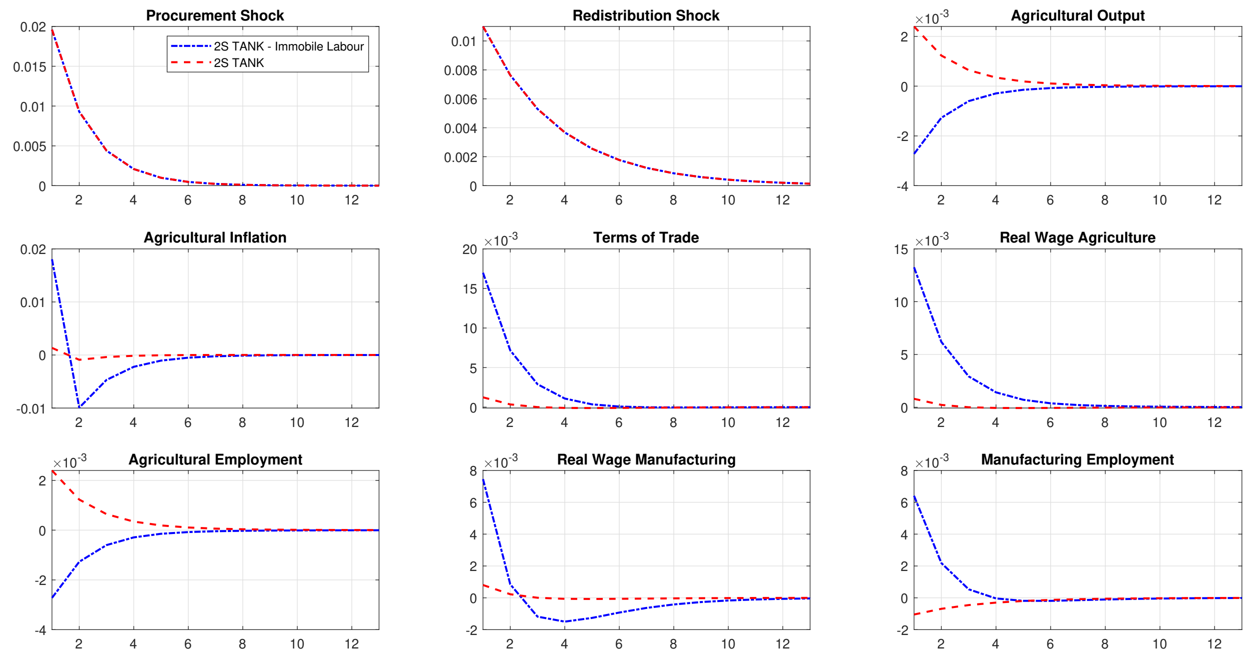

Figure 5a: Impact of a positive procurement and redistributive policy shock with immobile labor

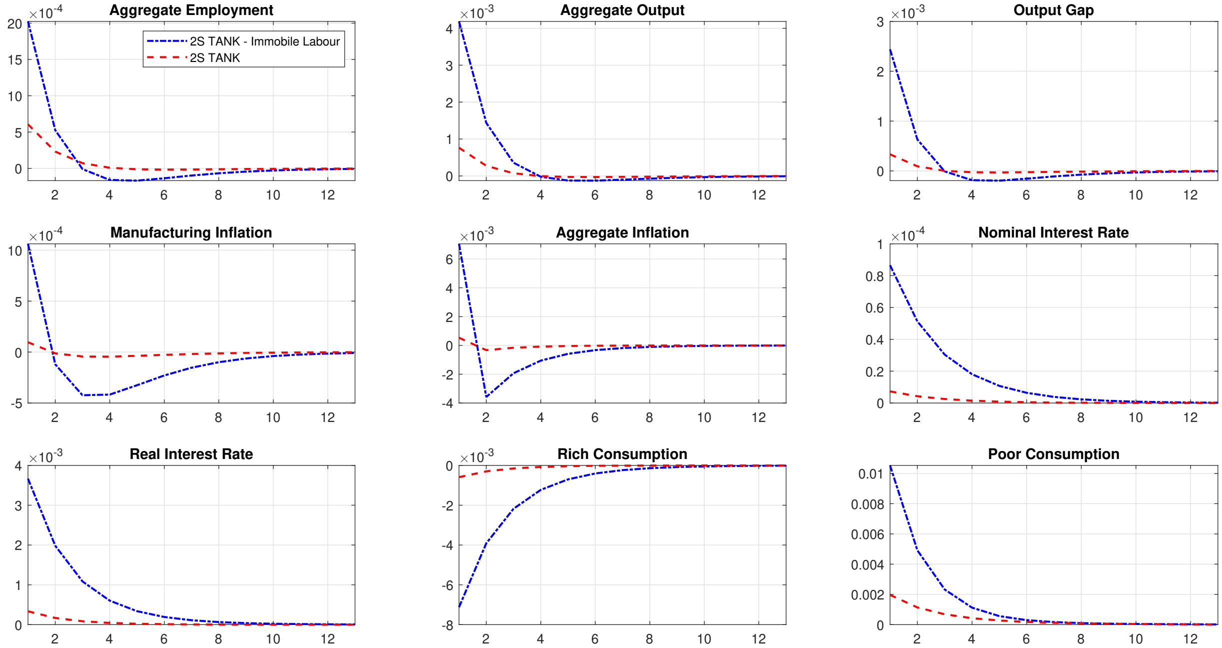

Figure 5b: Impact of a positive procurement and redistributive policy shock with immobile labor

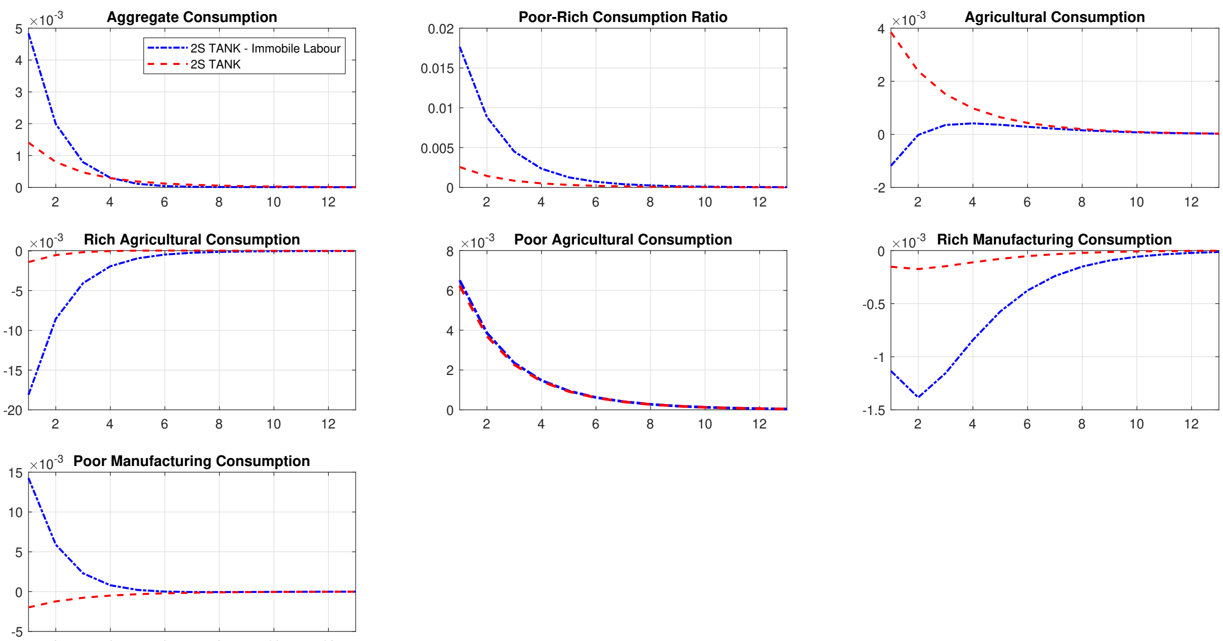

Figure 5c: Impact of a positive procurement and redistributive policy shock with immobile labor

10 Data Appendix

In this section, we describe how we have estimated the structural parameters used in the calibration exercise.

- *Share of rich in population*: $\mu_R = 0.3279$
  - We define agents to be poor if they receive food grain under the NFSA 2013. Thus, we assume 25% of the rural population and 50% of the urban population to be rich. Taking population of the rural and urban areas to be 833.1 million and 377.1 million, respectively, from the Census of India 2011, we get $\mu_R = 0.3279$
- Share of agriculture in consumption for agents is determined by taking the ratio of expenditure on cereals and cereal substitutes in total expenditure where the latter is defined to be expenditure on cereals, cereals substitutes, pan tobacco and intoxicants, clothing, footwear, toilet articles, other household consumables, and minor durable type goods. We use data from Table 6B-R: Value of consumption (Rs) of broad groups of food and non-food per person for a period of 30 days for each fractile class of MPCE_{MRP} (Page 104) and Table 6B-U: Value of consumption (Rs) of broad groups of food and non-food per person for a period of 30 days for each fractile class of MPCE_{MRP} (Page 105) from National Sample Survey (b)
  - *Share of agriculture purchases by poor*: $\delta_P = 0.4807$.
    * We split the 7^{th} decile (70-80%) into two halves for the rural data set (to be able to get division into bottom 75% and top 25% by MPCE). The agriculture expenditure shares for different fractile classes of rural areas are combined by taking a weighted average using appropriate weights (0.1333 for deciles and 0.0667 for the first two fractile classes (0-5% and 5-10%) and the (70-75%) fractile class). The agriculture expenditure shares for different fractile classes of urban areas are combined by taking a weighted average using appropriate

weights (0.2 for deciles and 0.1 for first 2 fractile classes (0-5% and 5-10%)). These two shares are combined by taking a weighted average using rural and urban shares in total poor population as weights.

- *Share of agriculture purchases by rich:* $\delta_R = 0.3527$.
  - The agriculture expenditure shares for different fractiles of rural areas are combined by taking a weighted average using appropriate weights (0.4 for the 70-80th percentile and 0.2 for the 70-75th, 90-95th and 95-100th percentiles)). The agriculture expenditure shares for different fractiles of urban areas are combined by taking a weighted average using appropriate weights (0.2 for deciles and 0.1 for the 90-95th and 95-100th percentiles). These two shares are combined by taking a weighted average using shares in the total rich population as weights.

- *Share of rich consumption relative to total consumption*: $s_R = 0.5367$
  - We use data from Table 1C of National Sample Survey (b): Estimated number of households and persons by sex, and average MPCE for each fractile class of MPCE$_{MMRP}$ (Page 83). Share of Total Consumption Expenditure for each fractile is computed by multiplying the estimated number of people in each fractile class with Average MPCE of that fractile class. The share of rich agents for the respective areas is determined by dividing total consumption estimates for fractiles greater than 75% for the rural areas and above 50% for urban areas by their respective total consumption estimates. The two shares are combined using the population shares

- *Share of subsidized consumption*: $\lambda = 0.2457$
  - We use data from Statement 2 of National Sample Survey (c) (Page 18). It states Percentage of consumption (quantity) coming from PDS for households in dif-

ferent fractile classes of MPCE separately for wheat, rice, sugar and kerosene (separately for urban and rural areas). We combine the PDS shares of wheat and rice by taking a weighted average using relative shares in consumption for each fractile. (For example, the weight of rice is determined by taking the expenditure on rice divided by the expenditure on wheat and rice). The data is taken from Table 5C-R (Page 100) and Table 5C-U (Page 101) from the NSS Report 555 -Value (Rs) of consumption of cereals and pulses per person for a period of 30 days for each fractile class of MPCE_{MMRP}. (MMRP is used here as PDS shares are available using type 2 data-MMRP approach). The share of subsidy in consumption is determined by taking a weighted average of shares for bottom 9 fractile classes (0-75%) for the rural areas and by taking a weighted average of shares for bottom 6 fractile classes (0-50%) for the urban areas. These two values are combined by using relative shares of agents among the poor.

- Steady state value of ϕ
  - Using the selected parameter values in equation (67), the steady state value of ϕ is computed to be 47.93%

11 Welfare Appendix

11.1 Ramsey Optimal Monetary Policy with Varying ϕ

In this Appendix, we report several other welfare results. Since the focus of our paper is on the welfare costs of agriculture sector interventions, we compare conditional welfare under Ramsey for shocks emanating from the agriculture sector (a procurement and redistribution shock and an agricultural productivity shock) with conditional welfare corresponding to the deterministic steady state. We also present implied volatilities of key variables as standard deviation in percentages when a Ramsey planner maximizes equation 53. To achieve this, we fix the steady-state amount of agriculture output procured and assess the implication of varying steady-state redistribution on consumption equivalent welfare gains under Ramsey. The results are in Table 5.

We notice from Table 5 that raising steady state redistribution from $\phi = 0.4$ to $\phi = 0.8$ leads to higher inflation variability (.214% versus .241%) because of a procurement and redistributive policy shock. The planner, however, does not find it optimal to stabilize inflation perfectly[45]. We verify that raising the steady state redistributive share of procured output raises the amount available for consumption (because of lower buffer stock accumulation), thereby raising steady state consumption of both agents. However, an increase in ϕ increases the variability of poor agent consumption (0.329 versus 0.889). This is on account of higher inflation volatility (which leads to higher variability in the subsidy policy, λ_t). Rich consumption volatility falls with higher ϕ because the Ramsey planner raises the steady state interest rate to counteract higher inflation variability. The poor agents are more risk averse and are unable to smooth consumption. In the presence of higher inflation, they are willing to forgo a greater amount (0.0132%) of their steady state consumption than the rich (0.0050%) to avoid fluctuations in consumption. When $\phi = 0.80$, the consumption equivalents increase

[45] We have verified that this result is applicable to manufacturing productivity shock also. Core inflation and output gap is stabilized, but standard deviation of aggregate inflation is 0.535%

Table 5: Welfare Cost and Standard Deviations under Ramsey Optimal Monetary Policy

Panel A: Low Steady State Redistribution ($\phi = 0.40$)

	Redis.Policy	Agri. Prodty	Both Shocks
Welfare Cost (%)			
χ_R	0.0050	0.0020	0.0071
χ_P	0.0132	0.0022	0.0154
Standard Deviation (%)			
Inflation	0.214	0.806	0.834
Manufacturing Inflation	0.033	0.012	0.035
Output Gap	0.137	0.057	0.149
Rich Consumption	2.617	2.354	3.520
Poor Consumption	0.329	0.400	0.518

Panel B: High Steady State Redistribution ($\phi = 0.80$)

	Redis.Policy	Agri. Prodty	Both Shocks
Welfare Cost (%)			
χ_R	0.0085	0.0019	0.0105
χ_P	0.0325	0.0015	0.0341
Standard Deviation (%)			
Inflation	0.241	0.803	0.839
Manufacturing Inflation	0.038	0.012	0.040
Output Gap	0.155	0.055	0.164
Rich Consumption	2.279	2.335	3.262
Poor Consumption	0.889	0.353	0.956

to 0.0325% and 0.0085% respectively. The welfare cost of procurement and redistributive interventions is apparent across higher values of ϕ.

With an agricultural productivity shock, a higher steady state redistribution lowers variability in consumption for both agents. Inflation variability falls because higher steady-state redistribution requires lower open market purchases of the agricultural good by the poor. This leads to lower consumption volatility of the poor. Thus the poor are willing to forgo a lower amount of steady state consumption to achieve stable consumption when the redistribution share is higher (0.0015% when $\phi = 0.80$ as compared to 0.0022% when $\phi = 0.40$.

When both shocks in the agricultural sector hit the economy simultaneously - a plausible scenario in the context of EMDEs - we find that inflation volatility rises marginally from 0.834 to 0.839. The output gap volatility also rises. The combined shocks lead to higher consumption volatility of the poor but lower consumption volatility of the rich, reflecting a higher steady state interest rate with $\phi = 0.8$. Compared to the each individual shock, the consumption equivalents for both agents are higher, as is to be expected.

11.2 Optimal Simple Rules with Varying ϕ

As the Ramsey allocations are not observable, we conduct welfare analysis using optimal simple rules (OSR) to see how close they are able to replicate the Ramsey allocations. We study the implications of optimal policy conditional on the simple rule given by the Bayesian Estimation Taylor Rule (84):

$$R_t = R_{t-1}^{\phi_r} \pi_t^{(1-\phi_r)\phi_\pi} \tilde{Y}_t^{(1-\phi_r)\phi_y} \epsilon_t \tag{84}$$

We maximize the weighted average of variances of aggregate inflation and output gap with weights being 0.9 and 0.1, respectively [46]. As is standard in the literature, we set the bounds for the persistent coefficient in the Taylor Rule, ϕ_r, to be [0,0.99],[47] and the bounds for the coefficient on inflation, ϕ_π, and the output-gap, ϕ_y, to be [0,3]. We fix the procured amount to be 0.21[48] and report the results by varying the steady state level of redistribution from $\phi = 0.4$ to $\phi = 0.8$.

The results of the analysis are shown in Table 6. As in the Ramsey analysis, we restrict

[46] We also perform sensitivity analysis by choosing alternative weights 0.1 and 0.9 on aggregate inflation and output gap respectively. See Table 9

[47] We limit the upper bound to 0.99 to prevent introduction of singularity

[48] This amounts to 26% of the steady state output. The average procurement share of wheat production was 27.5% in the last 5 years (excluding FY20). We use this as a proxy for the proportion of procured agricultural good in the model.

Table 6: Welfare Cost and Standard Deviations under Optimal Simple Rules

Panel A: Low Steady State Redistribution ($\phi = 40\%$)

OSR Rule	ϕ_r	ϕ_π	ϕ_y	Welfare Cost (%)	$\sigma_\pi(\%)$	$\sigma_{\pi_M}(\%)$	$\sigma_{\tilde{Y}}(\%)$
Redis. Policy	0	3	0	χ_R : 0.0096 χ_P : 0.0161	0.191	0.137	0.146
Agri. Prodty	0.2183	3	2.4310	χ_R : 0.0091 χ_P : 0.0074	0.068	0.121	0.444
Both Shocks	0	3	0.2844	χ_R : 0.0222 χ_P : 0.0256	0.381	0.231	0.378

Panel B: High Steady State Redistribution ($\phi = 80\%$)

OSR Rule	ϕ_r	ϕ_π	ϕ_y	Welfare Cost (%)	$\sigma_\pi(\%)$	$\sigma_{\pi_M}(\%)$	$\sigma_{\tilde{Y}}(\%)$
Redis. Policy	0	3	0	χ_R : 0.0120 χ_P : 0.0350	0.169	0.122	0.128
Agri. Prodty	0.2176	3	2.4227	χ_R : 0.0091 χ_P : 0.0071	0.067	0.121	0.441
Both Shocks	0	3	0.7263	χ_R : 0.0283 χ_P : 0.0465	0.359	0.250	0.400

our discussion to shocks emanating from the agricultural sector. We find that the OSR that minimizes the variances of inflation and the output gap from a procurement and redistribution shock puts the maximum weight on inflation, and no weight on interest rate persistence and the output gap, i.e., the monetary authority finds it optimal to target aggregate inflation only. Changing steady state redistribution has no impact on the optimal policy parameters

Table 7: Comparison of Consumption with Varying Redistribution

Shock	Variable	ϕ	Steady State	Standard Deviation
Redis. Policy	C_R	0.4	3.206	2.589%
Redis. Policy	C_R	0.8	3.248	2.327%
Redis. Policy	C_P	0.4	0.865	0.324%
Redis. Policy	C_P	0.8	0.930	0.878%
Agri. Prodty.	C_R	0.4	3.206	3.448%
Agri. Prodty.	C_R	0.8	3.248	3.453%
Agri. Prodty	C_P	0.4	0.865	0.532%
Agri. Prodty	C_P	0.8	0.930	0.526%
Both Shocks	C_R	0.4	3.206	4.002%
Both Shocks	C_R	0.8	3.248	3.897%
Both Shocks	C_P	0.4	0.865	0.583%
Both Shocks	C_P	0.8	0.930	1.005%

(see Table 6 Panel B), however, it does have an implication for the variances.

As the shock affects the level and volatility of the share of subsidized consumption, it leads to greater volatility of consumption for poor agents (Table 7). We also find that $\phi = 0.8$ leads to lower volatility of aggregate inflation, sticky price inflation and the output gap (Panel B, 6). As higher redistribution of the procured output lowers the reliance of the poor on open market purchases, we verify that it lowers the variability of the terms of trade, sectoral and aggregate inflation, and thereby interest rates. The lower volatility of interest rates leads to lower volatility of rich consumption (from 2.589% to 2.327%, see Table 7). The cost of the redistributive policy is apparent in the higher consumption equivalent of the poor driven by higher poor consumption volatility because of higher variability in the subsidized share.[49].

The agricultural productivity shock lowers the relative price of the agricultural commodity. As can be seen from Table 6 for given ϕ, it is optimal to have persistence in the interest

[49] We verify that in the case of $\phi = 0.8$ the variability in λ_t, the subsidized share of food increases to 3.151% from 2.439% (corresponding to $\phi = 0.4$). Despite lower rich consumption volatility when $\phi = 0.8$, the steady state consumption of the rich rises which increases the conditional welfare corresponding to the deterministic steady state. This leads to a higher consumption equivalent.

rates, although the values of ϕ_π does not change. This reflects the inflationary nature of the shock. With these parameters there is no discernible change in the volatility of inflation, the output gap and sticky-price inflation. Rich consumption variability rises marginally to 3.453% while poor consumption volatility falls marginally to 0.526% as can be seen in Table 7 with $\phi = 0.8$. We find that, under an agricultural productivity shock, the optimal response of a monetary authority should be to respond to both deviations in inflation and output gap from their targets while exhibiting persistence in the interest rate. As in the case of a procurement and redistribution shock, the monetary authority responds aggressively to deviations of inflation from its target. The similar levels of volatility across different values of ϕ leads to similar values of consumption equivalents for the two cases.

With combined shocks, both agent's consumption is more volatile compared to the individual shocks. Since the agricultural productivity shock is a supply side shock, and the redistributive policy shock is a demand side shock, the offsetting effects in the agricultural goods market leads to lower variability of inflation. The consumption equivalents rise because the poor agent's consumption is more volatile (Table 7) and thus they are willing to forgo 0.046% of their steady state consumption to be in an economy with no interventions in the agricultural sector as compared to 0.028% by the rich. The optimal policy in this scenario is to respond aggressively to deviations of contemporaneous inflation, more aggressively to deviations in the output gap (0.7263 versus 0.2844), but with no interest rate persistence.

11.3 Changing Weights in the Planner's Objective Function

Table 8: Comparison of Standard Deviation by altering the objective function for Ramsey Planner

Variable	Rich Welfare ($\Omega = 1$)	Average Welfare ($\Omega = \mu_R$)	Poor Welfare ($\Omega = 0$)
Inflation	0.129%	0.241%	0.353%
Manufacturing Inflation	0.022%	0.038%	0.052%
Aggregate Output	0.758%	0.841%	0.921%
Output Gap	0.085%	0.155%	0.222%
Rich Consumption	2.401%	2.277%	2.170%
Poor Consumption	0.867%	0.889%	0.908%
Employment	0.713%	0.760%	0.804%

11.4 Varying weights in the OSR Objective Function

Putting higher weight on the output gap in the monetary authority's objective function raises the relative importance on stabilization of output relative to inflation. This can be achieved in by having higher value of ϕ_y, lower value of ϕ_π or higher value of ϕ_r as the latter reduces the effective weight on inflation (1-ϕ_r)ϕ_π. We observe that the third does indeed take place.

Table 9: Welfare Cost and Standard Deviations under Optimal Simple Rules Using Alternative Weights

$(\Omega_\pi = 0.1,\ \Omega_y = 0.9)$ with $\phi = 0.80$							
OSR Rule	ϕ_r	ϕ_π	ϕ_y	Welfare Cost (%)	$\sigma_\pi(\%)$	$\sigma_{\pi_M}(\%)$	$\sigma_{\tilde{Y}}(\%)$
Redis. Policy	0	3	0	$\chi_R = 0.0120$	0.169	0.122	0.128
				$\chi_P = 0.0350$			
Agri. Productivity	0.7160	3	0	$\chi_R = 0.0032$	0.590	0.074	0.103
				$\chi_P = 0.0029$			
Both Shocks	0.5585	3	0	$\chi_R = 0.0156$	0.542	0.146	0.244
				$\chi_P = 0.0380$			