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Abstract

Governments in EMDEs routinely intervene in agriculture markets to stabilize food prices in the wake of adverse domestic or external shocks. Such interventions typically involve a large increase in the procurement and redistribution of food, which we call a redistributive policy shock. What is the impact of a 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 tractable two-sector (agriculture and manufacturing) two-agent (rich and poor) New Keynesian DSGE model with redistributive policy shocks. We calibrate the model to the Indian economy. We show that for an inflation targeting central bank, consumer heterogeneity matters for whether monetary policy responses to a variety of shocks raises aggregate welfare or not. Our paper contributes to a growing literature on understanding the role of consumer heterogeneity in monetary policy.

Keywords TANK models, HANK Models, Inflation Targeting, Emerging Market and Developing Economies, Food Security, Procurement and Redistribution, DSGE.

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

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1 Introduction

Governments in many emerging market and developing economies (EMDEs) routinely intervene in their agricultural markets. Higher food security norms, for instance, 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.[1] 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. 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% per cent 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, or government intervention 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. Second, such interventions are conducted at a relatively high frequency, i.e., several times

[1] See https://dfpd.gov.in/nfsa-act.htm

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 ? The novel part of our analysis is that we allow for government intervention in the agriculture market in a way that captures the essence of procurement and redistribution style interventions in EMDEs.

We build a two-sector (agriculture and manufacturing) two agent (rich and poor) New Keynesian DSGE model. Our theoretical model builds on earlier work by Debortoli and Gali (2018), Aoki (2001), and Ghate, Gupta and Mallick (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) in a tractable way. 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 rich and poor households consume both the agriculture good and the manufacturing good. To provide the subsidized agriculture good to the poor, the government taxes the rich via lump sum taxes and uses the proceeds to procure agricultural output from the open market. It then re-distributes a fraction of the procured agriculture good to the poor. Further, we assume that rich agents have a higher inter-temporal elasticity of substitution of consumption compared to the poor which affects their labor supply decisions differentially in response to changes in the real wage.[2]

We calibrate the model to India, an economy subject to frequent government interventions in the agriculture market.[3] From the impulse response functions (IRFs), we focus our attention on how the transmission of agricultural productivity shocks, redistributive policy shocks, and monetary policy shocks affect sectoral inflation rates, the economy 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

[2] In Debortoli and Gali, all agents have the same inter-temporal elasticity of substitution. Our assumption is driven by evidence for Indian household data that estimates different inter-temporal elasticity of substitution parameters for rich and poor households. 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, Curdia, and Ferrero (2012).

[3] We calibrate the model to India since it is an EMDE with a large agriculture sector and many parameter values are available for India.

the lines of Debortoli and Gali, and the simple one sector one agent NK model in Gali (2015, Chapter 3).[4] By comparing our results to these benchmarks, we are able to highlight the role that consumer heterogeneity (demand side factors) and multiple sectors (supply side factors) play in determining sectoral and aggregate inflation rates, and rich and poor consumption, when the economy is hit by a redistributive policy shock.

We show that a positive agricultural productivity shock leads to a decline in inflation, a rise in the output gap, a rise in both poor and rich consumption, and higher welfare. We define welfare in the model to explicitly depend on aggregate consumption, as is standard in the literature. In contrast, a procurement and redistribution shock leads to higher inflation, a higher output gap, higher consumption of the poor and higher aggregate consumption in the economy, even though such shocks raise inflation, and there is a decline in consumption of the rich. Because of the redistributive effect of procurement and redistribution, the rise in poor consumption makes aggregate welfare rise. Compared to the Aoki model, since the poor receive a fraction of their agriculture consumption for free (via the redistributive shock) and spend a higher share of their income on the agriculture good compared to the rich, the market demand for the agriculture good is less, and so the inflationary impact of a procurement-and-redistribution shock is much lower in our model compared to the Aoki model (where there is no redistribution).

A recent focus in the monetary policy literature explores the impact of monetary policy when there is consumer heterogeneity. 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 that rich and poor consumption, and therefore aggregate demand, has 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 in our model creates a large deflation in the economy because of the contractionary monetary policy. 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

[4] Both productivity shock and procurement and redistributive 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.

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. As a result, the welfare losses from monetary policy shocks are less when there is a flexible price sector. In all cases, consumer heterogeneity interacts with rich inter-sectoral dynamics to determine the general equilibrium responses to a variety of shocks.

Our two sector-two agent NK framework builds on the seminal work by Gali and Monacelli (2005), Aoki (2001), and Debortoli and Gali (2018). The main difference with respect to 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 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 provides lump sum transfers to poor agents. In Aoki's framework there is no government intervention.[5]

Debortoli and Gali (2018) build a DSGE model in which agents are Ricardian/rich and rule of thumb/poor. They show that a tractable 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 (2018), 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 in a tractable way.

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

[5] Gali, Lopez-Salido, and Valles (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.

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.[6] 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.

Our paper builds on a growing literature on heterogenous agent New Keynesian (HANK) models (McKay, Nakamura, and Steinsson, 2016; Kaplan, Moll, and Violante, 2018; Auclert, 2019, and Broer et al., 2019). The main methodological contribution our paper makes is to 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 tractable New Keynesian DSGE framework.

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 homogenous good. The M-sector is characterized by monopolistic competition and staggered price setting.[7] 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. 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. This implies that the total number of firms equals the sum of rich and poor households.

Like GGM, the government procures grain in the open market. It does this by taxing (lump-sum) the rich and uses the proceeds to procure/buy A-sector output from the market at the market price.[8] 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

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

[7] 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.

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

have labor income, whereas rich households have labor and dividend income.

Following Atkeson and Ogaki (1996), we assume that poor and rich households have different inter-temporal elasticities of substitution. In particular, we assume that the poor have a lower inter-temporal elasticity of substitution than the rich, which means that they 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, Curdia, and Ferrero, 2012).

2.1 Households

All households are assumed to have identical preferences.[9] At time 0, a household of type K ($= R$, P) maximizes its expected lifetime utility given by

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

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 $K \in \{R, P\}$ derives utility from consumption, $C_{K,t}$, and disutility from labor supply, $N_{K,t}$. $\beta \in (0, 1)$ 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 inter-temporal 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 $\delta_R \in [0, 1]$ is the share of income spent on agricultural goods by the rich while $\delta_P \in [0, 1]$ is the share of income spent on agricultural goods by the poor.

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

Rich households maximize utility given in equation (1) subject to the following inter-temporal budget constraint

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

where Q_{t+1} is the stochastic discount factor, B_{t+1} are the nominal payoffs in period $t+1$ of the bond 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 homogenous good, whose price is $P_{A,t}$. 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.,[10]

$$C_{M,t} = \left(\int_0^1 C_{M,t}(j)^{\frac{\varepsilon-1}{\varepsilon}}\, dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \varepsilon > 1.$$

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 poor to each household as a subsidy, $C^S_{P,A,t}$, while the remaining portion is put into a buffer stock.[11] 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 ($C^O_{P,A,t}$) and

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

Poor households are assumed to be rule of thumb consumers, and maximize their current

[10] 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.

[11] 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.

utility (1) subject to the following (static) budget constraint

$$\int_0^1 \left[P_{M,t}(j) C_{P,M,t}(j) \right] dj + P_{A,t} C^O_{P,A,t} \leq W_t N_{P,t} \tag{7}$$

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 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

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

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 index (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 to $P_t^{'}$ in their consumption basket.

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 then 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,

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

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 $Y_{A,t}^P$ 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.[12] The redistributed amount is given by $\phi_t Y_{A,t}^P$. The agricultural sector output is the sum of consumption and the amount accumulated by the buffer stock

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

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 $\varepsilon_\phi \sim i.i.d(0, \sigma_\phi)$.

3 Equilibrium Dynamics

3.1 Market Clearing

Market clearing is given by the following equations:

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

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

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

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

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

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

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

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.[13] 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 ($C_{P,A,t}^S(1-\mu_R)$) and the fraction of procured output that goes towards buffer stock accumulation ($(1-\phi_t)Y_{A,t}^P$).

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 (35)) gives

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

where c is the steady state consumption share in output and is defined in equation (59). Log linearization of aggregate consumption, C_t, in equation (32) gives

[13] 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).

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

where s_R is the steady consumption share of the rich households, and $\tau = \frac{\lambda(1-\delta_p)}{1-\lambda(1-\delta_p)}$. 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

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

where $\lambda_p = \frac{\delta_p\lambda}{(1-\delta_p)\lambda}$.[14] 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 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 (assuming the sign in front of $\widehat{T}_t$ is positive) 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

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

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

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

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

$\tau = \frac{\lambda(1-\delta_p)}{(1-\lambda(1-\delta_p))}$, $\Psi = \frac{\lambda_p(1-s_R)(1+\sigma_P\tau)}{\sigma_P+\lambda_p}$, 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, $\widehat{X}^N_t$ as the deviation of $\ln X_t$ under flexible prices from the steady state , $\widehat{X}^N_t = \ln X^N_t - \ln X$. Also, define a gap of a variable as $\widetilde{X}_t = \widehat{X}_t - \widehat{X}^N_t$. Then, the dynamic IS equation (DIS) is given by

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

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

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

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, Chapter 3) 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.[15]

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. We use a simple generalization of Taylor (1993):

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

[15] 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, Chapter 3). 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

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

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

4.1 Calibrated and Estimated Parameters

In this section, we calibrate the model to Indian data.[16] Our primary goal is to understand the quantitative implications of a positive procurement and redistributive shock (a demand side shock) to the economy. We first however discuss the case of a positive agricultural productivity shock (a supply side shock). This is done to determine the differential impacts of a positive demand side and positive supply side shock on the economy. We use the impulse response functions to assess implications for the aggregate dynamics of the economy, highlighting the intuition behind how the shock impacts rich and poor consumption. A detailed description of parameter estimates is in the Data Appendix.

4.1.1 Description of parameters

We use Levine et al. (2012) to set the discount factor for India at β= 0.9823. Following Anand and Prasad (2010), we choose the value of the inverse of the Frisch elasticity of substitution, $\varphi = 3$ Using Atkeson and Ogaki (1996), we fix the value of the inter-temporal elasticity of substitution (IES) for the rich and poor to be 0.8 and 0.5, respectively. We use the 2011-2012 Employment and Unemployment Survey of the National Sample Survey (NSS) 68^{th} round to set the share of workers in agriculture to 0.48 (this figure excludes allied activities). The share of rich in population, μ_R, is estimated to be 0.3279. The share of agriculture in consumption of the rich, δ_R, and poor, δ_p, is determined by the share of cereals and cereal substitutes in total expenditures net of expenditures on services, durables, vegetables, fuels and is equal to 0.3527 and 0.4807, respectively.

We set the measure of price stickiness for the manufacturing sector, $\theta = 0.75$, as estimated in Levine et al. (2012) for the formal sector in India. We set the value of the persistence parameters and standard errors for the agricultural and manufacturing productivity equal to those given in Anand and Prasad (2010). Thus, for productivity shocks in the agriculture

[16] We use Dynare Version 4.5.7 to calibrate the model.

sector, the AR(1) coefficient is calibrated to be, $\rho_A = 0.25$ and for the manufacturing sector, $\rho_M = 0.95$. The standard error of the regressions are given by $\sigma_A = 0.03$ and σ_M =0.02, respectively. Following Levine et. al. (2012), the elasticity of substitution between varieties of manufacturing goods is set to $\varepsilon = 7.02$ for the Indian case

We estimate an AR (1) processes on procurement and redistribution as described in equation (30) and (31) using the procurement and off-take data from *Table 27: Public Distribution System – Procurement, off-take and stocks.*[17] In our paper, we confine our analysis to procurement of wheat and rice, two of the major grains procured under the NFSA and distributed under the PDS (the Public Distribution System). Using data from 1980-2019, we first make both the procurement and off-take series stationary by subtracting the natural log of the average (value of the series) from the natural log of total procurement and total off-take (wheat and rice) series and regress it on a constant, trend and AR(1) term.[18] This yields the persistence coefficient and the standard error of the regression. The estimated persistence parameters for procurement ($\rho_{Y_A^P}$) and redistribution (ρ_ϕ) processes are 0.43 and 0.59, respectively, while the standard errors are $\sigma_{Y_A^P} = 0.13$ and $\sigma_\phi = 0.11$.

We estimate the steady state share of the rich in consumption as $s_R = 0.5367$. This is calculated by computing the share of consumption by the rich in total consumption. This is done by taking a weighted average of rich agents' consumption expenditure shares in rural and urban areas with their respective population share as weights. We calculate the economy-wide parameter λ, which is the subsidized proportion of grain, to be a weighted average of the rural and urban λ with their respective share in the total poor as weights. This implies $\lambda = 0.2457$. We calculate the steady state share of redistribution, ϕ, from equation (63).

Following Levine et al. (2012), we fix the interest rate smoothening parameter to be $\phi_r = 0.66$, with weights on inflation to be $\phi_\pi = 1.2$, and the weight on the output gap, $\phi_y = 0.5$. Table 1 below summarizes the structural parameters used in the calibration exercise in our model and their values.

[17] See the *RBI's Handbook of Statistics on the Indian Economy*, 2018-2019.

[18] Since $\phi_t \in [0, 1]$, ln $(\phi_t) < 0$. Hence, we use the logs of total (rice and wheat) off-take (instead of fractions) to estimate ρ_ϕ and σ_ϕ.

Structural and Steady State Parameters	Notation	Value	Source
Discount factor	β	0.9823	Levine et al. (2012)
Inverse of the Frisch elasticity of labor supply	φ	3	Anand and Prasad (2012)
IES - Rich	$1/\sigma_R$	0.8	Atkeson and Ogaki (1996)
IES - Poor	$1/\sigma_P$	0.5	Atkeson and Ogaki (1996)
Population share of rich	μ_R	0.3279	Calculated by Authors
Steady state consumption share of rich	s_R	0.5367	Calculated by Authors
Steady state share of subsidy in $C_{P,A,t}$	λ	0.2457	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	Levine et al. (2012)
Measure of price stickiness (M)	θ	0.75	Levine et al. (2012)
Shock Parameters			
Productivity shock in A-sector	ρ_{A_A}	0.25	Anand and Prasad (2012)
Productivity shock in M-sector	ρ_{A_M}	0.95	Anand and Prasad (2012)
Procurement shock	$\rho_{Y_{PG}}$	0.43	Estimated by Authors
Redistribution shock	ρ_ϕ	0.59	Estimated by Authors
Standard Errors			
Productivity shock in A sector	σ_A	0.03	Anand and Prasad (2012)
Productivity shock in M sector	σ_M	0.02	Anand and Prasad (2012)
Procurement shock	$\sigma_{Y_{PG}}$	0.13	Estimated by Authors
Redistribution shock	σ_ϕ	0.11	Estimated by Authors
Monetary Policy Parameters			
Interest rate smoothing	ϕ_r	0.66	Levine et al. (2012)
Weight on inflation gap	ϕ_π	1.2	Levine et al. (2012)
Weight on output gap	ϕ_y	0.5	Levine et al. (2012)

Table 1: Summary of Parameter Values

4.2 Impulse response analysis

In this section, we study the impulse response functions (IRFs) of the relevant macroeconomic variables with respect to shocks to agriculture productivity (a supply shock) and procurement and redistribution (a demand side shock). Both shocks are bench-marked against a one agent two sector NK DSGE model along the lines of Aoki's model[19] This allows us to highlight the importance of having rich and poor agents and redistributive policy shocks in the model. We also discuss the case of a monetary policy shock. 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 therefore welfare.

Depending on the nature of the shock, we benchmark these IRFs against a simple NK model a la Gali (2015, Chapter 3), Aoki, and Debortoli and Gali. We allow for the procurement wedge to be positive, i.e. $\mu_A - \bar{\delta} > 0$, and $\lambda > 0$, in our model.[20] Also, given the calibrated parameters, $\delta_p > \delta_R$. 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.

4.2.1 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-dashed line in Figures 1a-1c. A positive agricultural productivity shock raises the supply of agricultural output on impact, which in turn leads to a reduction in price of the agricultural good, P_A. This leads to a fall in agriculture inflation, π_A, overall inflation, π, and a decline (worsening) in the terms of trade, T. Nominal wages, W, rise on impact since the value of the marginal product in agriculture ($= P_A A_A$) rises (despite P_A falling). Real wages ($\frac{W}{P}$) also rise as the nominal wage rises and the price level of the economy falls. The substitution effect of higher real wages increases the cost of leisure relative to consumption and causes C to rise and leisure to fall (N to rise). Given the parameters in the model, the income effect (which causes N to fall) dominates the substitution effect, and so aggregate employment, N, falls (Figure 1b).[21] The income effect from a higher real wage also implies that the demand for the agricultural good (C_A) and manufacturing good (C_M) both rise. The rise in C_M induces a shift of employment out of the agriculture sector (N_A falls) into the manufacturing sector (N_M rises) on impact, although aggregate employment falls.

Aggregate output increases because both agriculture output (Y_A) and manufacturing output (Y_M) increase despite a fall in the terms of trade. Inflation in the manufacturing

[19] 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.

[20] 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.

[21] This is because of our estimated parameters. If we choose $\sigma_R = 0.5$ and $\sigma_P = 0.8$, aggregate employment in the economy increases.

sector falls because the sum of current and expected future marginal costs fall. This can be seen from equation (78). The output gap becomes positive because it depends on the consumption gap and the terms of trade gap. Since inflation in both the agriculture sector (π_A) and the manufacturing sector (π_M) falls, aggregate inflation (π) falls. The decline in inflation induces the central bank 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. Hence, welfare rises. In sum, a positive agriculture productivity shock leads to a rise in both poor and rich consumption, and therefore higher welfare.

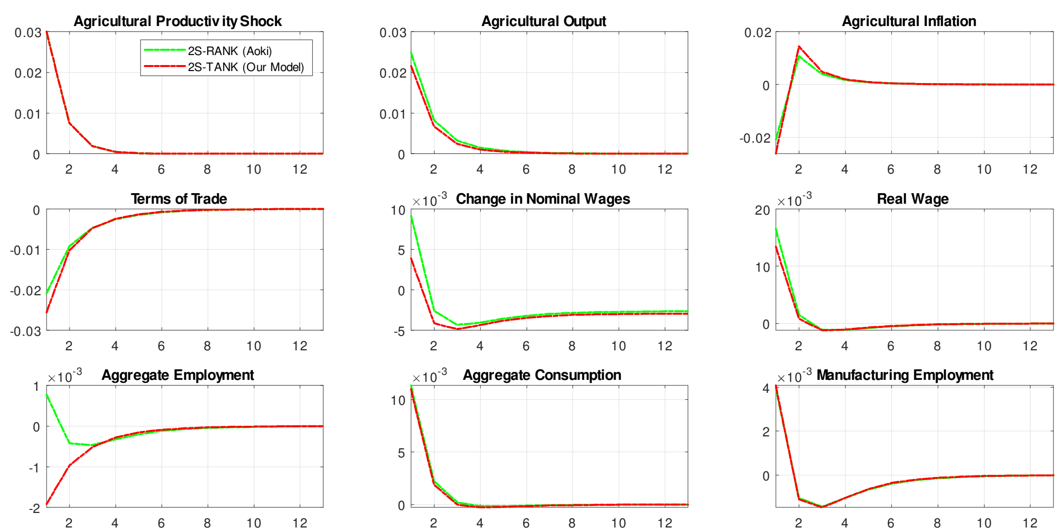

Figure 1a: Impact of single period positive agriculture productivity shock

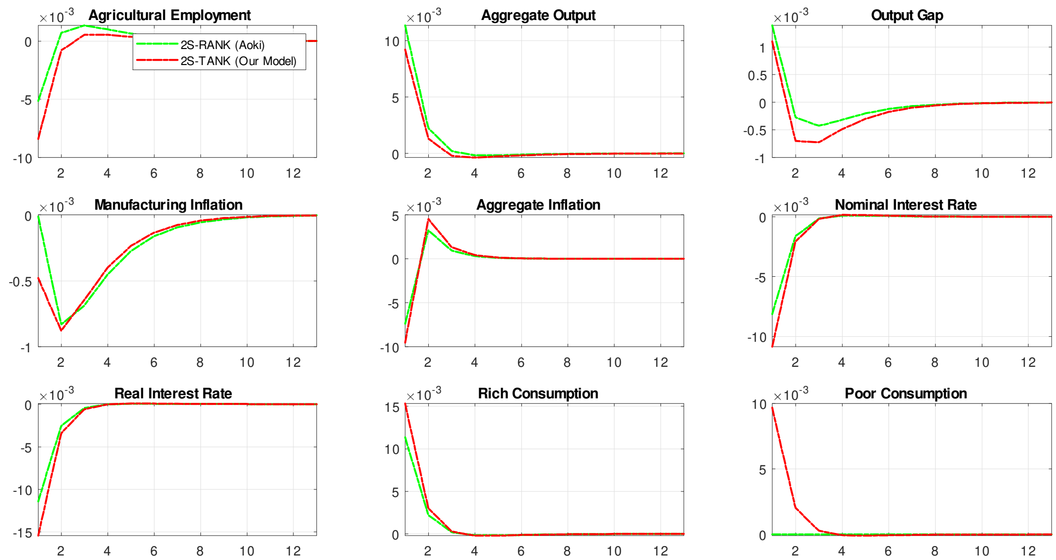

Figure 1b: Impact of single period positive agriculture productivity shock

Distributional Impact Both the rich and poor benefit from higher 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.

As can be seen in Figures 1a-1c, the model dynamics in our model and the Aoki (green-dashed line) model are qualitatively similar. In our model, the impact effect on aggregate employment is lower because of the presence of agents that have a lower inter-temporal elasticity of substitution in consumption. They would like to enjoy a greater level of leisure relative to consumption. This leads to lower consumption by the poor in our model relative to Aoki (Figure 1b), and a greater decline in aggregate employment on impact. Compared to Aoki, the steady state values of sectoral and aggregate consumption are lower.[22] This causes the effect of a positive agriculture shock to have a greater effect on (dis)inflation, and a greater effect on impact on the terms of trade. Due to a higher share of consumption of the

[22] In the Aoki model, the income effect causes consumption of both goods to rise. As the share of manufacturing in the (representative) agent's basket is larger ($1 - \delta_R = 0.648$), aggregate employment rises.

agriculture good in the consumption basket of the poor, the inter-good substitution effect is strong for the poor, and the poor agent's manufacturing consumption increases by less as compared to the rich agent's consumption in the Aoki model. In both models however, a productivity shock raises aggregate consumption and welfare.

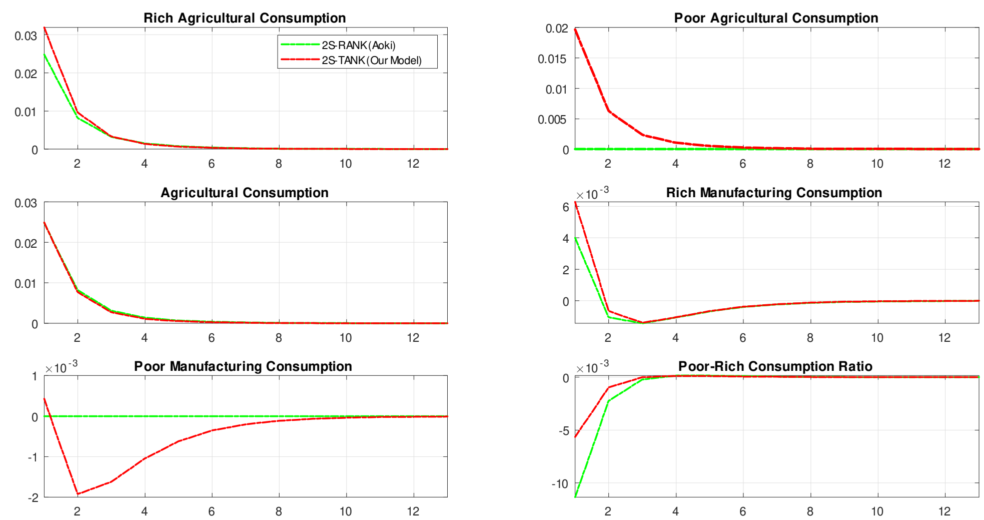

Figure 1c: Impact of single period positive agriculture productivity shock

4.2.2 Transmission of a single period procurement and redistribution shock

We first describe what happens in our (2 sector TANK) model. This corresponds to the red-dashed line in Figures 2a-2c. A procurement and re-distribution (which are orthogonalized) shock acts like a demand shock to the economy.[23] On impact, a procurement and redistribution 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 sector, equilibrium in labor markets (the same nominal wage in both sectors) means that economy wide real wages rise.[24]

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

[24]This is broadline 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 Shrinivas, Baylis, and Crost (2019).

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. However, in the presence of a procurement and redistribution shock, their consumption is governed by another effect, a "re-distributive effect". The redistributive aspect of the policy 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 $C_{P,M}$.[25]

Under the current parametrization, consumption of the rich is determined by the inter-temporal substitution effect while the poor agent's consumption is determined by income and redistributive effects. As π_A is positive and current and future marginal costs of production are positive, manufacturing and aggregate inflation are positive on impact. A positive output gap obtains because under flexible prices, manufacturing prices increase in response to higher real wages. This causes a greater reduction in manufacturing output relative to the sticky price level of output causing 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.

[25] 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.

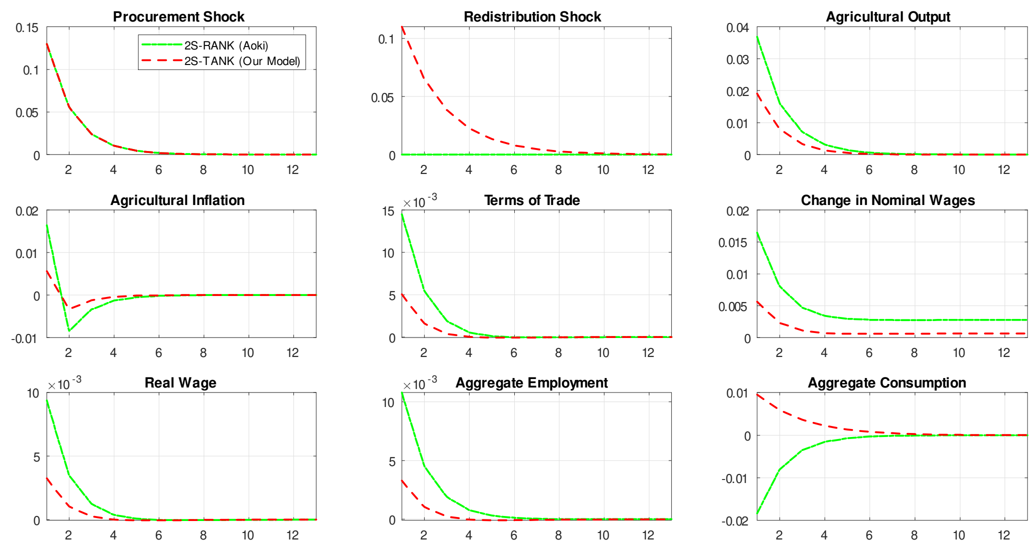

Figure 2a: Impact of single period positive procurement and redistribution shock

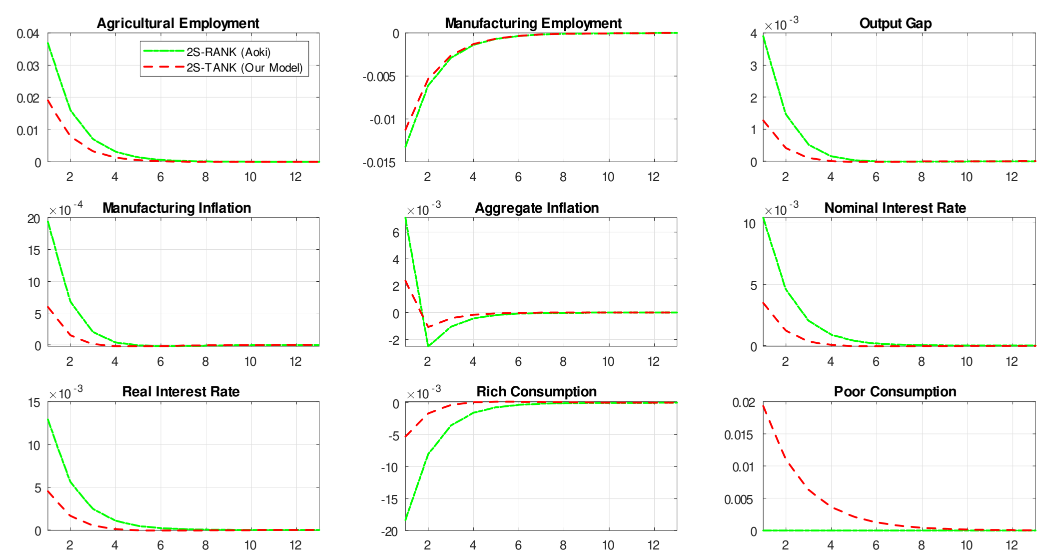

Figure 2b: Impact of single period positive procurement and redistribution shock

Distributional Impact As can be seen in Figure 2c, rich agriculture and rich manufacturing consumption fall because of inter-temporal 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.

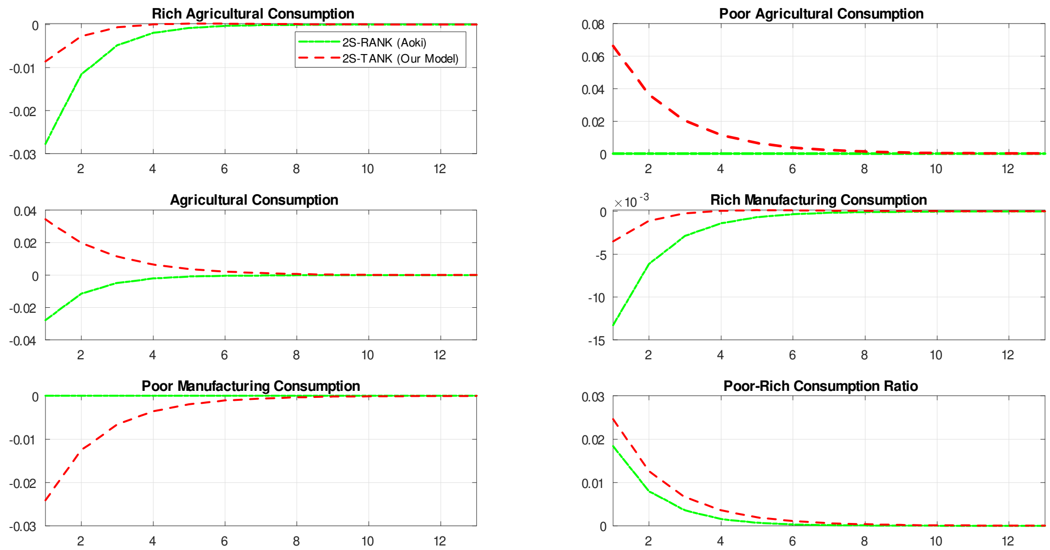

Figure 2c: Impact of single period positive procurement and redistribution shock

Compared to Aoki's model (green dashed line), there are interesting differences.[26] In the 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.

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

4.2.3 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-dashed line) leads to a muted impact (less monetary transmission) compared to a variety of benchmarks (the simple NK model (magenta line), Aoki (green-dashed line), and Debortoli and Gali (blue dashed line)).[27] Crucially, we show that monetary policy has both output effects *and* redistributive effects, as in the HANK literature. 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-dashed 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, the 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) good falls (inter-good substitution effect). Consequently N_A rises on impact, and therefore,

[27] 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 $\sigma_R = \sigma_P = 1.25$, 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 a contractionary monetary policy shock that are consistent with Gali (2015, Chapter 3, page 69).

N_M falls.

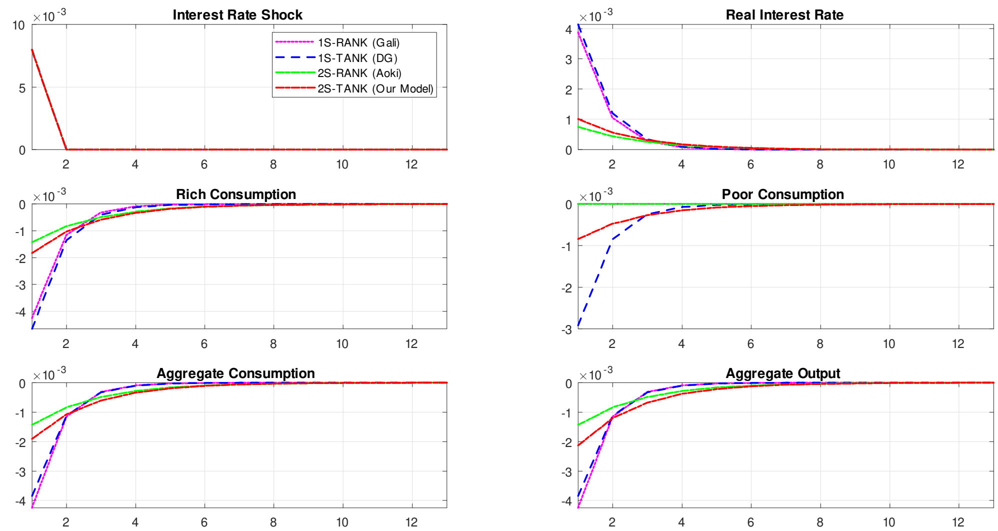

Figure 3a: Impact of single period contractionary monetary policy shock

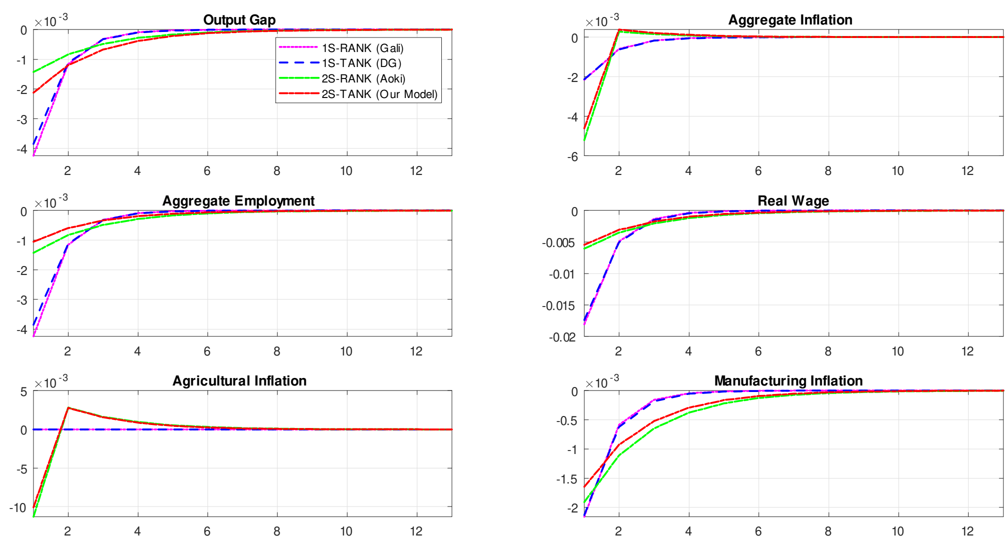

Figure 3b: Impact of single period contractionary monetary policy shock

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.[28] However, as the output

[28] 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.

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), $C_R = C_P = C < 0$.

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 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 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. This implies the welfare losses from contractionary monetary policy shocks are less in magnitude because of the muted increase in real interest rates, which in turn, is driven by the presence of a flexible price sector.

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.

Our analysis therefore highlights that monetary policy shocks have *both* output effects and redistributive effects.

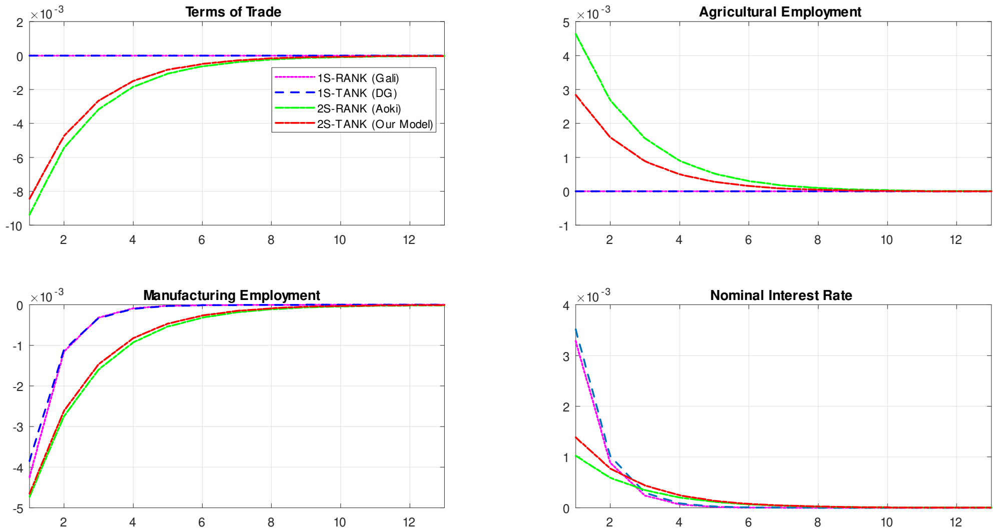

Figure 3c: Impact of single period contractionary monetary policy shock

5 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 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 tractable two-sector (agriculture and manufacturing) two-agent (rich and poor) New Keynesian DSGE model with redistributive policy shocks. We calibrate the model to the Indian economy. There are two novel aspects of our framework. First, we extend the framework of Debortoli and Gali to two sectors in a tractable way. 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.

We show that a procurement and redistribution shock leads to higher sectoral and aggregate inflation and higher aggregate consumption in the economy, even though such shocks raise real interest rates, and there is a decline in the consumption of the rich. Our main result is that for an inflation targeting central bank, consumer heterogeneity matters for whether monetary policy responses to shocks raise aggregate welfare or not. Hence, it is important to take into account consumer heterogeneity when evaluating the general equilibrium effects of monetary policy in the economy. 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.

For future work, we plan to characterize optimal monetary policy in our framework.

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6 Technical Appendix

6.1 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 inter-temporal 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: $P_{A,t}C_{P,A,t}^{O} + P_{M,t}C_{P,M,t} = M_t$, where M_t corresponds to the income of the poor, by choosing $C_{P,A,t}$ and $C_{P,M,t}$ optimally. Note that $C_{P,A,t}^{O} = (1-\lambda_t)C_{P,A,t}$ 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

6.2 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

$$s_R = \frac{\mu_R C_R}{C} \tag{52}$$

and that of the poor as

$$1 - s_R = \frac{(1-\mu_R) C_P (1-\lambda)^{-(1-\delta_p)} (1-\lambda(1-\delta_p))}{C}. \tag{53}$$

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 define the steady state employment share of the rich, N_R

$$N_R = \mu_R N \tag{54}$$

and the employment share of the poor as N_P

$$N_P = (1-\mu_R) N. \tag{55}$$

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

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

The steady state aggregate consumption is therefore,

$$
C = \Gamma^{\frac{1}{\sigma_R - \sigma_P}} \tag{56}
$$

where Γ is a constant. Once we know the expression for C, equations (52) and (53) yield C_R and C_P, respectively. From the market clearing condition (equation ((34)), the production function for manufacturing, and the optimal demand allocation (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 $\bar{\delta} = s_R \delta_R + \frac{(1-s_R)\delta_P}{1-\lambda(1-\delta_P)}$.

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

$$
N = \frac{N_M}{1-\mu_A} = \frac{1-\bar{\delta}}{1-\mu_A} C. \tag{57}
$$

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

$$
N = \frac{N_A}{\mu_A} = \frac{Y_A}{\mu_A} = \frac{1}{\mu_A} \left[\bar{\delta} C + Y_A^P (1-\phi) \right]. \tag{58}
$$

Equating (57) and (58), 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

$$c = \frac{1-\mu_A}{1-\bar{\delta}} \tag{59}$$

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,

$$c_A = \frac{\bar{\delta}(1-\mu_A)}{\mu_A(1-\bar{\delta})}. \tag{60}$$

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.(53). 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

$$\lambda = \frac{(\mu_A-\bar{\delta})\phi(1-\lambda(1-\delta_P))}{\delta_P(1-\mu_A)(1-\phi)(1-s_R)} \tag{61}$$

Solving for λ, we obtain

$$\lambda = \frac{\phi(\mu_A-\bar{\delta})}{(1-\delta_P)\phi(\mu_A-\bar{\delta}) + \delta_P(1-\mu_A)(1-s_R)(1-\phi)}. \tag{62}$$

Solving for ϕ,this implies

$$\phi = \frac{\lambda\delta_P(1-\mu_A)(1-s_R)}{\lambda\delta_P(1-\mu_A)(1-s_R) + (\mu_A-\bar{\delta})(1-\lambda(1-\delta_P))}. \tag{63}$$

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

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

6.3 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 $\lambda_t = \frac{\phi_t Y_{A,t}^P}{C_{P,A,t}(1-\mu_R)}$, and using equation (11), we have

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

Log linearization of this equation gives

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

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

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

We assume that rich and poor labor supply is proportional to total labor supply, i.e., $N_{R,t} = \mu_R N_t$ and $N_{P,t} = (1-\mu_R)N_t$, we have $\widehat{N}_{R,t} = \widehat{N}_{P,t} = \widehat{N}_t$. for all t. Combining this with equations ((40) we get equation (42).

Derivation of Equation (64): 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,

$$\begin{aligned}\widehat{C}_{R,t} = &\left[s_R + \frac{(1-s_R)\sigma_R(1-\lambda_p\tau)}{\sigma_P+\lambda_p}\right]^{-1} \qquad (64)\\ &\left[\widehat{C}_t - \Psi\left[\frac{\widehat{\phi}_t}{\phi} + \widehat{Y}_{A,t}^P\right] - \left\{\Psi(1-\delta_P) + (1-s_R)(\delta_P-\delta_R)\left(\frac{\sigma_P+\lambda_P-(1-\lambda_P\tau)}{\sigma_P+\lambda_P}\right)\right\}\widehat{T}_t\right]\end{aligned}$$

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

$$\widehat{Y}_t = E_t\{\widehat{Y}_{t+1}\} - c\Phi^{-1}\left[\widehat{R}_t - E_t\{\Pi_{t+1}\}\right] \tag{65}$$
$$- c\left[(1-\delta_R)\left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right) + \Psi\left\{(1-\delta_p) + (\delta_p - \delta_R)z\right\}\right] E_t\left\{\Delta\widehat{T}_{t+1}\right\}$$
$$- c\left[\left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right) + \Psi\right] E_t\left\{\Delta\widehat{Y}^P_{A,t+1}\right\} - c\left[\frac{\Psi}{\phi} - \left(\frac{1}{1-\phi}\right)\left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right)\right] E_t\left\{\Delta\widehat{\phi}_{t+1}\right\}$$

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

$$\widehat{Y}_{A,t} = \frac{c}{\mu_A}\left[s_R\delta_R\widehat{C}_{R,t} + (1-s_R)\frac{\lambda_p}{x\lambda_s}\widehat{C}_{P,t} + \left\{\frac{(1-s_R)\lambda_p(1-\delta_p)}{x} + \left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right)\right\}\widehat{Y}^P_{A,t}\right] \tag{66}$$
$$+ \frac{c}{\mu_A}\left[\frac{(1-s_R)\lambda_p(1-\delta_p)}{x\phi} - \left(\frac{1}{1-\phi}\right)\left(\frac{\mu_A - \bar{\delta}}{1-\mu_A}\right)\right]\widehat{\phi}_t$$
$$- \frac{c}{\mu_A}\left[s_R\delta_R(1-\delta_R) + \frac{(1-s_R)\lambda_p(1-\delta_p)}{x\lambda_s}\right]\widehat{T}_t$$

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

$$\widehat{Y}_{M,t} = \frac{1}{1-\bar{\delta}}\left[s_R(1-\delta_R)\widehat{C}_{R,t} + \frac{(1-s_R)(1-\delta_P)(1-\lambda)(1+\lambda_p)}{x}\right]\widehat{C}_{P,t} \tag{67}$$
$$+ \frac{1}{1-\bar{\delta}}\left[s_R(1-\delta_R)\delta_R + \frac{(1-s_R)(1-\delta_P)(1-\lambda)(\delta_p - \lambda_p(1-\delta_p))}{x}\right]\widehat{T}_t$$
$$- \frac{1}{1-\bar{\delta}}\left[\frac{\lambda_p(1-s_R)(1-\lambda)(1-\delta_p)}{x}\right]\left(\frac{\widehat{\phi}_t}{\phi} + \widehat{Y}^P_{A,t}\right)$$

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

$$\widehat{N}_t = \mu_A\widehat{N}_{A,t} + (1-\mu_A)\widehat{N}_{M,t} = \mu_A\widehat{Y}_{A,t} + (1-\mu_A)\widehat{Y}_{M,t} - \widehat{A}_t \tag{68}$$

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

$$\widehat{W}_t - \widehat{P}_t = \varphi\widehat{N}_t + \Phi\widehat{C}_t - \Psi\Phi\left[\frac{\widehat{\phi}_t}{\phi} + \widehat{Y}^P_{A,t} + \{(1-\delta_p) + (\delta_p - \delta_R)z\}\,\widehat{T}_t\right] \tag{69}$$

Substituting equations (66) and (67) into (68), and the resulting equation into (69), we get

$$\widehat{W}_t - \widehat{P}_t = \Lambda \widehat{C}_t + \{\varphi(1-c) - \Psi\Phi\} \widehat{Y}^P_{A,t} - \left\{\varphi(1-c)\left(\frac{1}{1-\phi}\right) + \frac{\Psi\Phi}{\phi}\right\} \widehat{\phi}_t \\ - [\varphi c(1-s_R)\{\delta_p \tau + \delta_P - \delta_R\} + \Psi\Phi\{1-\delta_P + (\delta_P - \delta_R)z\}] \widehat{T}_t - \varphi \widehat{A}_t \tag{70}$$

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

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

$$\widehat{mc}_{M,t} = \widehat{W}_t - \widehat{P}_t + \delta_R \widehat{T}_t - \widehat{A}_{M,t} \tag{71}$$

6.4 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 (71) 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 (70), we get

$$\widehat{C}^N_t = \Lambda^{-1}\left\{\varphi(1-c)\left(\frac{1}{1-\phi}\right) + \frac{\Psi\Phi}{\phi}\right\}\widehat{\phi}_t \\ - \Lambda^{-1}\{\varphi(1-c) - \Psi\Phi\}\widehat{Y}^P_{A,t} + \Lambda^{-1}\left(\varphi \widehat{A}_t + \widehat{A}_{M,t}\right) \\ + \Lambda^{-1}\left[(1-s_R)\varphi c \delta_P \tau + \Psi\Phi(1-\delta_p) + (\delta_p - \delta_R)\left\{(1-s_R)\varphi c + \frac{\Psi\Phi(\sigma_P + \lambda_P - (1-\lambda_P\tau))}{\lambda_P(1+\tau\sigma_P)}\right\} - \delta_R\right]\widehat{T}^N_t \tag{72}$$

Note that procurement is the same under both sticky and flexible prices. Substituting out for c and $1-c$ in the above expression, the flexible price counterpart of equation (38) is

$$\widehat{Y}^N_t = c\widehat{C}^N_t + (1-c)\left[(1-\delta_R)\widehat{T}^N_t + \widehat{Y}^P_{A,t} - \left(\frac{1}{1-\phi}\right)\widehat{\phi}_t\right] \\ = \left(\frac{1-\mu_A}{1-\bar{\delta}}\right)\widehat{C}^N_t + \left(\frac{\mu_A - \bar{\delta}}{1-\bar{\delta}}\right)\left[(1-\delta_R)\widehat{T}^N_t + \widehat{Y}^P_{A,t} - \left(\frac{\phi}{1-\phi}\right)\widehat{\phi}_t\right] \tag{73}$$

Substituting equation (72) into equation (73), forwarding one period and then subtracting from each other, we obtain

$$
\begin{aligned}
\widehat{Y}_t^N &= E_t\left\{\widehat{Y}_{t+1}^N\right\} - (1-\delta_R)\{1-c+c\Psi\}E_t\left\{\Delta\widehat{T}_{t+1}^N\right\} \qquad (74)\\
&- [c\Lambda^{-1}\{(1-s_R)\varphi c\left((\delta_p-\delta_R)+\delta_p\tau\right)-\delta_R+\Phi\Psi\left\{1-\delta_p+(\delta_p-\delta_R)z\right\}+(1-c)(1-\delta_R)]E_t\left\{\Delta\widehat{T}_{t+1}^N\right\}\\
&- [c\Lambda^{-1}\{\Psi\Phi\}+(1-c)(1-\Lambda^{-1}\varphi c)]E_t\left\{\Delta\widehat{Y}_{PA,t+1}\right\}\\
&- \left\{c\Lambda^{-1}\left[\frac{\Psi\Phi}{\phi}\right]-\left(\frac{1}{1-\phi}\right)(1-c)(1-\Lambda^{-1}\varphi c)\right\}E_t\{\Delta\widehat{\phi}_{t+1}\}\\
&- c\Lambda^{-1}E_t\left\{\varphi\Delta\widehat{A}_{t+1}+\Delta\widehat{A}_{M,t+1}\right\}
\end{aligned}
$$

Finally, substituting (44) into (38) and then subtracting equation (74) 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

$$\widetilde{C}_t = \frac{1}{c}\left[\widetilde{Y}_t - (1-c)(1-\delta_R)\widetilde{T}_t\right] \qquad (75)$$

From equation (71) and given that $\widehat{mc}_{M,t}^N = 0$,

$$\widetilde{mc}_{M,t} = \widetilde{W}_t - \widetilde{P}_t + \delta_R\widetilde{T}_t. \qquad (76)$$

And from equation (70),

$$\widetilde{W}_t - \widetilde{P}_t = \Lambda\widetilde{C}_t - \left[\varphi c(1-s_R)\left\{\delta_p\tau+(\delta_p-\delta_R)\right\}+\Psi\Phi\left\{1-\delta_p+(\delta_p-\delta_R)z\right\}\right]\widetilde{T}_t \qquad (77)$$

Substituting equation (77) in equation (76) yields the manufacturing sector real marginal cost gap in terms of the aggregate consumption gap and the terms of trade gap.

$$\widetilde{mc}_{M,t} = \Lambda\widetilde{C}_t + \left[\delta_R - \varphi c(1-s_R)\left\{\delta_p\tau+(\delta_p-\delta_R)\right\}-\Psi\Phi\left\{1-\delta_p+(\delta_p-\delta_R)z\right\}\right]\widetilde{T}_t \qquad (78)$$

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

$$\pi_t = \pi_{M,t} + \delta_R\Delta\widetilde{T}_t \qquad (79)$$

Substituting equations (75) and (79) into equation (28) yields equation (49).

7 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 population to be 833.1 million and 377.1 million 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 NSS Report 555- Level and Pattern of Consumer Expenditure 2011-12.
  - *Share of agriculture purchases by poor*: $\delta_P = 0.4807$.
    - We split the 7th 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 NSS-Report 555: 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 NSS-Report 565-Public Distribution System and Other Sources of Household Consumption 2011-12 (Page 18). It states Percentage of consumption (quantity) coming from PDS for households in different 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 (63), the steady state value of ϕ turns out to be 47.93% .