The Contribution of Food Subsidy Policy to Monetary Policy in India

William Ginn, Marc Pourroy

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Abstract

Food price volatility is a major threat for welfare, economic prosperity and political stability. The monetary authority is generally viewed in the literature as the only institution responsible for price stability, however this approach overlooks the importance of food price stabilization policies using fiscal instruments. We develop and estimate a Bayesian DSGE model that incorporates monetary and fiscal policy tailored to India, replicating food demand and food supply subsidies. We find that following a world food price shock, CPI and therefore interest rate volatility would be 21% higher in the absence of food subsidies. Putting this effect aside would lead to overestimating the effectiveness of inflation targeting by the central bank. Accordingly, we find that the subsidy policy has large heterogeneous distributional welfare effects: while farmers benefit from all subsidies, the inclusion of urban households into the demand subsidy program is required to offset supply subsidy welfare cost.

JEL Classification: E52; E60; E30; E32.

Keywords: Monetary Policy; Commodities; Food prices; Price stabilisation; DSGE Model.

Highlights :

- We develop and estimate a DSGE model using Indian data that incorporates food supply and demand subsidies.
- Empirical evidence suggests that food subsidies create a policy-induced food price-stickiness.
- Food subsidies reduce inflation volatility and monetary policy reaction.
- While the demand subsidy improves all household's welfare, we find that the supply subsidy has distributional effects.

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1 Introduction

Not since the 1970s has the world experienced numerous episodes of high and volatile food inflation as it has since the mid-2000s (see Figure 16 in Appendix 8.1), acknowledged as an international crisis. This creates a challenge for the conduct of monetary policy, particularly for LMICs with a large proportion of households that are credit constrained and the share of food expenditures is large.

The literature generally assumes that the central bank is responsible for price stability (e.g., Woodford, 2003). However, Ginn and Pourroy (2019) document that food subsidies are a common fiscal policy instrument designed to stabilize food prices in LMICs, where the share of people living under the poverty line is high; are prevalent in countries where the share of agricultural production is high; and are associated with households in countries that have a high share of food expenditures. Food price subsidies produce a gap between the actual selling price and a benchmark price (e.g., Sdralevich et al., 2014, Koplow, 2009 and Clements et al., 2013). If such a gap exists, food prices are then considered "policy-driven".

We incorporate a food price subsidy and estimate a DSGE model using Indian data. Using India as an empirical study, our paper contributes to a small, albeit burgeoning literature on the conduct of monetary and fiscal policy in the presence of a food price shock. India provides an interesting case in point considering high food inflation has been chronic, particularly from 2006 to 2014, which was one of the highest in emerging economies (Bhattacharya and Sen Gupta, 2018), where the average food inflation during that period was 8.4% (see Figure 1).[1] India also represents the second most populous country and has the largest policy-driven distribution of subsidized food in the world. Food inflation has an important prominence in the conduct of monetary policy in India considering food represents a sizable share of household expenditures and where aggregate inflation expectations are anchored by food inflation (Anand et al., 2014 and Anand et al., 2016).

Accordingly, our research addresses three questions: to what extent does fiscal policy via food subsidies create price stickiness? Does the Reserve Bank of India (RBI) react to food price shocks? Is the interaction between monetary and fiscal policy a strategic complement or substitute? Stripped to its core, these questions relate to price stabilization, a topic central to macroeconomic research. Food price shocks can have potential repercussions on aggregate price stability, where the latter is considered one of, if not the most important, objectives of most central banks around the world, a framework described as inflation targeting. The RBI has adopted an inflation targeting framework in May 2016 with a numerical objective for the CPI growth.[2]

To our knowledge, there are a couple of novelties in our paper. We develop the first empirical (as opposed to calibrated) DSGE model to estimate the mechanisms through which food price shocks affect monetary and fiscal conditions via Bayesian methods. We incorporate an incomplete pass-through of food prices and fiscal policy food designed to stabilize food prices. Second, our paper is the first research that establishes and quantifies monetary policy and fiscal policy responses as a strategic substitute. By developing an empirically-grounded framework, our research goes beyond existing papers by showing that the optimal monetary policy is dependent on the effective subsidy policy and by discussing the distributional effects of these policies. We apply an empirical approach by using the posterior values from the empirical model to conduct welfare evaluation relating to welfare gains of different fiscal policy options. This has two main advantages: this method does not suffer from an "identification problem" (Lubik and Schorfheide, 2007), as in single-equation estimation methods, and we produce counterfactual models to evaluate the interaction of monetary and fiscal policy by simulating what would be the monetary policy reaction to a world food price shock with and without food subsidies to understand the effect of that policy on the other variables.

[1] The inflation rate is more than double the inflation rate relative to 2000 to 2005 (3.9%).

[2] The inflation target is set for a period of five years, and is currently defined as 4% CPI inflation with a band of ± 2%.

Our contribution overlaps with four strands of literature. First, the model is based on a voluminous literature on sticky price models (e.g., Woodford, 2003 and Galì, 2008) which intersects with three features that are representative of LMICs: a fraction of consumers have no access to financial instruments (Anand et al., 2015) and food prices are subsidized by a fiscal authority (Ben Aïssa and Rebei, 2012). The model incorporates a food and manufacturing sector representative of a LMICs. We decompose the food sector into a grain and non-grain sector (Ghate et al., 2018). We develop a model that captures the main features of government intervention following a pre-announced rule to concomitantly stabilize the producer price in the grain sector while shielding households from price fluctuations. There is a narrow literature to address price subsidies using a theoretical definition of optimal monetary policy. Ben Aïssa and Rebei (2012) develop a DSGE model to estimate welfare optimizing monetary policy rules for a large set of countries. They conclude that the optimal policy is a function of markets distortions. Considering that subsidies are heterogeneous across countries, they find no single optimal monetary rule would work for all countries. Using a DSGE model for a middle-income country, Ginn and Pourroy (2019) find that coordinated fiscal and monetary reactions to food price shocks can improve aggregate welfare. They also underline that subsidies smooth consumer price index (CPI) and reduce the need for monetary policy action.[3]

The second strand relates to the transmission of global food price pass-through to domestic consumer prices. This area of empirical research is limited and has not necessarily achieved consensus. Ciccarelli and Mojon (2010) argue that inflation is largely a global phenomenon. Parker (2018) confirms these findings for high-income countries but only to a limited extent for LMICs. Fernández et al. (2017) show how commodity prices, including food in an agricultural index, transmit world disturbances. Focusing on the BRIC economies, Mallick and Sousa (2012) uncover the importance of commodity price shocks which lead to a rise in inflation. Gelos and Ustyugova (2017) question why all countries do not react homogeneously when facing commodity price shocks and find that economies with a larger weight of food in the CPI experience more sustained inflationary effects. Holtemöller and Mallick (2016) and Bekkers et al. (2017) find that food price shocks are, in part, explained by the international food price. In an RBI report, Misra and Sangita (2014) find evidence for co-movement between international and domestic prices for all food groups from 2002-2008 for the case of India.We contribute to this literature in two ways. First, our empirical results confirm the presence of an incomplete pass through between the international food price and domestic consumer food price. Second, our model allows us to decompose the pass-through into several elements: exchange-rate pass-through, exchange rate change, food price subsidy and consumption substitution.

The third strand relates to the choice of policy indexation, which can pose challenges for monetary policy, particularly in recent years considering food inflation has propagating secondary effects on the aggregate price level as well as playing a pivotal role in inflation expectations (e.g., Anand et al., 2014, Anand et al., 2016). The foregoing consensus, largely based on the novel work of Aoki (2001), is that targeting core inflation (which excludes volatile components from headline inflation, e.g. energy and food), as opposed to headline inflation, is optimal, since fully-flexible prices are posited as mean-reverting in the long-run and that targeting core inflation can achieve headline price stability (see Goodfriend, 2007). While consistent with high-income economies, the new Keynesian framework has been extended to encompass LMICs in particular incomplete financial markets (Anand et al., 2015), a large share of domestically produced food in the consumer basket (Pourroy et al., 2016) and an exposure to global food price shocks (Catão and Chang, 2015). These authors consistently find that targeting core inflation may not necessarily be welfare maximizing. We contribute to this literature by developing an empirically-grounded framework showing that optimal monetary policy is dependent on the effective subsidy

[3]Producer subsidies may operate in parallel. Chen et al. (2014) find that, while a target zone policy with agricultural product purchases may not stabilize prices, a target zone policy with price subsidy can stabilize the wholesale price level.

policy and by discussing the distributional effects of these policies.

The fourth strand relates to a sparse literature on the conduct of monetary policy to control for food inflation. Yu (2014) finds that China's monetary easing can have heterogeneous distributional effects such that five of seven food prices considered[4] decline in response to a money expansion. This can in turn improve (harm) consumer (producer) welfare. Kara (2017) finds a significant weight for food inflation in the U.S. Federal Reserve's Taylor Rule. Ginn and Pourroy (2020) estimate an alternative Taylor rule and similarly find that the Chilean Central Bank responds to short-term developments of food inflation. They show that a food price shock generates second-round effects despite monetary policy reaction. As opposed to Kara (2017) and Ginn and Pourroy (2020) that conclude the central bank's ability to control prices, Bhattacharya and Jain (2020) show that at the backdrop of food inflation, a monetary tightening may in turn precipitate food inflation in a panel of emerging economies.[5] Our results go in the opposite direction. Similarly to what Kara (2017) has shown for the US, we find evidence of a non-trivial weight for food inflation in the RBI's Taylor Rule. Our results add to this literature by estimating the food weight using an alternative Taylor rule, while controlling for the effect of the food subsidy policy. In the absence of such a feature in our model, we would overestimate the effectiveness of the RBI's ability to tame a food price shock, which in turn contributes to price stabilization.

Our main results are fourfold:

- We confirm the existence of a policy-induced price-stickiness for food goods due to a producer and consumer price subsidy, hence monopolistic competition *à la* Calvo is not the only form of nominal rigidity;
- Evaluating the fit of an alternative Taylor rule, we find that the RBI does not overlook food price inflation, the weight of food inflation in the Taylor rule being close to its weight in the CPI;
- We show that fiscal policy via food subsidy complements the RBI with regard to price stability: in the absence of food subsidies, assuming the same monetary policy reaction function based on the posterior values, food-grain inflation volatility would be 31% higher; because of substitution effects non-grain inflation volatility would be about 9% higher; and because of second round effect non-food inflation volatility would be 7% higher following a one standard-deviation shock of the world food price. Overall, the interest rate responding to headline inflation, we find the central bank would have to increase its interest rate by an additional 21% in response to world food price shock.
- Our results indicate that fiscal intervention via a food price subsidy reduces aggregate welfare, albeit we find heterogeneous distributional effects by household type. The subsidy benefits credit constrained (non-Ricardian) households with no access to financial instruments to smooth consumption.

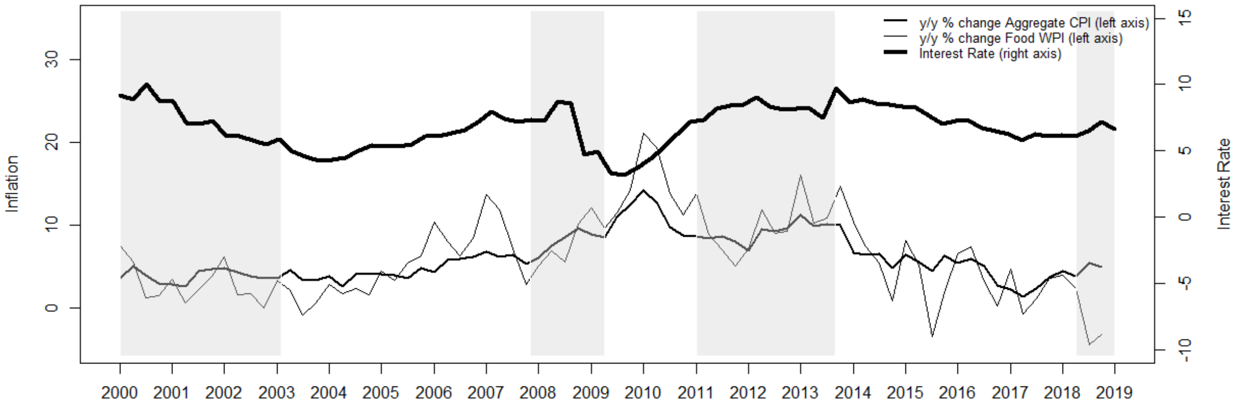
Overall, our results capture a fiscal policy-driven form of food price-stickiness that operates in parallel with, yet is different to, the classic Calvo monopolistic competition framework. This underscores the importance of a coordinated fiscal and monetary policy response considering the policy reactions are interdependent with regard to stabilizing food prices. Furthermore, our findings challenge a fiscal policy response that does not conform to a policy targeting vulnerable members of society.

The rest of the paper is organized as follows. Section 2 presents evidence on food subsidies and the conduct of monetary policy in India. Section 3 describes the model. Section 4 presents the results of the Bayesian estimation. Section 5 is dedicated to the counterfactual analyse of food subsidies. Section 6 contains the welfare results. Section 7 concludes the paper to include policy implications.

[4]These include soybean oil, poultry meat, pork, beef and mutton.

[5]Similarly Balke and Wynne (2007) find that, in the short run, nearly equal proportions of goods prices significantly increase and decrease in response to a contractionary shock.

Figure 1: Indian Inflation and Interest Rate



Sources: FRED and CEIC. Shaded areas indicate OECD recession dates.

2 Evidence of Policy Intervention

Intervention by means of a food subsidy is complex and is usually rationalized to prevent market failure in terms of food insecurity. Ginn and Pourroy (2019) find that food subsidies are a common instrument used to address food price stabilization in less advanced economies where the share of people living under the poverty line is high, are prevalent in countries where the share of agricultural production is high and are associated with households in countries having a high share of food expenditures.

Food subsidies can be viewed as a survival mechanism along two dimensions. The first relates to the government, which must be "seen to be doing something" (Poulton et al., 2006). Bellemare (2015) shows that food price spikes are correlated with civil unrest. Arezki and Bruckner (2011) find that "during times of international food price increases political institutions in Low Income Countries significantly deteriorated" (p. 11). Gouel (2014) discusses in a literature review that governmental stabilization policies may be considered as a second-best intervention in an absence of insurance and futures markets.

The second dimension involves the reduction of risk regarding food insecurity for households. According to Rocha (2007), "[t]here will be situations in which the only way of guaranteeing food security is through bypassing markets and having direct state provision of food..." Rocha (2001) argues that while food is not a public good, food security is, and that free markets may not satisfy a "socially efficient" quantity. According to Rashid (2018), "...the issue is not finding policy justifications for ensuring price stability, but rather finding appropriate policy instruments and institutions to address it..." (p. 2).

Timmer (1989) identifies three competing schools of thought concerning food price stabilization. A *free market* school, which is synonymous to a neo-classical synthesis, posits that food prices reflect market supply and demand conditions in the absence of intervention. The *structuralist* view, on the other hand, suggests domestic pricing may be misdirected; that prices may need to be set according to some income distribution mechanism. The *stabilization* school is a mix of the *free market* and *structuralist* views such that food price intervention may be warranted, yet overlooking a long-term trend may be sub-optimal which in turn could lead to a high fiscal burden.

Ginn and Pourroy (2019) provide evidence that the free market school is less in favor based on some form of food price policy intervention in lower income countries.[6] India is no exception such that food subsidies,

[6]Ginn and Pourroy (2019) find that food subsidies are common in countries where the share of households living under the poverty line is higher; the share of food consumption is higher; and food access is lower.

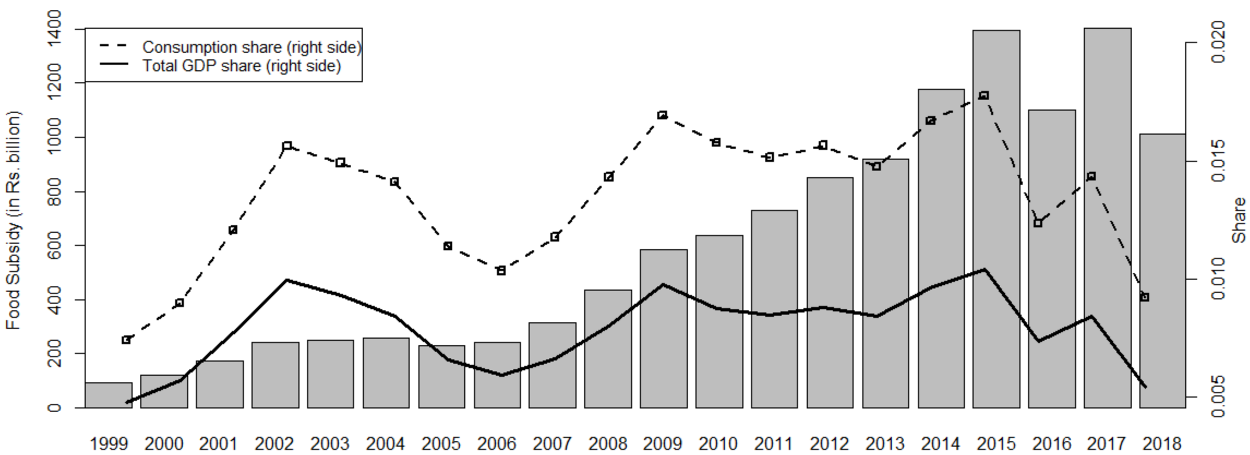
specifically for food grains, are a persistent and structural feature.

The food policy in India is based on a two tier policy, with a focus on production and consumption. In the first tier, the Government of India announces the minimum support prices (MSP) of food grains for procurement on the basis of the recommendation of the Commission of Agricultural Costs and Prices (CACP).[7]

The second tier relates to the Public Distribution System (PDS), which was introduced in the 1940s following the Bengal famine. The PDS aims to provide mainly food grains to people below the poverty line at subsidised prices from the PDS and food grains to people above the poverty line at relatively higher prices, known as the central issue price (CIP). The PDS is the largest distribution of subsidized food in the world (Balani, 2013) and is the largest safety net program in India in terms of government expenditure and beneficiary households (Bhattacharya et al., 2017). In 1992, the Revamped PDS (RPDS) replaced PDS to deliver food to mainly remote, urban areas. RPDS was replaced by the Targeted PDS in 1997, which targeted the poor in all areas (OECD, 2018). In 2013, the National Food Security Act extended access to a larger share of the population. According to Tadasse et al. (2016), "[a]lthough food grains are regarded mainly as commodities on the global market, they constitute the basic food of the poor and the "currency" of the poorest two billion people in the world."

Food subsidies in India have significantly increased since the turn of the century, accounting for circa 1.8% (1%) of total consumption (GDP) in 2015 (see Figure 2). The subsidy has increased considerably driven by elevated and persistent food prices (see Figure 1). High food inflation has been chronic, particularly from 2006 to 2014 where the average food inflation was 8.4%.[8]

Figure 2: Food Subsidy



Sources: Ministry of Finance and FRED data. FRED data includes total GDP (mnemonic INDGDPNADSMEI) and private consumption GDP (mnemonic INDPFCEADSMEI). As the food subsidy is based on the annual budget calendar which begins in April, we take the subsidy spend from the beginning fiscal year divided by GDP of the associated annual GDP measure as a proxy for the percentage share.

[7]The CACP takes into account numerous factors based on demand and supply conditions, which includes domestic and international prices. Sharma and Alagh (2013) find that the rising food subsidy is determined by high domestic and world food prices.

[8]This is more than double the inflation rate relative to 2000 to 2005 (3.9%).

3 The Model

We develop an open economy DSGE model which incorporates a food sector (F) and a manufacturing or non-food sector (N) (e.g., Catão and Chang, 2015, Pourroy et al., 2016 and Ginn and Pourroy (2019)), where the latter is decomposed by food grains (G) and food non-grains or vegetables (V) (Ghate et al., 2018). We follow Anand et al. (2015), Portillo et al. (2016) and Pourroy et al. (2016) by incorporating food subsistence in utility.[9]

Labor is assumed to be immobile between food and non-food sectors (e.g., Anand et al., 2015 and Ginn and Pourroy, 2019). Our treatment by household and production type can be rationalized since the agricultural sector is associated with rural regions. According to OECD (2018) research on agriculture policies in India, "[l]ow farm incomes lead to high poverty rates among farmers. Rural poverty is both widespread and severe, largely reflecting very low farm labour productivity and insufficient non-farm employment opportunities" (p. 102). According to the the FAO, the majority (70%) of India's rural household's depend mainly on agriculture for their livelihoods.[10] Furthermore, the World Bank estimates that 43.9% of India's share of the working population work in agriculture. According to RBI (2012), around 82.7% of the poor population live in rural areas.

We develop a model where food prices are explained by two factors, matching with stylized facts. First, the domestic price is, in part, driven by the international food price (Catão and Chang, 2015, Ginn and Pourroy, 2019), a property that is confirmed in empirical papers (e.g., Holtemöller and Mallick, 2016 and Bekkers et al., 2017). Second, we consider fiscal intervention through the effect of India's two-tier institutional food price subsidy in the grains sector, which includes a subsidized procurement price (MSP) and subsidized consumer (CIP) price a household pays. Ginn and Pourroy (2019) show fiscal intervention via food price subsidy is a prevalent feature of LMICs, which are a component of the pass-through from world food prices to domestic inflation, where India is no exception. Based on the empirical evidence presented in Section 2, food subsidies in India represent circa 1% of GDP in 2015. Such a policy can create a wedge between the distorted price faced by household and non-subsidized price. This allows us to capture key factors to analyze fiscal and monetary policy simultaneous responses to food price volatility. In an RBI report, Misra and Sangita (2014) find evidence for comovement between international and domestic prices for all food groups from 2002-2008. Mishra and Roy (2012) show the co-movement is stronger when prices are lower, which they conjecture may be that "the government is more unwilling to allow the pass-through when prices are higher" (p. 157). Similarly, Saini and Gulati (2016) find that while domestic and international food prices are incomplete in the short-run, they do tend to converge in the long-run. Taking this evidence into account, we assume the domestic food price and exported food price is subject to local currency pricing, which in turn allows for deviations in the law of one food price (Ginn and Pourroy, 2020).

3.1 Households

We introduce a two-agent New Keynesian model, where home is populated by a continuum of households indexed by $j \in [0, 1]$ (Galì et al., 2004). A share $1-\lambda$ represent the neo-classical Ricardian household (r), who has access to financial assets and is able to smooth consumption. The rest λ of the households are labeled non-Ricardian (n), who does not have access to asset markets. This type of household representation is referred to as TANK

[9]A large share of food subsistence in the consumption bundle is a key element of the "food problem" (Gollin et al., 2007) that justifies the food security program.

[10]See `http://www.fao.org/india/fao-in-india/india-at-a-glance/en/`. This phenomena is quite common relative to other LMICs. According to the U.N. (2003), "(t)hree quarters of the world's poor live in rural areas of developing countries and depend mainly on agriculture and related activities for their livelihood".

(two-agent New Keynesian) model in the literature, as opposed to single-agent RANK (representative agent New Keynesian) model and diverse-agent HANK (Heterogeneous Agent New Keynesian) model (see e.g., Galí, 2018). Bilbiie (2017) and Kaplan et al. (2018) show that taking into account household heterogeneity allows for a better understanding of the indirect effects of monetary policy (endogenous amplification on output), as opposed to RANK models which tend to over-estimate the direct effect of monetary policy (intertemporal substitution). Kaplan et al. (2018) have developed a HANK model where household heterogeneity includes a portion of poor households who behave in a hand-to-mouth fashion, combined with a wealthy hand-to-mouth manner. Thus, in the HANK model the direct effects of changes in the interest rate on demand is not as important than its indirect effect (e.g., different assets with different yields, borrowing constraint not always binding). Finally, Debortoli and Galí (2017) show that TANK models can be viewed as a "tractable framework that captures well the predictions of HANK models."

To simplify notation, let $i \in (r, n)$ denote the Ricardian and non-Ricardian household, respectively. Household member i is assumed to have symmetric consumption preferences for food ($C^F_{i,t}$) and non-food ($C^N_{i,t}$) goods combined in a CES basket:

$$C_{i,t} = \left[\varphi^{\frac{1}{\theta}} \left(C^F_{i,t}\right)^{\frac{\theta-1}{\theta}} + (1-\varphi)^{\frac{1}{\theta}} \left(C^N_{i,t}\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{1}$$

where φ relates to the share of food in consumption and θ is the elasticity of substitution between food and non-food goods. Following Ghate et al. (2018), we decompose food into grain (G) and non-grain or vegetable food goods (V):

$$C^F_{i,t} = \left[\varphi_G^{\frac{1}{\theta_G}} \left(C^G_{i,t} - \overline{C^G_i}\right)^{\frac{\theta_G-1}{\theta_G}} + (1-\varphi_G)^{\frac{1}{\theta_G}} \left(C^V_{i,t} - \overline{C^V_i}\right)^{\frac{\theta_G-1}{\theta_G}}\right]^{\frac{\theta_G}{\theta_G-1}} \tag{2}$$

where φ_G is the share of grain in food consumption, θ_G represents the elasticity of substitution between food grains and non-grains sector. $\overline{C^G_i}$ and $\overline{C^V_i}$ and represent food subsistence as in Portillo et al. (2016) among others. The consumption for food grains in Equation (2) can be further decomposed by access to subsidized (C^{GS}) and non-subsidized food grains (C^{GM}) as perfectly inelastic:

$$C^G_{i,t} = \mu_i C^{GS}_{i,t} + (1-\mu_i)\, C^{GM}_{i,t} \tag{3}$$

where μ_i denotes the relative share of subsidized food grain by household.

In a standard real business cycle model in the absence of a price distortion, the aggregate consumption price index (CPI) per unit of consumption corresponding to Equation (2), would be implied as follows:

$$P_t = \left[\varphi \left(P^F_t\right)^{1-\theta} + (1-\varphi)\left(P^N_t\right)^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{4}$$

Considering the government intervenes in the food grains sector via food price subsidy, we incorporate the presence of distorted prices in Equation (4) as follows:

$$\overrightarrow{P_{i,t}} = \left[\varphi \left(\overrightarrow{P}^F_{i,t}\right)^{1-\theta} + (1-\varphi)\left(P^N_t\right)^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{5}$$

where $\overrightarrow{P^F_t}$ and P^N_t represent relative prices faced by the household, where the former can be further defined as follows:

$$\overrightarrow{P^F_{i,t}} = \left[\varphi_G \left(\overrightarrow{P^G_{i,t}}\right)^{1-\theta_G} + (1-\varphi_G)\left(P^V_t\right)^{1-\theta_G}\right]^{\frac{1}{1-\theta_G}} \tag{6}$$

with $\overrightarrow{P^G_{i,t}}$ and P^V_t denoting subsidized consumer food grain price and non-grain price respectively.

Following Ben Aïssa and Rebei (2012) and Ginn and Pourroy (2019), we introduce the effect of fiscal intervention to smooth prices in the food grains sector as follows:

$$\overrightarrow{P_t^{GS}} = \kappa \overrightarrow{P_{t-1}^{GS}} + (1-\kappa) P_t^{GM} \tag{7}$$

where $0 \leq \kappa \leq 1$ is the degree of fiscal intervention, $\overrightarrow{P_t^{GS}}$ is the subsidized consumer price and P_t^{GM} is the consumer market price, for food grain. As κ approaches zero (unity), the household effectively pays the market price (fully subsidized) price.

The average food grain price paid by households correspond to the weights attributed to GS and GM in Equation 3 and can therefore be defined as

$$\overrightarrow{P_{i,t}^{G}} = \mu_i \overrightarrow{P_{i,t}^{GS}} + (1-\mu_i) P_t^{GM} \tag{8}$$

Equation 8 simplifies to $\overrightarrow{P_{i,t}^{G}} = \mu_i \kappa \overrightarrow{P_{t-1}^{GS}} + (1-\kappa) P_t^{GM}$ and consequently $\overrightarrow{P_{i,t}^{G}}$ can be written as a function of its own past and market price :

$$\overrightarrow{P_{i,t}^{G}} = P_t^{GM} - \kappa(P_{t-1}^{GM} - \overrightarrow{P_{i,t-1}^{G}}) - \mu_i \kappa (P_t^{GM} - P_{t-1}^{GM}) \tag{9}$$

Equation 9 can be interpreted as follows: there is only one subsidized food grain consumer price that applies for both household types n and r (i.e., $\overrightarrow{P_t^{G,S}}$ in Equation 7). However households do not necessarily exhibit the same proportion of subsidized food grain consumption (governed by μ_i in Equation 3 and 9). Accordingly, households n and r may face different total food grain price $\overrightarrow{P_{n,t}^{G}}$ and $\overrightarrow{P_{r,t}^{G}}$ (given by equation 9). This mechanism generates a policy-induced form of price stickiness determined by the degree to which the fiscal authority subsidizes food grain consumption to shield consumers from changing food prices. In the absence of policy intervention $\kappa = 0$ and therefore $\overrightarrow{P_{i,t}^{G}} = P_t^{GM}$, meaning households' price is the market price. Similarly, if a given household type i does not consumed subsidized food-grain $\mu_i = 0$. Consequently $\overrightarrow{P_{i,t-1}^{G}} = P_{t-1}^{GM}$ and therefore whatever the value of κ we have $\overrightarrow{P_{i,t}^{G}} = P_t^{GM}$, the market price. Finally, assuming household i has access to subsidized food-grain we have $\kappa \in [0,1]$ and $\mu_i \in [0,1]$. Therefore, the price of food-grains paid by household i (i.e., $\overrightarrow{P_{i,t-1}^{G}}$) is based on food-grains market price (P_{t-1}^{GM}) partly brought back to its previous level ($\mu_i \kappa (P_t^{GM} - P_{t-1}^{GM})$) and partly corrected by the subsidy received during the previous period ($-\kappa(P_{t-1}^{GM} - \overrightarrow{P_{i,t-1}^{G}})$).

The optimal consumption for food and non-food consumption by household type is:

$$C_{i,t}^{N} = (1-\varphi) \left(\frac{P_{i,t}^{N}}{\overrightarrow{P_{i,t}}} \right)^{-\theta} C_{i,t} \tag{10}$$

$$C_{i,t}^{F} = \varphi \left(\frac{\overrightarrow{P}_{i,t}^{F}}{\overrightarrow{P_{i,t}}} \right)^{-\theta} C_{i,t} \tag{11}$$

The optimal demand for grain and non-grain food is as follows:

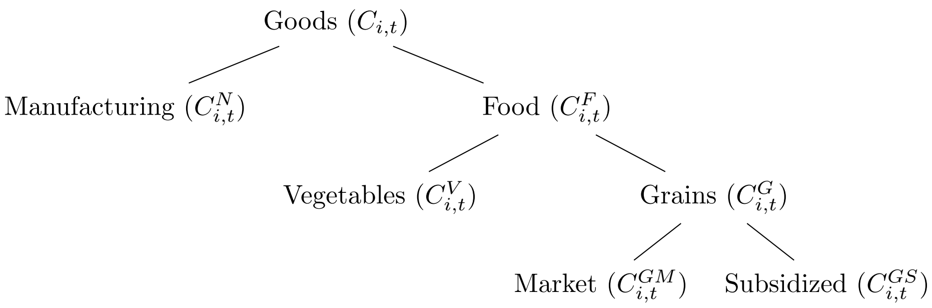
$$C_{i,t}^{G} = \varphi_G \left(\frac{\overrightarrow{P_{i,t}^{G}}}{\overrightarrow{P_{i,t}^{F}}} \right)^{-\theta_G} C_{i,t}^{F} + \overline{C_i^{G}} \tag{12}$$

$$C_{i,t}^{V} = (1-\varphi_G) \left(\frac{P_{i,t}^{N}}{\overrightarrow{P_{i,t}^{F}}} \right)^{-\theta_G} C_{i,t}^{F} + \overline{C_i^{V}} \tag{13}$$

We assume the household has perfect foresight on the underlying price changes they face at the time they occur, and thus chooses the consumption bundle that minimizes expenditure.

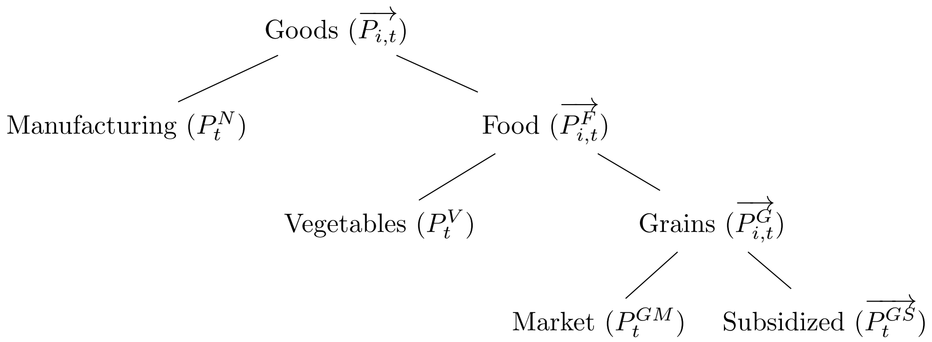
Figure 3 summarizes the goods variety for manufacturing and food goods, where the latter is decomposed by vegetables and grains. We further distinguish between food grains at the market price and the subsidized price.

Figure 3: Summary of Consumption Goods



Similarly, the definition of price indices is summarized Figure 4. The relative share of subsidized food grains in consumption is not the same for Ricardian households and Non-Ricardian households, based on parameter φ^S_i in equation 3. Therefore, $\overrightarrow{P^G_{i,t}}$, $\overrightarrow{P^F_{i,t}}$, and $\overrightarrow{P_{i,t}}$ are indexed by household type $i \in [n, r]$.

Figure 4: Summary of Consumer Price



3.1.1 Ricardian Household

Ricardian households represent optimizing agents, both inter-temporally and intra-temporally. These households derive utility from consumption ($C_{r,t}$) and labor effort ($N_{r,t}$) in the non-food sector :

$$U_{r,t} = E_t \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\rho} C_{r,t}^{1-\rho} - \frac{\psi}{1+\chi} N_{r,t}^{1+\chi} \right) \tag{14}$$

where β^t represents the subjective discount factor (0< β^t <1); χ is the intra-temporal elasticity of substitution of labor supply ($\chi > 0$); and ψ denotes the disutility of labor supply ($\psi > 0$). Ricardians solely owns financial assets. Financial assets include domestic (B_t) and foreign ($B^\star_t$) bonds, which pay a return of $(1 + i_{t+1})$ and $e_t \left(1 + i^\star_{t+1}\right) \Theta(\mathcal{B}_t)$, respectively. We follow Schmitt-Grohé and Uribe (2003) by assuming that the household faces an interest rate that is increasing in the net asset position. $i^\star_{t+1}$ is the foreign interest rate at which the households may borrow. The interest rate is a function of the world interest rate with a country risk premium:

$$\Theta(\mathcal{B}_t) = exp\left(-\zeta(\mathcal{B}_t - \mathcal{B})\right) \tag{15}$$

where $\mathcal{B}_t = \frac{e_t B_t^\star}{P_t Y_t}$ and $\mathcal{B}$ is the steady state net foreign asset position.

The representative Ricardian agent faces the following intertemporal budget constraint:

$$\frac{(1+i_{t+1})\,B_t}{\overrightarrow{P}_{r,t}} + \frac{e_t\left(1+i^\star_{t+1}\right)\Theta(\mathcal{B}_t)B_t^\star}{\overrightarrow{P}_{r,t}} + \frac{(1-\tau_t)(W_t^N N_{r,t} + \Pi_t^N)}{\overrightarrow{P}_{r,t}} =$$
$$\frac{B_t}{\overrightarrow{P}_{r,t}} + \frac{e_t B_t^\star}{\overrightarrow{P}_{r,t}} + (1+\tau_t)(C_{r,t} + \overline{C_r^G} + \overline{C_r^V}) \tag{16}$$

where Π_t^N and τ_t denote profit and the tax rate, respectively.

The representative Ricardian household maximizes utility as in equation (11) subject to the resource constraint in equation (13) with respect to $C_{r,t}$, B_t, $B_t^\star$ and $N_{r,t}$. The first order conditions (FOC) are provided in the Appendix.

3.1.2 Non-Ricardian Household

The non-Ricardian household is assumed to be financially constrained such that current consumption equates to wages. Their utility is based on consumption and labor in the food sector:

$$U_{n,t} = \frac{1}{1-\rho}C_{n,t}^{1-\rho} - \frac{\psi}{1+\chi}N_{n,t}^{1+\chi} \tag{17}$$

The budget constraint for the representative non-Ricardian agent evolves as follows:

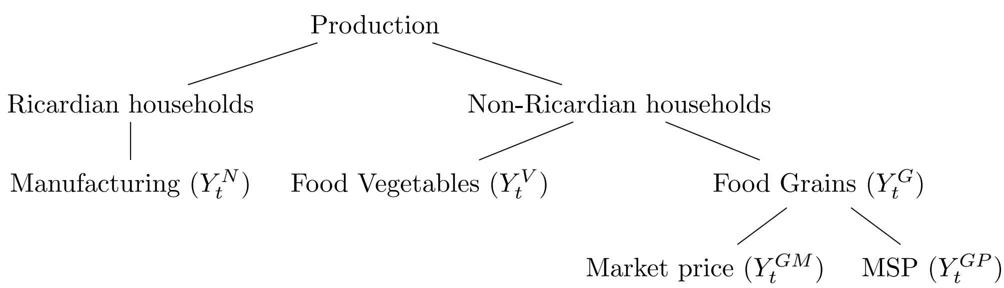
$$(1+\tau_t)(\overrightarrow{P}_{n,t}C_{n,t} + \overrightarrow{P}^G_{n,t}\overline{C_n^G} + P_t^V\overline{C_n^V}) = (1-\tau_t)(W_t^F N_{n,t} + S_t^S) \tag{18}$$

where S_t^S is the profit distributed to the household due to government intervention to incentive food grain production (defined in Section 3.2.1). The FOCs are provided in the Appendix.

3.2 Production

Production is based on the food (Y_t^F) and non-food (Y_t^N) sectors, which can be summarize in Figure 5. Firms maximize profit subject to demand and a labor augmenting technology (e.g., Lubik and Schorfheide (2005) and Del Negro and Schorfheide (2009)). Following Anand et al. (2015) and Ginn and Pourroy (2019), food (manufacturing) firms allocate labor resources from the non-Ricardian (Ricardian) household.

Figure 5: Summary of Production



Food grain prices are sticky due to government intervention, while food non-grain prices are flexible. Manufacturing (i.e. non-food) firms are allowed to set pricing à la Calvo (1983).

There are two types of wages, W_t^F and W_t^N, for the food and non-food sectors, respectively. Inter-sectoral food labor (i.e., grain and non-grain) is perfectly mobile and inter-sectoral food wages are equivalent, i.e. $W_t^F = W_t^G = W_t^V$.

3.2.1 Food Sector

There is empirical evidence showing that exchange rate fluctuations are partially transmitted to the prices of internationally-indexed goods in the short-run for India. In an RBI report, Misra and Sangita (2014) find evidence for co-movement between international and domestic prices for all food groups from 2002-2008 for the case of India.[11] The price transmission has been somewhat muted, considering India's ban on exports of rice and wheat during 2007–11 (Ganguly and Gulati, 2013). Sahoo et al. (2014) show that the rise in world food prices was much sharper than the rise in Indian food prices, especially in 2007-08 and 2010-11. Mishra and Roy (2012) show the co-movement is stronger when prices are lower, which they conjecture may be that "the government is more unwilling to allow the pass-through when prices are higher" (p. 157). Sahoo et al. (2014) show that since 2013, global prices declined while domestic prices remained slightly elevated where the co-movement between wheat and rice are is limited due to price interventions, whereas domestic palm oil and sugar prices exhibited co-movement with international prices. Saini and Gulati (2016) find that while domestic and international food prices are incomplete in the short-run for the case of India, they do tend to converge in the long-run. Taking this evidence into account, we incorporate deviations from the law of one food price in the short-run between international and domestic prices.[12] Hence, we incorporate an international linkage between the domestic ($P_t^{\mathbb{X}}$) and foreign sector price ($P_t^{\mathbb{X}\star}$) at the prevailing exchange rate, i.e. $P_t^{\mathbb{X}} = e_t P_t^{\mathbb{X}\star}/\Psi_t^{\mathbb{X}}$ indexed by sector $\mathbb{X} \in \{G, N\}$ relating to the food grains and non-grains, respectively. Variable $\Psi_t^{\mathbb{X}}$ corresponds with deviations in the law of one price (Monacelli, 2005).[13]

Vegetables Production

Food production in the non-grain sector is based on labor and aggregate productivity:

$$Y_t^V = A_t^V N_t^V \tag{19}$$

The non-grain food sector optimally allocates labor resources by minimizing cost subject to production technology:

$$min_{N_t^V} \; \frac{W_t^V}{P_t^V} N_t^V + \varphi_t^V \left(Y_t^V - A_t^V N_t^V\right) \tag{20}$$

Optimization yields the real marginal cost:

$$\varphi_t^V = \frac{W_t^V}{A_t^V P_t^V} \tag{21}$$

Food Grain Production

Food grain production is similarly using labor augmenting technology and aggregate productivity:

$$Y_t^G = A_t^G N_t^G \tag{22}$$

The food grains sector optimally allocates labor resources by minimizing cost subject to production technology:

$$min_{N_t^G} \; \frac{W_t^G}{P_t^{GM}} N_t^G + \varphi_t^G \left(Y_t^G - A_t^G N_t^G\right) \tag{23}$$

[11] The study includes the following groups: edible oil (0.87), food articles (0.80), rice (0.79), wheat (0.80) and sugar (0.79). See `https://www.rbi.org.in/scripts/PublicationsView.aspx?id=18621`.

[12] Our approach is similar to e.g. Medina and Soto (2005), An and Kang (2011), Poghosyan and Beidas-Strom (2011) and Ginn and Pourroy (2020) who apply a law of one price gap for commodity prices as an AR(1) process.

[13] Note that purchasing price parity holds if $\Psi_t^{\mathbb{X}}$ is equal to unity. Our approach is similar to e.g. Medina and Soto (2005), An and Kang (2011), Poghosyan and Beidas-Strom (2011) and Ginn and Pourroy (2020) who apply a law of one price gap via an AR(1) process.

where φ_t^G can be interpreted as the marginal cost for the respective firm and P_t^{GM} is food grain market price. Optimization yields the real marginal cost:

$$\varphi_t^G = \frac{W_t^G}{A_t^G P_t^{GM}} \tag{24}$$

The government intervenes in the food grain sector via the Food Corporation of India (FCI), which provides the grains producers a cash transfer for a fraction of their production, through the food grain procurement price (MSP). The food grain MSP price (P_t^{GP}) is set higher than the market price (P_t^{GM}) in order to provide a mark up (η) to producers :

$$P_t^{GP} = \left(\frac{\eta}{\eta - 1}\right) P_t^{GM} \tag{25}$$

We assume the amount Y_t^{GP} procured by the government under the MSP scheme is a fraction γ of total food grain production Y_t^G. Therefore $Y_t^{GP} = \gamma Y_t^G$. See Ghate et al. (2018) for similar approach. The remaining fraction of total food grain production, that is $Y_t^{GM} = (1-\gamma)Y_t^G$, is sold by producers on the open market at market price P_t^{GM}.

S_t^S denoted the supply subsidy provided to producers thanks to MSP :

$$S_t^S = Y_t^{GP}(P_t^{GP} - P_t^{GM}) \tag{26}$$

Therefore, it can easily be shown that through MSP, the government provides the grains producer a cash transfer subject to the amount produced:

$$S_t^S = Y_t^G P_t^{GM} \gamma \mathcal{M}^G \tag{27}$$

where $\mathcal{M}^G = (\eta - 1)^{-1}$ is the net markup (Bilbiie et al., 2008). Equation (27) can be interpreted as follows: the MSP consists of an amount, equal to the net margin ($\mathcal{M}^G$), transferred to the food grain producer applied to a fraction (γ) of producers' turnover ($Y_t^G P_t^{GM}$). The difference between the MSP and producer price is paid as a producer subsidy by the government to ensure remunerative prices to farmers and incentive food grains production (Sharma and Alagh, 2013). Our framework is consistent with Sharma and Alagh (2013) and Acharya et al. (2012), such that the MSP can be explained, in part, by world food prices.

3.2.2 Manufacturing Sector

The non-food sector production is derived as follows:

$$Y_t^N = A_t^N N_t^N \tag{28}$$

These firms optimally allocate labor resources by minimizing costs subject to output, with an additional step involving pricing decisions. The first stage consists in minimizing cost to maximize profit based on perfectly competitive factor markets which is generalized as follows:

$$min_{N_t^N} \ \frac{W_t^N}{P_t^N} N_t^N + \varphi_t^N \left(Y_t^N - A_t^N N_t^N\right) \tag{29}$$

Optimization yields the real marginal costs:

$$\varphi_t^N = \frac{W_t^N}{A_t^N P_t^N} \tag{30}$$

As in Schmitt-Grohé and Uribe (2005), we incorporate price stickiness à la Calvo (1983) in the second stage such that each non-tradable firm faces an exogenous probability $\phi_N > 0$ of not being able to re-optimize its price charged from the previous period. This can be expressed in the following optimization process:

$$max_{P^N_{j,t}} E_t \sum_{s=0}^{\infty} \phi_N^s \Xi_{t+s} \left\{ \left(\frac{P^N_{j,t}}{P^N_{t+s}} - \text{mc}^N_{t+s} \right) Y^N_{j,t+s} \right\} \tag{31}$$

subject to sector specific demand:

$$Y^N_{j,t} = \left(\frac{P^N_{j,t}}{P^N_t} \right)^{-\epsilon} Y^N_t \tag{32}$$

The pricing kernel is equivalent to the marginal utility of consumption, i.e. $\Xi_{t+s} = \Lambda_{r,t+s}/\Lambda_{r,t}$. Inserting the demand (31) into the maximization process (30) simplifies the optimization from a constrained maximization to an unconstrained one:

$$max_{P^N_{j,t}} E_t \sum_{s=0}^{\infty} \beta^s \phi_N^s \Xi_{t+s} \left(\frac{P^N_{j,t}}{P^N_{t+s}} \left(\frac{P^N_{j,t}}{P^N_t} \right)^{-\epsilon} - \left(\frac{P^N_{j,t}}{P^N_t} \right)^{-\epsilon} mc^N_{t+s} \right) Y^N_t \tag{33}$$

Note that $P^N_{j,t}$ is decided in period t and not $t+1$ since manufacturing firms choose the optimal price in the current time which will occur in the next period. The first order conditions with respect to $P^N_{j,t}$ yields the well-known optimal price setting equation as follows:

$$\frac{\tilde{P_t}^N}{P^N_t} = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{s=0}^{\infty} (\beta\phi_N)^s \Xi_{t+s} Y^N_{t+s} mc^N_{t+s} \left(\frac{P^N_{t+s}}{P^N_t} \right)^{\epsilon}}{E_t \sum_{s=0}^{\infty} (\beta\phi_N)^s \Xi_{t+s} Y^N_{t+s} mc^N_{t+s} \left(\frac{P^N_{t+s}}{P^N_t} \right)^{\epsilon-1}} \tag{34}$$

Note that if prices are completely flexible (i.e., $\phi_N = 0$), equation (29) simplifies to $\frac{\tilde{P_t}^N}{P^N_t} = \frac{\epsilon}{\epsilon-1} mc^N_t$. We work with the condition of symmetric prices where $\tilde{P_t}^N = P^N_t$, implying marginal cost would be equivalent to the inverse mark-up, i.e. $mc^N_t = \frac{\epsilon-1}{\epsilon}$. It is convenient to express (33) recursively, which simplifies to $\epsilon \times f^N_{1,t} = (\epsilon - 1) f^N_{2,t}$ where:

$$f^N_{1,t} = \Xi_t Y^N_t mc^N_t + (\beta\phi_N)^s E_t \left(\frac{P^N_{t+1}}{P^N_t} \right)^{\epsilon+1} f^N_{1,t+1} \tag{35}$$

$$f^N_{2,t} = \Xi_t Y^N_t + (\beta\phi_N)^s E_t \left(\frac{P^N_{t+1}}{P^N_t} \right)^{\epsilon} f^N_{2,t+1} \tag{36}$$

Prices can be expressed as a weighted average of the fraction of manufacturing firms which optimized its price and those that did not optimize prices (which are stuck at charging prices from the previous period):

$$P^N_t = \left[(1 - \phi_N) \left(P^N_t \right)^{1-\epsilon} + \phi_N \left(P^N_{t-1} \right)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \tag{37}$$

3.3 Fiscal Policy

Fiscal intervention has two distinct objectives: on the one hand, the fiscal authority aims to smooth consumer prices, while on the other hand the fiscal authority aims to support farmers' incomes. In the following we refer to the former policy as "demand subsidy" and the latter as "supply subsidy".

Based on Equation (3) we can define the spending by the fiscal authority for the demand subsidy:

$$S^D_t = (\mu_n C^G_{n,t} + \mu_r C^G_{r,t})(P^{GM}_t - \overrightarrow{P^{GS}_t}) \tag{38}$$

That the fraction of grain food being subsidized for each household type, times the spread between market price and subsidized price. Also, recall that the supply subsidy is defined in Equation 27, where P^{GP}_t is synonymous with India's MSP.

The government's inter-temporal budget constraint is funded via domestic (B_t^G) debt and tax (T_t) revenues to finance a stream of food price subsidies.[14]

$$B_t^G - (1 + i_{t-1})B_{t-1}^G = S_t^D + S_t^S - T_t \tag{39}$$

$$T_t = \tau_t(\overrightarrow{P}_{n,t}C_{n,t} + \overrightarrow{P}_{r,t}C_{r,t} + W_t^F N_t^F + W_t^N N_t^N + S_t^S + \Pi_t^N) \tag{40}$$

For purposes of ensuring stability, a Ponzi scheme is ruled out, i.e. both the consumer budget constraint and a debt ceiling will always bind. The share of the government's budget financed via debt: $\tau_t = \phi \frac{B_t^G}{P_t Y_t}$ which relies on the leverage parameter ϕ. As ϕ approaches zero, the fiscal response will be financed mainly by debt. However, $\phi > 0$ ensures solvency related to time-varying marginal tax rates on consumption, labor wages and profits.

3.4 Monetary Policy

The central bank conducts monetary policy by following a Taylor-like Rule (Taylor, 1993) via changing short-term interest rates in response to changes in the price level and output:[15]

$$\frac{1 + r_t}{1 + r} = \left(\frac{1 + r_{t-1}}{1 + r}\right)^{\psi_s} \left[\left((\pi_t^N)^{\varrho}(\pi_t^F)^{1-\varrho}\right)^{\omega_\pi} (\Delta y_t)^{\omega_y}\right]^{1-\psi_s} e^{\varepsilon_t^{MP}} \tag{41}$$

The Taylor Rule incorporates interest rate smoothing depending on the degree of inertia $0 < \psi_s < 1$. The policy weights with respect to deviations from the inflation rule and output are denoted ω_π and ω_y, respectively. The inflation rule makes an assignment on non-food (π_t^N) and food sector (π_t^F) CPI which is governed by $0 \leq \varrho \leq 1$. This allows a simple framework to evaluate whether the central bank pursues core inflation ($\varrho = 1$) versus a policy response that responds to food inflation ($\varrho < 1$).[16] ε_t^{MP} relates to a monetary disturbance.

3.5 Foreign Economy

The balance of payment is equivalent to the trade balance (TB_t) and the foreign asset position:

$$e_t B_t^\star = e_t \left(1 + i_{t-1}^\star\right) \Theta(\mathcal{B}_t) B_{t-1}^\star + TB_t \tag{42}$$

$$TB_t = P_t^V Y_t^V - P_t^V C_t^V \tag{43}$$

Equation (42) represents the position on foreign bond holdings ($B_t^\star$). Equation (43)[17]

[14] See e.g. Stähler and Thomas (2012) and Ginn and Pourroy (2019).

[15] The RBI has formally adopted an inflation targeting framework in 2016. Prior to that adoption, consumer price stability was already the main objective of monetary policy. According to Hutchison et al. (2010), the exchange rate is not an important determinant of India's monetary policy relating to the period of the period of 1999:Q1 to 2008:Q2. Consistent with recent empirical evidence, we apply a Taylor-like rule in relation to changes in prices and output (e.g., Banerjee and Basu, 2015, Banerjee and Basu, 2019, Anand and Khera, 2016) for the case of India. Nevertheless, we add an exchange rate to the Taylor-like rule and present the findings in Section 8.3.1.

[16] The assignment ϱ is motivated by Anand et al. (2015) and subsequently Ginn and Pourroy (2019) who develop a DSGE model to describe optimal inflation used in a welfare analysis.

[17] Grain exports were limited for a certain time due to government restrictions (Sharma, 2011), therefore only non-grain are assumed to be traded internationally.

3.6 Aggregation

Following Galí et al. (2007), aggregate consumption (C_t) and labor effort (N_t) are defined by, respectively:

$$C_t = (1 - \lambda) C_{n,t} + \lambda C_{r,t} \tag{44}$$

$$N_t = (1 - \lambda) N_{r,t} + \lambda N_{n,t} \tag{45}$$

4 Estimation Method

The model is evaluated using Bayesian methods, which are commonly used in empirical macroeconomic research (e.g., Schorfheide, 2000, Smets and Wouters, 2007, Fernandez-Villaverde and Rubio-Ramirez, 2004). Bayesian DSGE models have also been used in business cycle research to understand commodity price shocks (e.g., Medina and Soto, 2005, Bodenstein et al., 2011, An and Kang, 2011, Poghosyan and Beidas-Strom, 2011 and Ginn and Pourroy, 2020).

4.1 Data

The model is based on eight observable variables (see Table 1). The variables include real GDP[18]; CPI inflation; WPI food inflation[19]; the international grain and non-grain food inflation (proxied via the FAO international food price data); real effective exchange rate (REER); the policy rate and an international interest rate.[20] The sample period covers 1999:Q1 to 2019:Q4. With the exception of the interest rate, all variables are seasonally adjusted and computed as a quarter-to-quarter log-difference.[21] The policy rate and foreign interest rate are transformed from an annualized rate to a quarterly gross interest rate to conform the model with observable data: $R_t^{obs} = 1 + \frac{R_t^{data}}{100 \times 4}$. We take the three month treasury bill rate as a proxy of the nominal interest rate (e.g., Patnaik et al., 2011, Anand et al., 2014 and Gabriel et al., 2016).

Table 1: Variable Selection

Description	Source	Mnemonic / Descriptor
Nominal GDP	FRED	INDGDPNQDSMEI
Aggregate CPI	FRED	INDCPIALLQINMEI
Food WPI	FRED	WPOTFD01INQ661N
REER	FRED	RBINBIS
International Grain Food CPI	FAO	Real Grain Food CPI
International Non-Grain Food CPI	FAO	Real Non-Grain Food CPI (see [a])
Interest Rate	CEIC	3 Month Treasury Bill Rate
International interest rate	U.S. Federal Reserve	Shadow Federal Funds Rate

[a]: The Non-Grains Food CPI is computed by excluding the grains price and reindexing the weights (provided by FAO) using the FAO price data by product group applied to the non-grains food groups.

[18] Real output is derived by dividing nominal GDP by the GDP price deflator of a base year. The approach is consistent with "Databasics" from the Federal Reserve. See: https://www.dallasfed.org/research/basics/nominal.aspx.

[19] We take the food WPI as a proxy for food inflation considering food CPI is not available prior to 2013. The food WPI and food CPI has a correlation of 0.98 from 2013:Q1 to 2018:Q4.

[20] Considering the sample period overlaps with the U.S. federal funds rate was at the zero lower bound between 2008:Q4 until 2015:Q4, we use the shadow federal funds rate (Wu and Xia, 2016) to reflect the stance of U.S. monetary policy.

[21] For consistency, CPI, food CPI, food WPI and REER are seasonally adjusted using the U.S. Census Bureau's ARIMA X12 algorithm. Hence, with the exception of the interest rate, all variables are seasonally adjusted.

4.2 Calibrated Parameters

The model parameters are summarized in Table 2. The discount factor (β) is set to 0.9832, which is in line with the observed data over the sample period. The share of food in aggregate consumption (φ) is set to 0.4.[22] The share of labor attributed to the food sector (λ) is set to 0.4.[23] The share of food grains (φ_G) is set to one-third of the share of food.[24] The share of farmers that receive the food grain MSP (γ) is set 0.4.[25] For purposes of ensuring stability, a Ponzi scheme is ruled out, i.e. both the consumer budget constraint and a debt ceiling will always bind. Therefore, we set the leverage response (ϕ) is set to 0.2 to ensures stability (e.g., Stähler and Thomas, 2012, Ginn and Pourroy, 2019).

Table 2: Calibrated Parameters

Description	Symbol	Value
Discount factor	β	0.9832
Share of food in consumption	φ	0.4
Share of food grains in food consumption	φ_G	0.33
Share of Non-Ricardian	λ	0.4
Share of farmers under MSP scheme	γ	0.4
Leverage Response (ensures stability)	ϕ	0.2

4.3 Prior Distributions:

The prior distributions of the estimated parameters are summarized in the Table 3.

The inverse of intertemporal elasticity of substitution (ρ) is set to 2 (e.g., Aguiar and Gopinath, 2007). The inverse Frisch parameter (χ) is set unity (e.g., Medina and Soto, 2005, García-Schmidt and García-Cicco, 2020). We set the elasticity of food (θ) to 0.75.[26] The elasticity between grain and non-grain food is set to 0.85.[27]

Following Ginn and Pourroy (2020), we assume the central bank targets aggregate headline inflation, hence ϱ has a prior set to the ratio of the aggregate food expenditure (i.e., $\varrho = 0.60$) consistent with the RBI mandate.[28] The prior for the interest rate smoothing parameter (ψ_s) and the policy weights with respect to deviations from the inflation rule (ω_π) and output (ω_Y) are set to 0.7, 1.5 and 0.5, respectively (e.g., Ginn and Pourroy, 2020).

Following Schmitt-Grohé and Uribe (2003), we incorporate a bond adjustment cost; the prior is set to ζ=0.01.

[22] According to the World Bank (Global Consumption database), food represents 44.63% of total household expenditures in India. According to the World Bank (ILOSTAT database), agriculture represents 43.86% of employment for 2018 in India.

[23] Financial access is estimated to be 79.9%, while 42.4% have borrowed money (age 15+) based on 2018 Indian data (World Bank Global Findex database). Furthermore, 43.9% of the Indian working population work in agriculture according to the World Bank.

[24] According to Anand et al. (2016), the grains sector represents 34.2% of total food consumption.

[25] According to the FCI, the procurement of rice and wheat relative to production represents 43.60% and 36.52% for the 2019-2020 period. See `https://dfpd.gov.in/writereaddata/Portal/Magazine/webupdationAugust20213.pdf`.

[26] This is in line with the USDA estimate for India using 2005 data; the elasticity of food and uncompensated own-price elasticity for food is estimated to be 0.78 and 0.74, respectively.

[27] Anand et al. (2016) find the the expenditure elasticity of grain relative to total expenditure on food is 0.848 for India.

[28] Theoretically, the more recent research argues that targeting strictly core inflation is not necessarily optimal (Anand et al., 2015, Catão and Chang, 2015, Pourroy et al., 2016 and Ginn and Pourroy, 2019) for LMICs. In practice, the RBI has adopted an inflation targeting framework since May 2016, where the inflation target is set by the Government of India, in consultation with the Reserve Bank, once every five years.

The Calvo price signal (ϕ_N) in the manufacturing sector is assumed to be two-thirds (see e.g. Anand et al., 2015).

The share of subsidized food grains consumption by the Ricardian (μ_r) and non-Ricardian (μ_n) household is set to 0.1 and 0.33, respectively, to reflect fiscal authorities' propensity to subsidize food prices by household type, which may be poorly targeted (e.g., Ramaswami and Balakrishnan, 2002, Jha and Ramaswami, 2010 and Sharma and Alagh, 2013).[29] The degree of price smoothing of by the government (i.e., κ in Equation (7)) is set to 0.75, in line with Ben Aïssa and Rebei (2012).

We incorporate eight shocks in the model which obey an AR(1) process, each of them drawn from an i.i.d. normal process. These shocks include a sector-specific technology shock (e.g., Anand et al., 2014); global food price shock (e.g., Catão and Chang, 2015, Pourroy et al., 2016, Ginn and Pourroy, 2019 and Ginn and Pourroy, 2020); law of one price gap (e.g., Monacelli, 2005, Medina and Soto, 2005 and Ginn and Pourroy, 2020); monetary policy shock (Smets and Wouters, 2007); and foreign interest rate shock (Devereux et al., 2006).

4.4 Empirical Findings

4.4.1 Posterior Distributions

The prior and posterior distributions are summarized in Table 3.

Parameter θ is estimated to be 0.71, hence food has an inelastic demand. The posterior for food grains (θ_G) is estimated to be 0.98. Considering the value of θ_G is lower than unity demonstrates that food grain and non-grain are two clearly separated goods in the consumer basket that cannot be easily substituted.

The posterior Calvo probabilities for the manufacturing sector (ϕ_M) is estimated to be 0.60, a standard value for monopolistic competition sector. The subsistence value for grains and non-grains food is estimated to 0.03 and 0.02 respectively. While these values are low, they are consistent with the literature (see Portillo et al., 2016).

The interest rate smoothing parameter (ψ_S) has a posterior mean of 0.52, suggesting presence of policy inertia. The policy coefficients on the inflation (ω_π) and output deviations (ω_y) are estimated to be 0.45 and 1.72, respectively. The posterior for the policy price index reaction ($\varrho = 0.63$) is marginally higher than the share of food in aggregate consumption price index ($\varphi = 0.60$). This indicates that the RBI has a clear headline inflation targeting framework, as opposed to a core inflation targeting strategy (see Anand et al., 2015), thereby indicating RBI action is consistent with its mandate for food price stability.

The posterior policy intervention κ is estimated to be 0.76, which is consistent with Ben Aïssa and Rebei (2012) estimations for other emerging economies (ranging from 0.57 in Brazil to 0.81 in Philippines). The share of subsidized food grains consumed by the Ricardian (μ_r) and non-Ricardian(μ_n) household is estimated to be 0.22 and 0.38, respectively, indicating demand subsidies are slightly targeted toward the poorer households. Overall, the estimated values of fiscal intervention (κ, μ_r, μ_n) confirm three findings: (1) food subsidies are an important component of India' economy; (2) food prices are sticky due to fiscal policy; and (3) food subsidies are targeted toward by households type.

4.4.2 Model Fit

To evaluate model performance, we provide the actual moments (standard deviation) and first-order autocorrelation values compared with the model derived values (see Table 4). The model tends to overpredict the

[29] According to OECD (2018), the average expenditure of subsidized wheat and rice consumption increases as incomes are lower. For example, households in the lowest deciles got around 45% (38%) of the rice (wheat) they consumed in 2011-2012 vs. 13% and 16% for the highest decile.

Table 3: Prior and Posterior Distributions

			Prior		Posterior			
		Density	Mean	StD	Mean	90% interval		StD
Fiscal Policy								
η	Supply subsidy intensity (MSP)	I	6	2	4.5983	3.0823	5.7339	1.1522
κ	Degree of grain price smoothing (CIP)	B	0.75	0.05	0.7624	0.6926	0.8644	0.0440
μ_r	Share of grain subsidized Ric. consum.	B	0.1	0.05	0.2175	0.1616	0.2698	0.0603
μ_n	Share of grain subsidized Non-Ric. consum.	B	0.35	0.05	0.3756	0.3124	0.4547	0.0509
Monetary policy								
ϱ	Policy price index	B	0.6	0.05	0.6284	0.5481	0.6806	0.0428
ψ_S	Interest rate smoothing	B	0.7	0.10	0.5195	0.4388	0.6083	0.0406
ω_π	TR response: inflation	N	1.5	0.10	1.7224	1.5959	1.8566	0.0916
ω_y	TR response: GDP	N	0.5	0.05	0.4549	0.3784	0.5172	0.0500
Utility function								
$\overline{C^G}$	Food subsistence: grains	I	0.1	2	0.0356	0.0255	0.0485	0.0062
$\overline{C^N}$	Food subsistence: non-grains	I	0.1	2	0.0226	0.0181	0.0271	0.0034
ρ	Inverse of intertemp. elasticity of subst.	G	2	0.10	2.1278	1.9612	2.3095	0.0989
χ	Inverse Frisch	G	1	0.10	0.9720	0.8405	1.1317	0.0929
θ	Elasticity of substitution F and N	G	0.75	0.05	0.7058	0.6610	0.7649	0.0425
θ_G	Elasticity of substitution G and V	G	0.85	0.05	0.9756	0.9152	1.0335	0.0450
Other								
ζ	Bond adjustment costs	I	0.01	2	0.0173	0.0114	0.0246	0.0032
ϵ	Manufacturing sector market power	I	11	2	10.6471	8.5669	13.1898	1.6074
ϕ_M	Calvo signal	B	0.66	0.05	0.5984	0.5399	0.6549	0.0451
Shocks								
ρ^{A^N}	AR on non-food productivity	B	0.8	0.10	0.9460	0.9250	0.9663	0.0177
ρ^{A^G}	AR on food grain productivity	B	0.5	0.10	0.8893	0.8477	0.9311	0.0254
ρ^{A^V}	AR on food non-grain productivity	B	0.5	0.10	0.9040	0.8657	0.9358	0.0265
ρ^{MP}	AR monetary policy	B	0.5	0.05	0.2556	0.2213	0.2958	0.0270
$\rho^{i\star}$	AR foreign interest rate	B	0.46	0.05	0.5850	0.5347	0.6435	0.0437
$\rho^{F\star}$	AR on food price	B	0.75	0.10	0.8899	0.8646	0.9081	0.0116
ρ^{Ψ_G}	AR law of one food grain price gap	B	0.9	0.05	0.9269	0.9125	0.9446	0.0100
ρ^{Ψ_N}	AR law of one food non-grain price gap	B	0.9	0.05	0.7566	0.7114	0.8003	0.0349
σ^{AN}	StD manufacturing productivity	I	0.1	2	0.0144	0.0126	0.0165	0.0013
σ^{AG}	StD food grain productivity	I	0.1	2	0.0218	0.0195	0.0247	0.0020
σ^{AV}	StD food non-grain productivity	I	0.1	2	0.0239	0.0187	0.0287	0.0022
σ^{MP}	StD monetary policy	I	0.1	2	0.0118	0.0103	0.0134	0.0010
$\sigma^{i\star}$	StD foreign interest rate	I	0.1	2	0.0103	0.0090	0.0121	0.0009
$\sigma^{P^{F\star}}$	StD food price	I	0.1	2	0.0329	0.0286	0.0366	0.0026
σ^{Ψ_G}	StD law of one food grains price gap	I	0.1	2	0.0498	0.0444	0.0545	0.0036
σ^{Ψ_V}	StD law of one food non-grain price gap	I	0.1	2	0.0375	0.0308	0.0429	0.0047

Note: distributions include Beta (B), Gamma (G), Inverse Gamma (I) and Normal (N). "StD" for standard deviation.

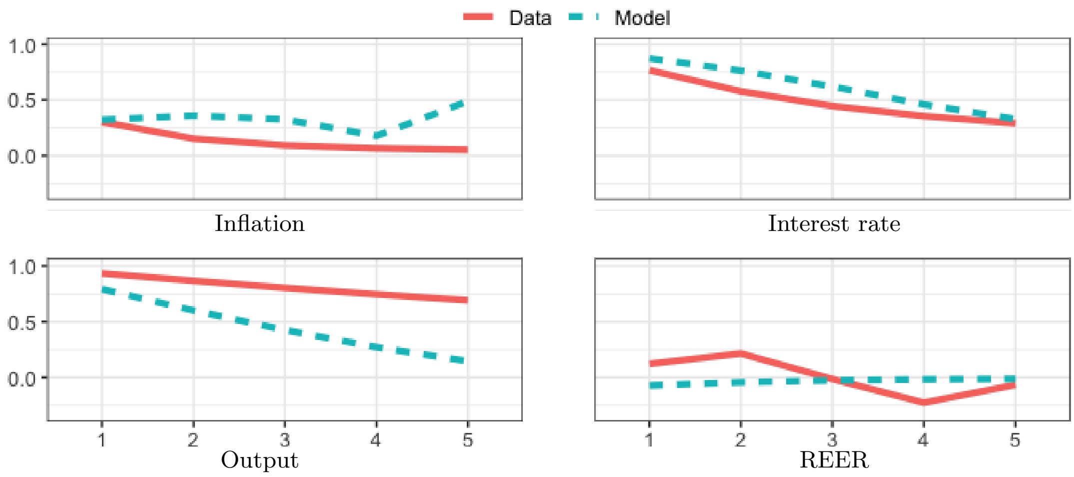
volatility of output growth, inflation, the policy rate and the exchange rate (Table 4). The persistence between the data and estimated model for output, inflation and interest rate are similar at order 1. Figure 6 plots the autocorrelation (up to lag 5). Overall, the model is able to replicate the key features in the data reasonably well.

Table 4: Business Cycle Statistics

	Growth ($\Delta \ln Y_t$)	Inflation (π_t)	Interest rate (R_t)	Exchange rate ($\Delta \ln e_t$)
	Standard Deviation			
Data	0.0140	0.0096	0.0041	0.0254
Empirical Model	0.0230	0.0177	0.0128	0.0405
	Autocorrelation (order=1)			
Data	0.7930	0.3640	0.8743	0.0180
Empirical Model	0.9328	0.3020	0.7625	-0.0374

Note: "Data" refers to data-based standard deviation values; "Empirical Model" refers to the estimated model standard deviation values. The sample includes 1999:Q1 to 2019:Q4.

Figure 6: Autocorrelation



We report the conditional variance decomposition (Table 5) at different time horizons (quarters 1, 4 and 8). The manufacturing, food grains and food non-grains technology shocks account for the majority of output fluctuations, particularly relating to the former. A shock to the policy rate has a significant effect on inflation, interest rate and the exchange rate. The exchange rate is mainly affected by external factors. The international food price and the deviations from the law of one price jointly exhibit large contributions in explaining variability in inflation, the exchange rate and the policy rate. In the short-term (quarter 1), the international food price accounts for around 2%, 5% 11% and 15% of domestic output, inflation, the policy rate and the exchange rate.

Table 5: Conditional Variance Decomposition (in %)

	Prod			World	World	Monet.	G	N
	M	G	N	$P^{F\star}$	$i^{\star}$	Policy	LOP	LOP
				Quarter 1				
Growth (ΔlnY_t)	45	41	6	2	2	2	2	0
Inflation (π_t)	0	0	1	5	27	62	2	2
Interest rate (R_t)	0	1	2	11	76	0	4	5
Exchange rate (Δe_t)	9	2	1	14	30	25	19	1
				Quarter 4				
Growth (ΔlnY_t)	55	30	5	4	1	1	3	0
Inflation (π_t)	1	0	1	4	24	66	2	2
Interest rate (R_t)	1	1	1	18	65	0	8	7
Exchange rate (Δe_t)	8	2	1	14	31	24	18	1
				Quarter 8				
Growth (ΔlnY_t)	63	25	4	4	1	0	3	0
Inflation (π_t)	1	0	1	5	24	65	2	2
Interest rate (R_t)	2	1	1	22	58	0	10	7
Exchange rate (Δe_t)	8	2	1	15	30	24	18	1

Note: The columns indicate the respective shock. Each shock is treated as an AR(1) process. "M" refers to manufacturing, "G" food grains, "N" food non-grains, "$P^{F\star}$" the world food price, "$i^{\star}$" the world interest rate, and law of one price (LOP) gap.

5 Model Experiments

We conduct two types of model experiments based on a disturbance of the food price level. The first relates to analyzing the effect of different fiscal intervention models (μ_i and η) that may be used to circumvent a food price shock. The second analyzes the effect of the monetary policy response type (ϱ).

5.1 International Food Price Shock and Fiscal Policy

We conduct four experiments to better understand how fiscal intervention affects the model. The first experiment (Model I.a) relates the estimated model ($\mu_n = .4$; $\mu_r = .2$; $\eta = 4.6$). The second experiment (Model II.a) relates to no subsidy ($\mu_n = \mu_r = 0$; $\eta = 10e5$). The third experiment (Model III.a) is a "strong" demand subsidy response for both household types ($\mu_n = \mu_r = 0.5$) and no supply subsidy ($\eta = 10e5$). The fourth experiment (Model IV.a) is a "strong" supply subsidy ($\eta = 2.2$) and no demand subsidy ($\mu_n = \mu_r = 0$).

The IRFs are provided in Figure 7. All other parameters remain unchanged for both model experiment types, i.e. are based on the posterior mean (see Table 3).

We find that food subsidies modify the propagation of the world food price in terms of duration and size. First, subsidies create a lag between the time of the shock (t=0) and the peak food price the household faces. In the presence of no fiscal intervention (strong demand intervention) as in Model II.a (Model III.a), the peak food price occurs at t=0 (t+4). Second, subsidies reduce the magnitude of the food price shock; the "strong demand subsidy" (Model III.a) policy implies that the maximum price is circa half of the price without subsidies at the onset of the shock. A "strong supply subsidy" (Model IV.a) is a polar case, which tends to strongly increase food grain price perceived by producers.

The effect of the food price shock on consumption differ by household type. Ricardian total consumption decreases in response to an increase in the interest rate response. Kumar et al. (2021) find that a domestic uncertainty shock in India is similar to the inflationary supply shock. The uncertainty shock can increase food inflation and the interest rate response.

Ricardians substitute food for non-food goods. The effect on non-Ricardian income is quite different as their consumption increases. Due to the relative increase in the food price, non-food consumption increases to a larger extent than food consumption. While food labor supply falls, it does not compensate for the food wage increase.[30]

As non-Ricardians are treated "hand-to-mouth", this household is unable to smooth consumption, yet the government may intervene and do so for them. In the absence of fiscal intervention, non-Ricardian food consumption drops. However, in the case of fiscal intervention (Models I.a and III.a), a food demand subsidy allows food consumption smoothing.

Despite the low elasticity of substitution between food grain and food non-grain goods, both households substitute food non-grain for food grain.[31] Consequently, food non-grain price increases. A strong demand subsidy decreases the need to substitute food-grain and non food grain thus stabilizing not only food grain price, but also food non-grain price. A strong supply policy provides an additional income to farmers and therefore has two effects. First, it smooths food grain consumption by rural households (albeit less than the demand subsidy). Second, the farmer labor supply falls. The latter contributes to increase non-grain price, with negative impact on non-grain consumption by urban households. To put it simply: the supply subsidy does not change the main characteristic of the shock, but the supply subsidy complicates the transmission channels through which the shock spreads throughout the economy.

In the absence of a subsidy policy, food exports increase at the time of the shock, reflecting a relative productivity gain. However, food subsidies reduce labor supply in the food sector: non-Ricardian households can consume a similar amount by spending less. Hence, since they are hand-to-mouth by nature, spending less means working less.

The last graph in Figure 8 shows the effect on public debt associated with fiscal intervention, depending on the degree of food price smoothing (μ_i) and producer support (η).

5.2 International Food Price Shock and Monetary Policy

We conduct three additional experiments to illustrate how the choice of monetary policy price indexation (ϱ) influences the model. We consider ϱ=0 (Model I.b) relating to core inflation; the empirical model (Model II.b); and "strong" policy reaction scenario (Model III.b).[32] The corresponding IRFs are shown in Figure 9. All other parameters remain unchanged for both model experiment types, i.e. are based on the posterior mean (see Table 3).

As expected, as ϱ increases, the interest rate response also increases at the time of the shock. Interestingly, even when $\varrho = 0$ there is still a positive increase in the policy rate. This is partly explained by monetary policy reaction to the output gap (which is positive due to an increase in non-food production).

The central bank reaction consists of raising the policy rate, which has a stronger impact on Ricardian consumers than on non-Ricardians. When the policy rate increases in response to an increase in the food price,

[30] Assuming productivity remains constant, an international food price shock can put upward pressure on non-Ricardian wages.

[31] While Non-Ricardian food non-grain consumption increases, Ricardian food-grain consumption decreases, but by a lower scale than food grain consumption.

[32] By "strong" reaction, we assume ϱ=0.8, which is higher than the value based on the posterior estimate (0.59).

Ricardian consumption falls.

Figure 9 shows that food prices are slightly lower the stronger the monetary policy reaction. The food price faced by non-Ricardian household is lower than the food price faced by Ricardian household due to the subsidy policy, creating a policy-induced price distortion. Two important findings can be drawn from Figure 9. First, in case of a food price shock, monetary policy is relatively inefficient considering food and non-food prices evolve in the same direction. Second, in the case of a strong monetary policy reaction, the increase in food inflation is lessened which also implies a lower fiscal policy reaction. Considering this inter-dependency into account underscores the importance of monetary and fiscal policy coordination.

When monetary policy reacts to core inflation, non-food inflation is the central bank target, and therefore core inflation remains almost flat. When monetary policy incorporates a strong reaction, overall consumer inflation is the central bank target.

5.3 Contribution of Food Subsidies to Price Stability

Monetary policy and food subsidies share a common goal of price stability, *inter alia*. To quantify the contribution that food subsidies has on price stability, we conduct a counterfactual experiment by assigning different fiscal policy values and observe how price volatility changes.[33] The results are presented in Figure 11. The x-axis represents the coefficient applied to the food subsidy parameters. The empirical model ($\mu_n = 0.4$, $\mu_r = 0.2$) corresponds to x = 1.[34] The y-axis represents the inflation standard deviation, expressed relative to the empirical model standard deviation. Therefore, any value higher (lower) than 1 corresponds with higher (lower) inflation volatility relative to the empirical model.

We highlight four findings. First, food demand subsidies can reduce inflation volatility, particularly food grain inflation, whereas the effect on food non-grain and non-food prices is limited. The limitation is due to the low elasticity between the two goods. Figures 11 and 12 demonstrate the effect of the food price subsidy in relation to the inflation standard deviation relative the empirical model (shown with a 90% confidence interval corresponding to the Bayesian posterior uncertainty). While a food demand subsidy stabilizes food grain inflation, this effect disappears for food non-grain prices when food subsidies for x > 1.5 to the extent that more subsidies maintain non-grain price volatility unchanged.

Second, while price stability is generally considered an objective of monetary policy, we show that food demand subsidies also contribute to price stability. The empirical model (point[1, 1]) compared with the non-food subsidy (point[0, 0]) underscores the stabilizing effect of food subsidies. Hence food-grain (non-grain) inflation volatility would be 31% (9%) higher in the absence of food subsidies, a non-trivial effect on the observed inflation rate. Thus, the interaction of the two policies can be viewed as a shared burden in India and a strategic substitute.

Third, food demand subsidies in our model can stabilize aggregate inflation because of the sizable share of household food expenditures ($\phi = 0.4$). Our results would be valid for a low and middle-income country with presence of a fiscal food price stabilization policy depending on the intensity of the policy.[35] Figure 13 demonstrates how the subsidy stabilizes aggregate and food CPI. Consistent with Figure 12, the larger the food subsidy, the lower inflation.[36] We estimate that in the absence of food subsidies and assuming Taylor rule

[33] All other parameters remain unchanged for model experiment types, i.e. are based on the posterior mean. We simulate a one standard deviation shock on the world food price.

[34] Similarly, if for example x = 2, then $\mu_n = 2 \times 0.4$ and $\mu_r = 2 \times 0.2$. In the case of no subsidy, x = 0.

[35] The effect of the subsidy would be less pronounced (if any) for a high-income country, considering food expenditures are lower (see Pourroy et al. (2016).)

[36] For sake of simplicity, the x-axis in Figure 13 is based on a universal subsidy (i.e., $\mu_n = \mu_r$). Assuming a universal subsidy

parameters remain unchanged, following a food price shock, CPI volatility would be 21% higher.

Lastly, we compute the contribution of food subsidy to the interest rate response to a food price shock. Assuming the estimated Taylor rule parameters remain unchanged, according to Figure 14 the interest rate volatility following a world food price shock would be 21% higher in the absence of a food subsidy, a non-negligible amount. Similarly, as shown on Figure 7 (second line, left graph, grey and red lines), the central bank would increase the interest rate twice more 6 basis points) at the time onset of the shock (t=0) in the absence of a food demand subsidy. Therefore our results show that in the absence of food demand subsidies, the policy rate would have to react stronger to external shocks in order to achieve the inflation target. Furthermore, our findings run counter to the voluminous literature which tends to side with inflation targeting as the only policy framework to achieve price stability, and that the central bank's role to achieve price stability may be overestimated if subsidies are not considered.

makes the computation of the CPI simpler because the two households face the same prices. Considering subsidies are not universal in the empirical model, we can only express the results in absolute terms.

Figure 7: Food Price Shock and Food Subsidies

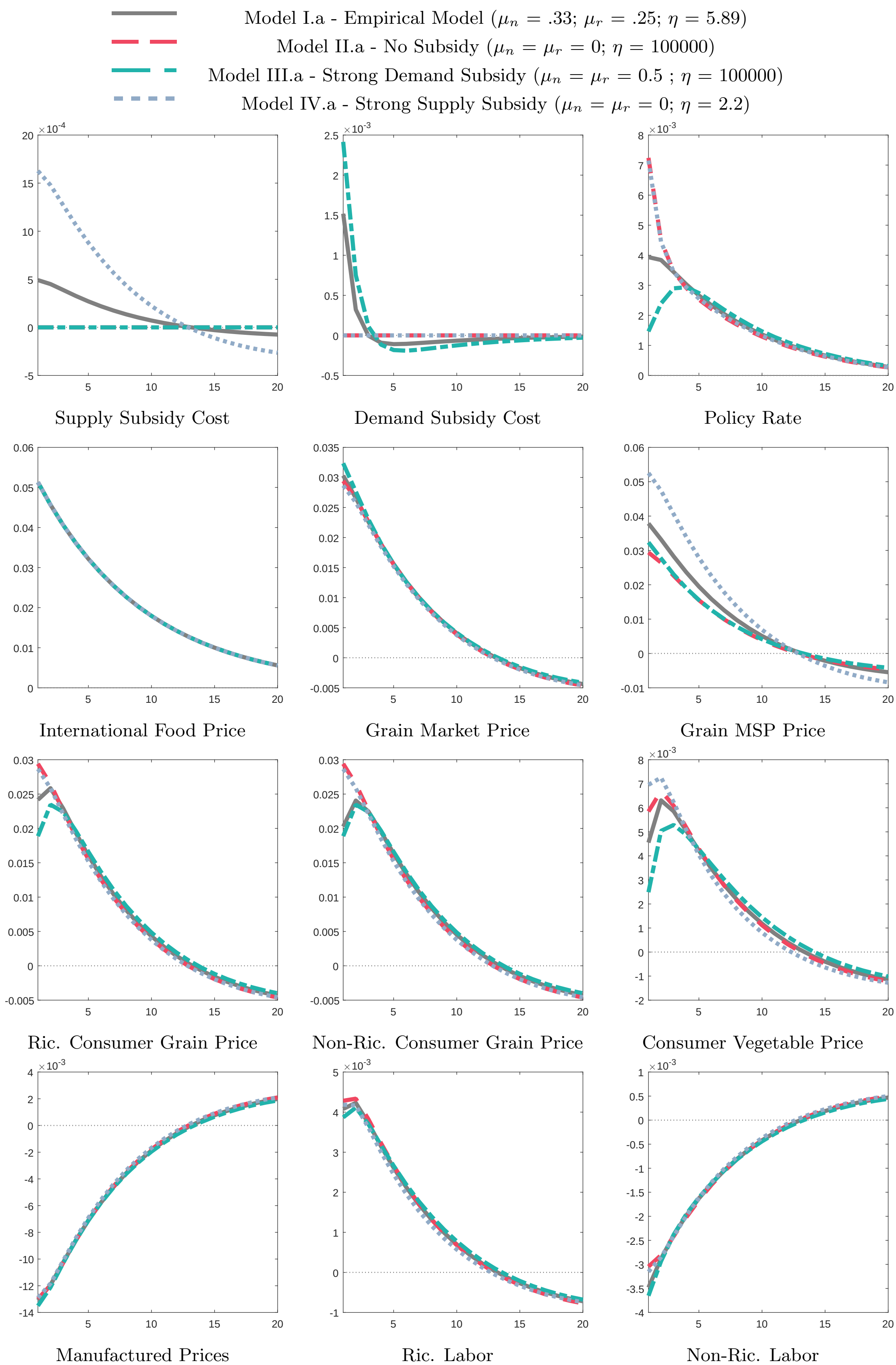


Figure 8: Food Price Shock and Food Subsidies, cont.

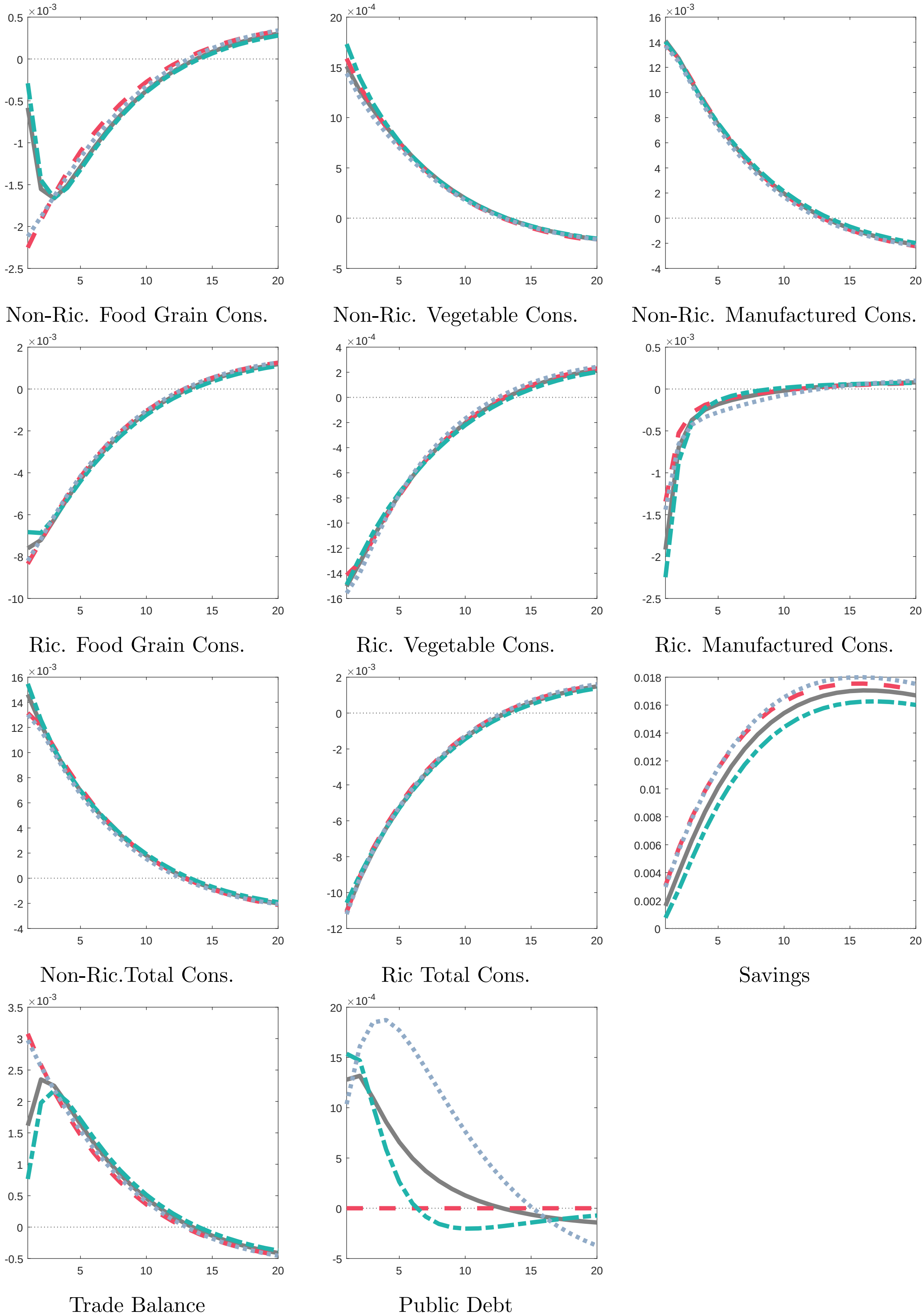


Figure 9: Food Price Shock and Monetary Policy

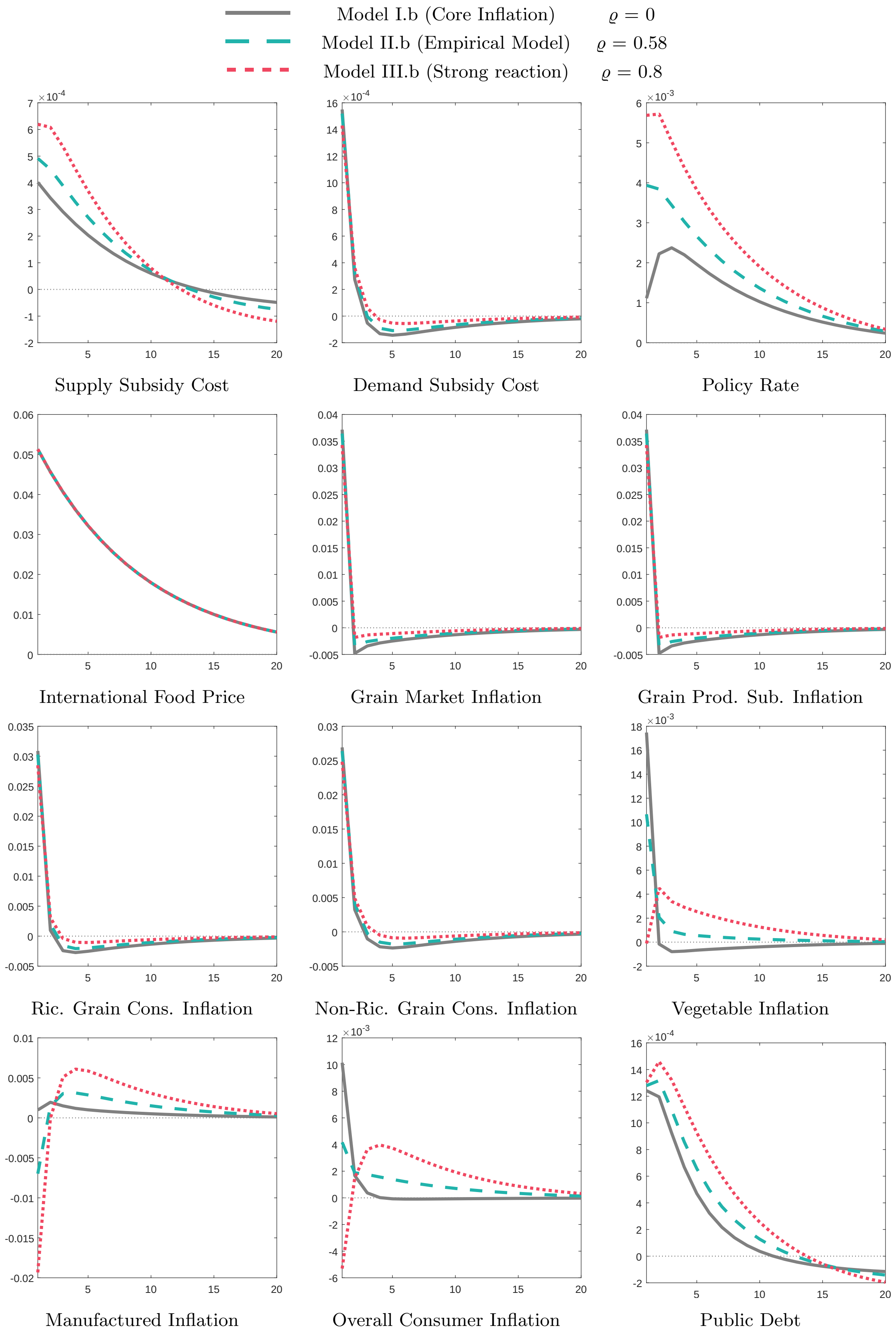


Figure 10: Food Price Shock and Monetary Policy, cont.

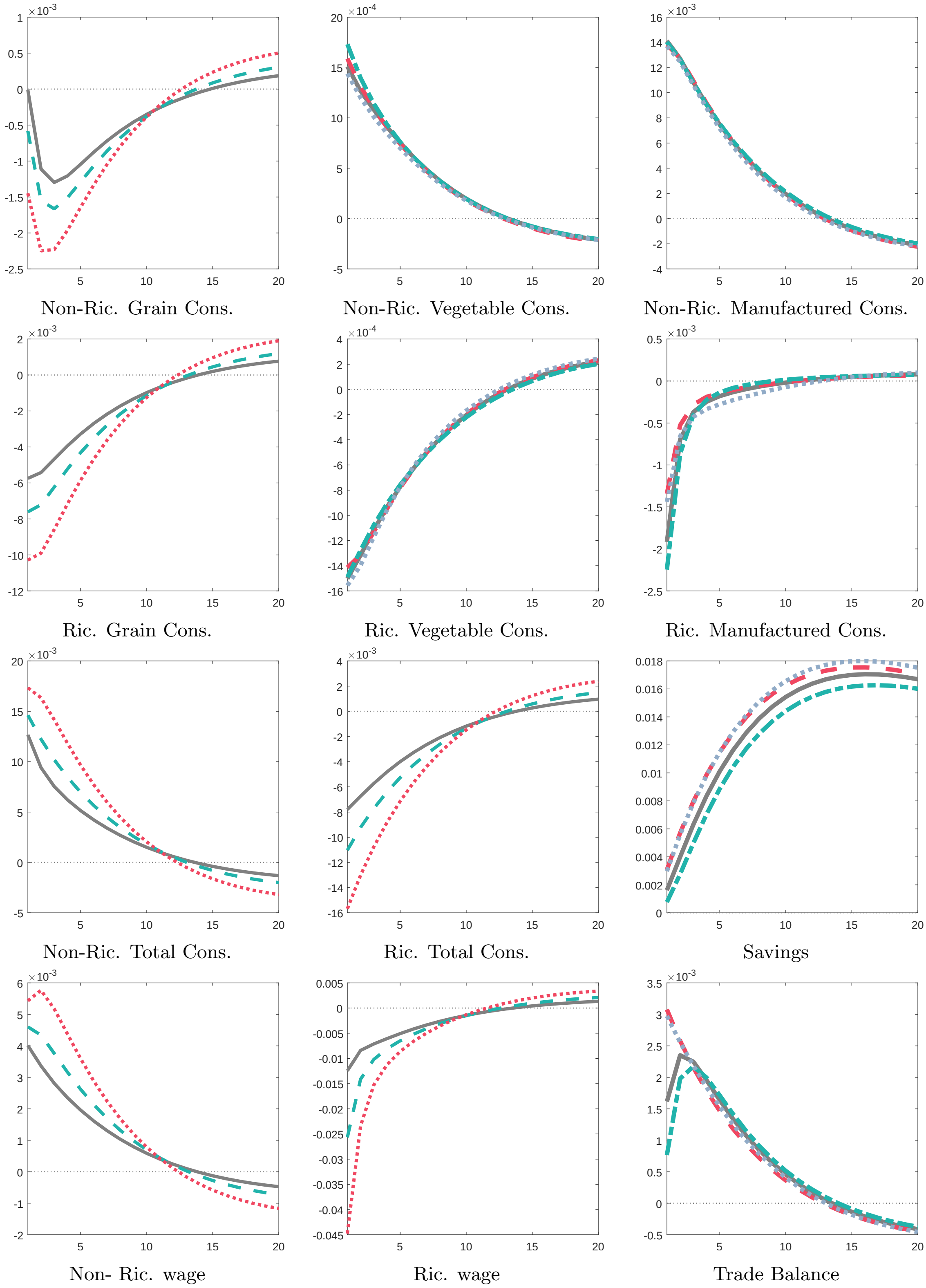


Figure 11: Food Subsidies Impact on Relative Price Volatility

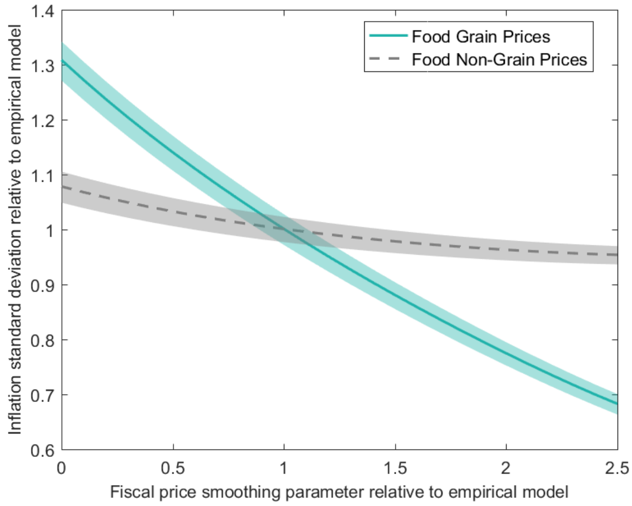


Figure 12: Food Subsidies Impact on Relative Price Volatility

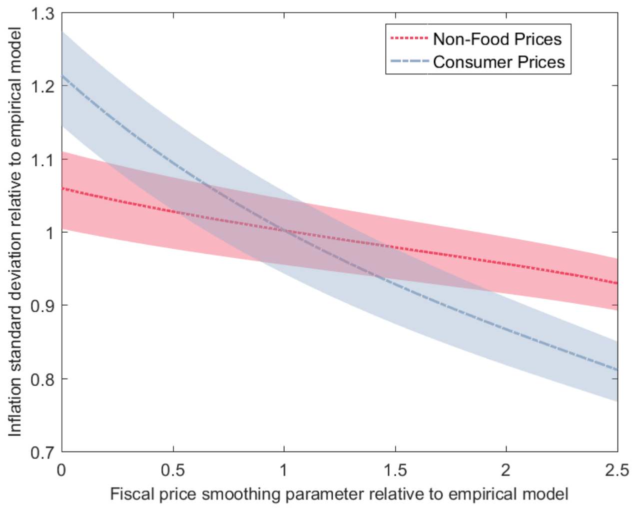


Figure 13: Food Subsidies Impact on Absolute Price Volatility

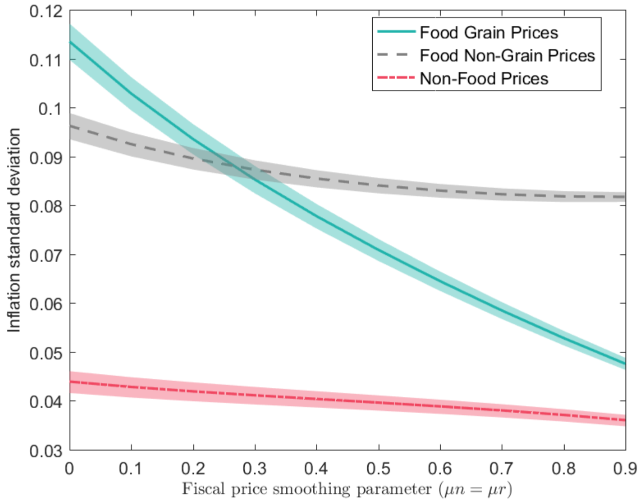


Figure 14: Food Subsidies Impact on Interest Rate Volatility

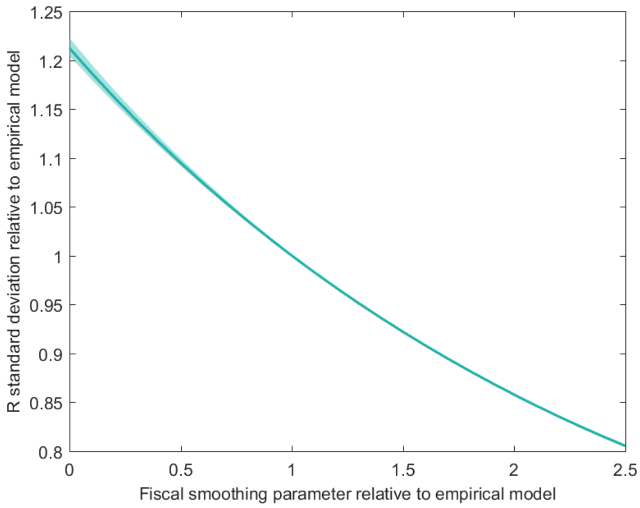
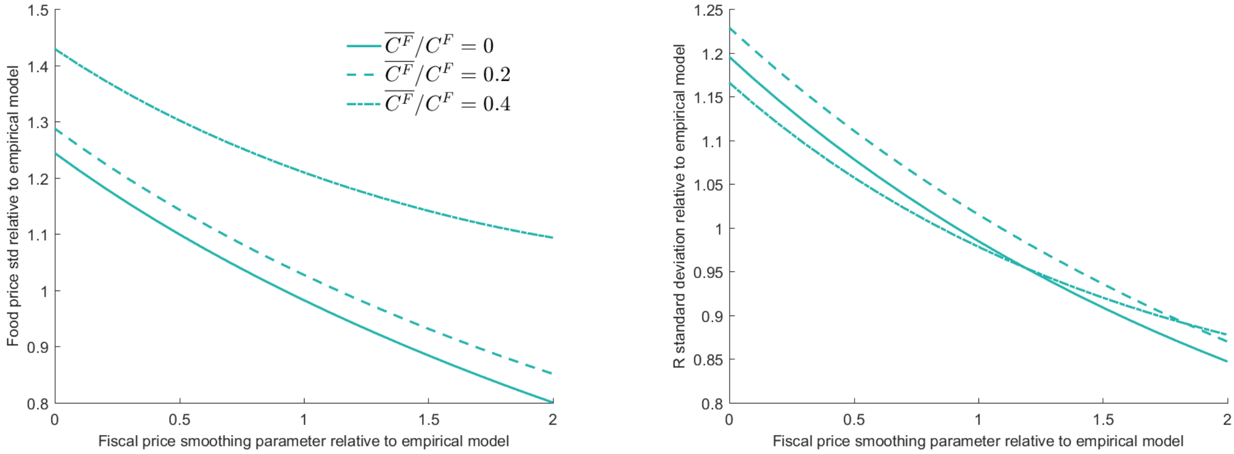
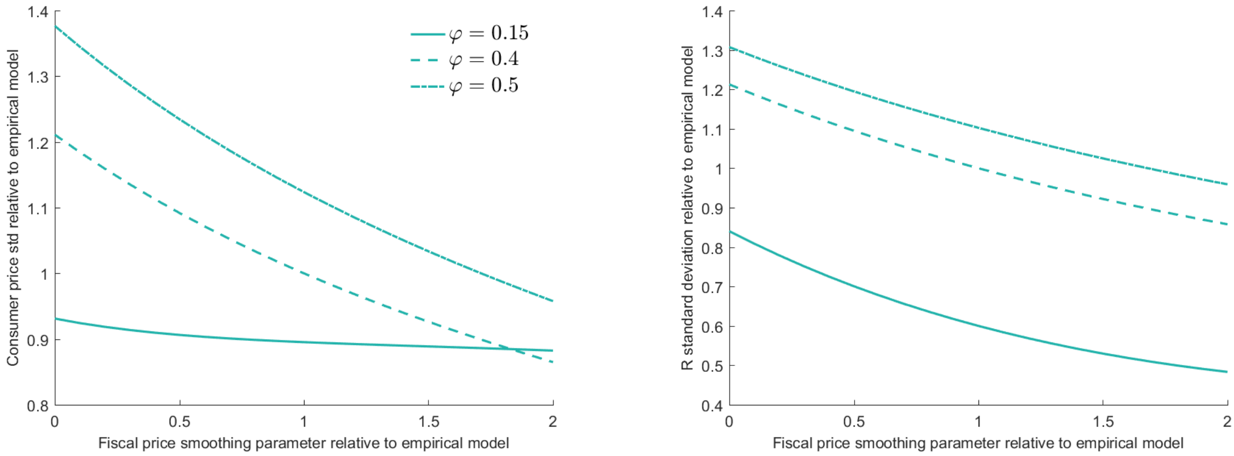


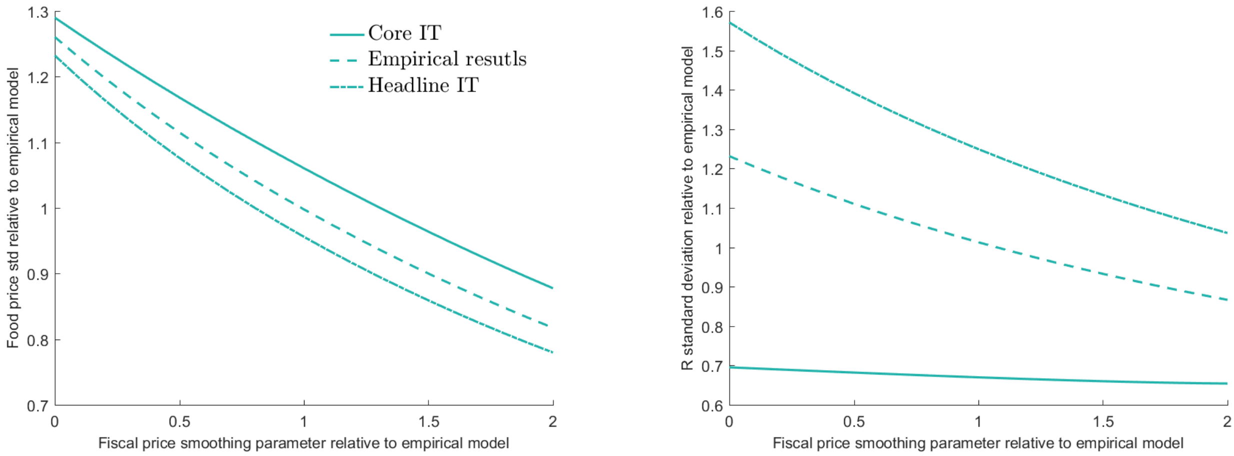
Figure 15: Food Price Intervention and Monetary Policy Interaction



Subsistence Share in Food Consumption



Food in Consumption



Monetary Policy

5.4 Sensitivity analysis

To further explore the conditions where food subsidies and monetary policy are complementary, we analyze the effect of a change in the share of food in consumption and the monetary policy target has on food inflation stabilization and the policy rate in standard deviation units (see Figure 15).

It follows that the higher (lower) the share of food subsistence, the greater (lower) food demand subsidies can contribute to stabilizing inflation. This is due to the fact that subsistence reduces the elasticity of substitution between food and non-food goods, which subsequently results in an increase of food price volatility. Consequently, we find an increase in the policy rate the higher the degree of food subsistence (see the top right graph in Figure 15).

As expected, the higher the share of food expenditures corresponds with a higher standard deviation of the inflation rate and policy rate (see middle-left and middle-right graph in Figure 15).

We find that the standard deviation on food inflation is lower if the RBI targets Headline Inflation, marginally followed by the Empirical Model. Under a Core IT framework, the RBI would not respond to food inflation, which would result in higher food inflation volatility which in turn yields a lower standard deviation of the policy rate.[37] A Core IT framework would then result in an absence of complimentary interaction between food price intervention and monetary policy (see the bottom right graph in Figure 15).

Overall, our results show that the interaction between food price intervention and monetary policy are complementary insofar that monetary policy reacts to food inflation for all three of the conditions analyzed.

6 Welfare

We consider the welfare gains (in consumption units) of fiscal policy to smooth food prices by household type. We evaluate the stabilization properties of five policy rules based on a second-order approximation of household welfare. The first rule corresponds with no price subsidy (i.e., $\mu_i = 0$ and large η). The second rule relates to supply subsidy only (i.e $\eta = 4.6$, the posterior value) and no demand subsidy ($\mu_i = 0$). The third and fourth rules relate to targeted ($\mu_n = 0.4$, the posterior value $\mu_r = 0$) and universal intervention ($\mu_n = \mu_r = 0.4$), respectively. All models have the same steady state. The last rule is based on the empirical model, i,e. η, μ_n and μ_r at posterior values (4.6, 0.4 and 0.2 respectively).

Following Faia and Monacelli (2007), we define welfare for household type as follows:

$$\mathcal{W}_{i,t} = E_t \left\{ \sum_{n=0}^{\infty} \beta^n U_i \left(C_{i,t+n}, N_{i,t+n} \right) \right\} \Big|_{x_0 = x} \tag{46}$$

Following Schmitt-Grohé and Uribe (2004), Adjemian et al. (2011) and Pourroy et al. (2016) the second-order welfare approximation takes the following form :

$$\mathcal{W} = \{ E_{-1} \{ \mathcal{W}_0 \} |_{y_{-1} = \bar{y}} = \bar{\mathcal{W}} + \frac{1}{2}[g_{\sigma\sigma}] + \frac{1}{2}\mathbb{E}_0 \{ [g_{uu}(u_1 \otimes u_1)] \},$$

where $\bar{\mathcal{W}}$ denotes the welfare value at the steady-state, $g_{\sigma\sigma}$ the second derivative of the policy function (g) with respect to the variance in the shocks, and g_{uu} the Hessian of g with respect to shock vector u. We can express welfare in Equation (46) recursively:

$$\mathcal{W}_{i,t} = U_i \left(C_{i,t}, N_{i,t} \right) + \beta \mathcal{W}_{i,t+1} \tag{47}$$

[37] Headline IT is represented by a Taylor rule where food inflation has the same weight as food goods in the consumption basket. Core IT is represented by a Taylor rule that reacts to non-food goods only.

Aggregate welfare is defined as the weighted sum of household welfare:

$$\mathcal{W}_t = (1-\lambda)\mathcal{W}_{r,t} + \lambda \mathcal{W}_{n,t} \tag{48}$$

The results of the welfare evaluation are presented in Table 6. Welfare gains are defined as additional perpetual consumption needed to make the level of welfare undera no-subsidy policy identical to that under the evaluated policy. Thus, a positive number indicates that welfare is higher under the alternative policy than under no-subsidy policy.

Results presented in Table 6 suggest that observed fiscal intervention (Empirical model) does improve *aggregate* welfare, albeit we find heterogeneous distributional effects by household type, in particular for food supply subsidy.

We find that food supply subsidies are welfare improving only for farmers (n). For these Non-Ricardian households, the supply subsidy brings an additional income that contributes to stabilize consumption in the event of a price increase. For Ricardian households working in the non-food sector, by providing an additional margin to farmers, food supply subsidies magnifies the food price shock (i.e., only farmers' incomes are stabilized, where the subsidy is funded via a combination of debt and taxes). Consequently, supply subsidies decrease Ricardians' welfare.

We find that a targeted food demand subsidies are welfare improving only for credit-constrained households. The non-Ricardian household type is sensitive to changes in food prices considering food represents a sizeable share of expenditures and their limited financial access to smooth consumption (Ginn and Pourroy, 2019). The government can thus borrow for non-Ricardians, thereby decreasing non-Ricardians' vulnerability to food price shocks.

Finally, universal demand subsidies increase welfare for non-Ricardian and Ricardian household, reflecting more stable consumer price.

In our setup, aggregate welfare is positive. however, it is worth noting that a policy recommendation is not straight forward. An analysis that gives the same weight to each household would reject a supply subsidy policy. However, in a Rawlsian perspective, it may be argued that the social planner should give more weight to the constrained household.[38] Finally, these results could also be seen in a political economy perspective as reflecting different households ability to control policy makers.

Overall, the empirical model welfare is positive for both non-Ricardians and Ricardians. At first glance, the demand subsidy does not seem justified for Ricardians, as this household can smooth consumption over time. However, the demand subsidy for Ricardian households offset the negative effect of the supply subsidy. Therefore demand subsidy for Ricardian households may be seen as a compensation for the supply subsidy. Once again, these results could also be seen as reflecting different households ability to react to policy makers.

7 Conclusion

This research offers a novel approach to understand the interaction between fiscal and monetary authorities. To our knowledge, our paper is the first study to estimate the contribution of fiscal subsidies to price stability. Accordingly, we have studied the implications of how fiscal intervention to shield households from food price volatility affects inflation and monetary policy. We estimate a Bayesian DSGE model that incorporates key features of LMICs including a food demand price smoothing subsidy, a food producer subsidy, incomplete

[38] As explained by Fontan et al. (2016): "Rawls's difference principle, which, as standardly understood, requires that institutions ensure inequalities in income and wealth maximize the expectations of the least advantaged." See Rawls (1999).

Table 6: Welfare Results

Scenario	Calibration			Relative Welfare		
	μ_n	μ_r	η	$\mathcal{W}$	$\mathcal{W}_n$	$\mathcal{W}_r$
No subsidy	0	0	10e4	0	0	0
Supply Subsidy	0	0	4.6	-0.002	0.004	-0.005
Targeted Demand Subsidy	0.4	0	10e4	0.013	0.045	-0.008
Universal Demand Subsidy	0.4	0.2	10e4	0.078	0.130	0.044
Empirical Model	0.4	0.2	4.6	0.054	0.098	0.025

Note: all other parameters are based on the posterior mean. Welfare results are presented in deviation to "No Subsidy".

markets with credit-constrained consumers and a high share of households food expenditures. The model is applied using Indian data, considering only food grain received subsidies.

Four key findings emerge from our analysis. First, the empirical evidence suggests that food demand subsidies creates a policy-induced form of price stickiness that is different to, yet operates in parallel with, the classic Calvo price stickiness. This underscores the importance of a coordinated fiscal and monetary policy response considering the joint policy reactions are interdependent with regard to stabilizing food prices.

Second, by evaluating the fit of an alternative Taylor rule, we find the RBI does not overlook food price inflation. This empirical link implies a revealed preference of the actions of RBI in response to developments in both core and headline price indices, consistent with the RBI's mandate to stabilize the CPI.

Third, we find that food demand subsidies contribute to stabilizing inflation, which in turn reduces the monetary reaction to food inflation volatility. We compare the contribution that the food subsidy policy has on the monetary policy objective of price stability, *inter alia*. Following a world food price shock, we find that in the absence of food subsidies, RBI's interest rate increase to a typical food price shock would be 24% larger in the absence of food subsidies. Thus, while monetary and fiscal policy may be viewed as achieving a shared policy goal of price stabilization, hence the interaction of the two policies can be considered a strategic substitute.

Fourth, aggregate welfare increases the higher the degree of food demand intervention, albeit there are heterogeneous distributional effects. Non-Ricardians are unable to smooth consumption, unlike the Ricardian household, however the government can do so for them by borrowing vis-á-vis a food price subsidy. This, in addition to the policy influence for food goods (due to survival consumption which does not exist for other goods), makes monetary and fiscal policy complementary in India. While food supply subsidies are not found to contribute to price stability, it appears to be welfare improving for farmers only. With largely heterogeneous distributional welfare effects, the precise setting of food subsidies may better be seen as a political economics object.

The existing literature generally relies on the assumption that monetary policy is solely charged with stabilizing inflation by setting the interest rate (Galì, 2008). In LMICs, the transmission channel of monetary policy is weakened by the presence of non-Ricardian households who are unable to smooth consumption (Galì et al., 2004). We contribute to the literature by highlighting that fiscal intervention via food price subsidies can complement monetary policy such that the former creates a policy-induced form of price stabilization to reduce the pass-through of global shocks to domestic prices. Our results therefore show that the standard NK model in which a primary goal of monetary policy is price stability, is not necessarily suitable to an emerging economy such as India. Not only would a standard NK model tend to overestimate the influence of monetary policy, it would also omit the interrelated influence of fiscal policy. The academic literature tends to view inflation targeting as the sole policy framework that is responsible for stabilizing prices. Our results show that fiscal policy based on a food subsidy, a feature that is common in many LMICs, contributes to the overall price stability.

Additionally, the results have two policy implications. First, the welfare results challenge a fiscal policy response that does not conform to a policy targeting vulnerable (non-Ricardian) members of society considering a scarcity of fiscal resources, particularly in LMICs. Second, a coordinated fiscal and monetary policy response may be optimal, considering the policy reactions are interdependent, under the condition that food price subsidies are properly targeted to households that are unable to smooth consumption.

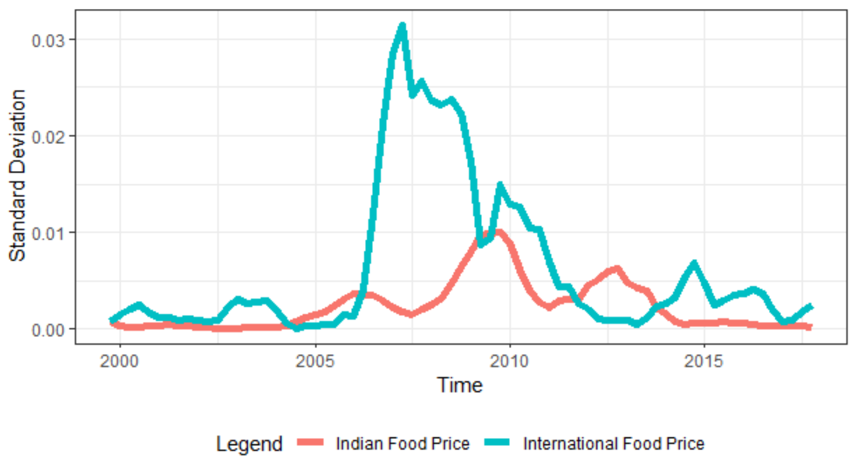
This paper opens new perspectives for future research. A range of tools for managing food prices in a country may be considered beyond the scope of this paper. These may include storage design for price stabilization and counter-cyclical tariffs (pro-cyclical tariffs) when the world price is high (low) for an importer (exporter) (Gouel et al., 2016). Additionally, while we have modelled India, a net-food exporter, the model could also be developed for a net-food importing economy. These questions are left for future research.

8 Appendix

8.1 Food price volatility

Figure 16 demonstrates that since approximately 2007, the international food price (based on FAO data) and domestic food price in India have been relatively more volatile and persistent. Furthermore, while the two prices share a dynamic relationship, the international food price volatility is leading where food price volatility appears to be less severe in India. We observe three main hikes in the international food price volatility occurring in 2007, 2010 and 2013.

Figure 16: Food Price Volatility



Note: volatility is measured as a moving average of the log food price standard deviation. Sources: FAO food price and FRED for the Indian food price (Mnemonic WPOTFD01INQ661N).

8.2 Household Optimization

8.2.1 Ricardian Household Optimization

The Ricardian agent's optimization can be formalized as follows:

$$L_{r,t} = \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\rho} C_{r,t}^{1-\rho} - \frac{\psi}{1+\chi} N_{r,t}^{1+\chi} \right) + \Lambda_{r,t} \left(\frac{(1+i_{t+1})\, B_t}{\overrightarrow{P_{r,t}}} + \frac{e_t \left(1+i^{\star}_{t+1}\right) \Theta(\mathcal{B}) B^{\star}_{t+1}}{\overrightarrow{P_{r,t}}} + \right.$$
$$\left. (1-\tau_t) W_t^M N_{r,t} + (1-\tau_t)\Pi^M_{r,t} + (1+\tau_t)(C_{r,t} + \overline{C_r^G} + \overline{C_r^N}) - \frac{B_t}{\overrightarrow{P_{r,t}}} - \frac{e_t B^{\star}_t}{\overrightarrow{P_{r,t}}} \right) \tag{49}$$

where $\Lambda_{r,t}$ represents the shadow value on the budget constraint. Optimization yields the following first-order conditions:

$$\frac{\partial L_{r,t}}{\partial C_{r,t}} : \ \Lambda_{r,t} = \frac{C_{r,t}^{-\rho}}{(1+\tau_t)} \tag{50}$$

$$\frac{\partial L_{r,t}}{\partial B_t} : \ \Lambda_{r,t} = \beta^t E_t \left[\Lambda_{r,t+1} \frac{(1+i_{t+1})}{\overrightarrow{\pi_{r,t+1}}} \right] \tag{51}$$

$$\frac{\partial L_{r,t}}{\partial B^{\star}_t} : \ \Lambda_{r,t} = \beta E_t \left[\Lambda_{r,t+1} \frac{\left(1+i^{\star}_{t+1}\right) \Theta(\mathcal{B})}{\overrightarrow{\pi}_{r,t+1}} \frac{e_{t+1}}{e_t} \right] \tag{52}$$

$$\frac{L_{r,t}}{\partial N_{r,t}} : \ \psi N_{r,t}^{\chi} = \Lambda_{r,t}(1-\tau_t) W_t^M \tag{53}$$

Equations (52) and (55) represent the inter-temporal optimization relating labor supply decisions with the marginal rate of consumption and real wage. The Euler equation is represented by Equations (53) and (54) for domestic and foreign bonds.

8.2.2 Non-Ricardian Household Optimization

The non-Ricardian utility maximization yields the normal intra-temporal labor supply optimality condition:

$$\frac{\partial L_{n,t}}{\partial C_{n,t}} : \ \Lambda_{n,t} = \frac{C_{n,t}^{-\rho}}{(1+\tau_t)} \tag{54}$$

$$\frac{\partial L_{n,t}}{\partial N_{n,t}} : \ \psi N_{n,t}^{\chi} = \frac{(1-\tau_t)\Lambda_{n,t} W_t}{\overrightarrow{P_{n,t}}} \tag{55}$$

8.3 Robustness tests

We consider two alternative models. The first includes an alternative Taylor rule where it may be argued that the stability of the exchange rate was also given some weight in the central bank objective function. The second alternative model is based on a fiscal policy that smooths the food grains price, where the food grain price is based on a steady state value. Each model is discussed in turn.

8.3.1 Alternative Taylor rule

The RBI has adopted an inflation targeting framework in 2016. Prior to this period, price stability was already a main objective of monetary policy. However, it may be argued that the stability of the exchange rate was also given some weight in the central bank objective function. See Garcia et al. (2011) among other, on this topic. Consequently, as a robustness test, we consider the following Taylor Rule:

$$\frac{1+r_t}{1+r} = \left(\frac{1+r_{t-1}}{1+r}\right)^{\psi_s} \left[\left((\pi_t^M)^{\varrho}(\pi_t^F)^{1-\varrho}\right)^{\omega_\pi} (\Delta y_t)^{\omega_y} (\Delta e_t)^{\omega_e}\right]^{1-\psi_s} e^{\varepsilon_t^{MP}} \tag{56}$$

where ψ_s is the degree of interest rate smoothing and ω_π, ω_y and ω_e are the weights given to inflation, the output-gap and exchange rate, respectively.

Consistent with Adolfson et al. (2007), we allow for an interest rate response to a change in the exchange rate (ω_e), with a prior mean of zero set for this parameter (we keep all other priors the same). The estimates of this alternative model are presented in Table 7. We obtain a low posterior mean ($\omega_e = 0.04$), where most of the posteriors are similar to the baseline model (see Table 3).

Table 7: Prior and Posterior Distributions via Alternative Taylor Rule

			Prior		Posterior			
		Density	Mean	StD	Mean	90% interval		StD
Fiscal Policy								
η	Supply subsidy intensity (MSP)	I	6.000	2	5.4593	3.9564	7.1761	1.1521
κ	Degree of grain price smoothing (CIP)	B	0.750	0.05	0.7898	0.7286	0.8660	0.0442
μ_r	Share of grain subsidized Ric. consum	B	0.100	0.05	0.2106	0.1527	0.2617	0.0610
μ_n	Share of grain subsidized Non-Ric. consum.	B	0.350	0.05	0.3703	0.2977	0.4379	0.0509
Monetary policy								
ϱ	Policy price index	B	0.600	0.05	0.6157	0.5726	0.6639	0.0429
ψ_S	Interest rate smoothing	B	0.700	0.10	0.5438	0.4838	0.6145	0.0406
ω_π	TR response: inflation	N	1.500	0.10	1.7367	1.6087	1.8357	0.0919
ω_y	TR response: GDP	N	0.500	0.05	0.4716	0.3797	0.5964	0.0500
ω_e	TR response: exchange rate	N	0.000	0	0.0543	-0.0285	0.1335	0.0463
Utility function								
$\overline{C^G}$	Food subsistence: grains	I	0.100	2	0.0329	0.0230	0.0428	0.0062
$\overline{C^N}$	Food subsistence: non-grains	I	0.100	2.00	0.0247	0.0207	0.0287	0.0034
ρ	Inverse of intert. elasticity of subst.	G	2.000	0.10	2.0679	1.8330	2.2438	0.0989
χ	Inverse Frisch	G	1.000	0.10	0.8970	0.7654	1.0038	0.0929
θ	Elasticity of substitution F and M	G	0.750	0.05	0.6864	0.6199	0.7440	0.0425
θ_G	Elasticity of substitution G and V	G	0.850	0	0.9859	0.9153	1.0499	0.0450
Other								
ζ	Bond adjustment costs	I	0.010	2	0.0099	0.0054	0.0138	0.0032
ϵ	Manufacturing sector market power	I	11.000	2.00	10.6368	7.5026	13.4718	1.6053
ϕ_N	Calvo signal	B	0.660	0.05	0.6266	0.5393	0.7021	0.0454
Shocks								
ρ^{A^N}	AR on non-food productivity	B	0.800	0.10	0.9349	0.9115	0.9639	0.0184
ρ^{A^G}	AR on food grain productivity	B	0.500	0.10	0.8959	0.8645	0.9305	0.0254
ρ^{A^V}	AR on food non-grain productivity	B	0.500	0.10	0.9167	0.8831	0.9505	0.0266
ρ^{MP}	AR monetary policy	B	0.500	0.05	0.2562	0.2074	0.2992	0.0271
$\rho^{i\star}$	AR foreign interest rate	B	0.460	0.05	0.5574	0.4978	0.6130	0.0435
$\rho^{F\star}$	AR on food price	B	0.750	0.10	0.8908	0.8690	0.9091	0.0122
ρ^{Ψ_G}	AR law of one food grain price gap	B	0.900	0.05	0.9276	0.9129	0.9464	0.0103
ρ^{Ψ_N}	AR law of one food non-grain price gap	B	0.900	0.05	0.7353	0.6649	0.8045	0.0358
σ^{AN}	StD manufacturing productivity	I	0.100	2	0.0150	0.0126	0.0177	0.0013
σ^{AG}	StD food grains productivity	I	0.100	2	0.0216	0.0184	0.0245	0.0020
σ^{AM}	StD food non-grains productivity	I	0.100	2	0.0221	0.0187	0.0253	0.0022
σ^{MP}	StD monetary policy	I	0.100	2	0.0121	0.0098	0.0144	0.0010
$\sigma^{i\star}$	StD foreign interest rate	I	0.100	2	0.0103	0.0090	0.0117	0.0009
$\sigma^{P^{F\star}}$	StD food price	I	0.100	2	0.0347	0.0293	0.0402	0.0026
σ^{Ψ_G}	StD law of one food grains price gap	I	0.100	2	0.0460	0.0406	0.0507	0.0036
σ^{Ψ_N}	StD law of one food non-grain price gap	I	0.100	2	0.0368	0.0276	0.0456	0.0047

Note: distributions include Beta (B), Gamma (G), Inverse Gamma (I) and Normal (N). “StD” for standard deviation.

8.3.2 Lump Sum Tax Model

In our model, the government budget is funded via combination of debt and tax revenues. Tax revenues are compulsory to rule out a Ponzi scheme. However, taxes may create a distortion in favor of one sector relative to others sectors. There are two solutions to avoid such a distortion: either to tax all flows identically (as in the baseline model) or to incorporate a lump sum tax.

In our baseline framework, we present a number of tax instruments based on a single tax rate.[39] To check the robustness of our model, we compare the baseline results with the alternative model based on a lump-sum tax. The household program takes the following form:

$$\begin{aligned} L_{r,t} = \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\rho} C_{r,t}^{1-\rho} - \frac{\psi}{1+\chi} N_{r,t}^{1+\chi} \right) + \Lambda_{r,t} \left(\frac{(1+i_{t+1})\, B_t}{\overrightarrow{P_{r,t}}} + \frac{e_t \left(1+i^{\star}_{t+1}\right) \Theta(\mathcal{B}) B^{\star}_{t+1}}{\overrightarrow{P_{r,t}}} + \right. \\ \left. W_t^M N_{r,t} + \Pi_{r,t}^M + C_{r,t} + \overline{C_r^G} + \overline{C_r^N} + \frac{B_t}{\overrightarrow{P_{r,t}}} - \frac{e_t B_t^{\star}}{\overrightarrow{P_{r,t}}} - tax_t \right) \end{aligned} \tag{57}$$

where $\Lambda_{r,t}$ represents the shadow value on the budget constraint.

The government's inter-temporal budget constraint is funded via domestic (B_t^G) debt and lump-sum taxes (tax_t):

$$B_t^G - (1+i_{t-1}) B_{t-1}^G = \overrightarrow{S_t} - tax_t \tag{58}$$

Stability is ensured by defining a relation between tax and debt. With ρ^{τ} the lump-sum tax elasticity to the government budget, we have: $tax_t = \rho^{\tau} \frac{B_{t-1}^G}{P_t Y_t}$.

We provide the results corresponding with the Bayesian estimation in Table 8. The results are closely aligned with the baseline model (see Table 4). Consistent with the baseline model, we highlight that the estimated posteriors for the food price intensity for the non-Ricardian (κ_n) is higher than the one for the Ricardian (κ_r), which suggests there is higher food price smoothing for the non-Ricardian household. Furthermore, the estimated posterior for the share of food that enters the Taylor-like rule is estimated to be 0.59 and 0.61 for the baseline and lump-sum model, respectively, which underscores the actions taken by the RBI in response to developments based on food and non-food inflation.

[39] The baseline model contains six instruments on taxes on consumption and income (see Equation (39).

Table 8: Prior and Posterior Distributions via Lump Sum Tax Model

			Prior		Posterior			
		Density	Mean	StD	Mean	90% interval		StD
Fiscal Policy								
η	Supply subsidy intensity (MSP)	I	6.000	2	9.2502	3.2043	15.3183	1.3221
κ	Degree of grain price smoothing (CIP)	B	0.750	0.05	0.7629	0.7034	0.8380	0.0439
μ_r	Share of grain subsidized Ric. consum.	B	0.100	0.05	0.2141	0.1469	0.2697	0.0605
μ_n	Share of grain subsidized Non-Ric. consum.	B	0.350	0.05	0.3757	0.2882	0.4692	0.0510
Monetary policy								
ϱ	Policy price index	B	0.600	0.05	0.6387	0.5619	0.6992	0.0427
ψ_S	Interest rate smoothing	B	0.700	0.10	0.5060	0.4449	0.5831	0.0405
ω_π	TR response: inflation	N	1.500	0.10	1.6880	1.5591	1.8328	0.0917
ω_y	TR response: GDP	N	0.500	0.05	0.4197	0.3360	0.5296	0.0500
Utility function								
$\overline{C^G}$	Food subsistence: grains	I	0.100	2	0.0362	0.0247	0.0463	0.0061
$\overline{C^N}$	Food subsistence: non-grains	I	0.100	2	0.0230	0.0172	0.0291	0.0034
ρ	Inverse of intert. elasticity of subst.	G	2.000	0.10	2.1107	1.9426	2.2438	0.0987
χ	Inverse Frisch	G	1.000	0.10	0.9712	0.7920	1.0962	0.0929
θ	Elasticity of substitution F and M	G	0.750	0.05	0.6991	0.6521	0.7507	0.0424
θ_G	Elasticity of substitution G and N	G	0.850	0.05	0.9672	0.8799	1.0350	0.0450
Other								
ζ	Bond adjustment costs	I	0.010	2	0.0092	0.0025	0.0162	0.0033
ϵ	Manufacturing sector market power	I	11.000	2	10.1820	7.5305	13.1377	1.6041
ϕ_M	Calvo signal	B	0.660	0.05	0.5817	0.5231	0.6454	0.0450
Shocks								
ρ^{A^N}	AR on non-food productivity	B	0.800	0.10	0.9442	0.9142	0.9728	0.0181
ρ^{A^G}	AR on food grain productivity	B	0.500	0.10	0.8970	0.8656	0.9375	0.0252
ρ^{A^V}	AR on food non-grain productivity	B	0.500	0.10	0.9003	0.8422	0.9480	0.0263
ρ^{MP}	AR monetary policy	B	0.500	0.05	0.2496	0.2224	0.2804	0.0269
$\rho^{i\star}$	AR foreign interest rate	B	0.460	0.05	0.5961	0.5205	0.6511	0.0437
$\rho^{F\star}$	AR on food price	B	0.750	0.10	0.8936	0.8799	0.9120	0.0116
ρ^{Ψ_G}	AR law of one food grain price gap	B	0.900	0.05	0.9302	0.9187	0.9396	0.0099
ρ^{Ψ_N}	AR law of one food non-grain price gap	B	0.900	0.05	0.7496	0.6976	0.7855	0.0350
σ^{AN}	StD manufacturing productivity	I	0.100	2	0.0149	0.0134	0.0164	0.0013
σ^{AG}	StD food grain productivity	I	0.100	2	0.0230	0.0191	0.0261	0.0020
σ^{AM}	StD food non-grain productivity	I	0.100	2	0.0234	0.0202	0.0267	0.0022
σ^{MP}	StD monetary policy	I	0.100	2	0.0124	0.0107	0.0139	0.0010
$\sigma^{i\star}$	StD foreign interest rate	I	0.100	2	0.0103	0.0092	0.0114	0.0009
$\sigma^{P^{F\star}}$	StD food price	I	0.100	2	0.0335	0.0290	0.0368	0.0026
σ^{Ψ_G}	StD law of one food grain price gap	I	0.100	2	0.0481	0.0435	0.0539	0.0036
σ^{Ψ_N}	StD law of one food non-grain price gap	I	0.100	2	0.0352	0.0279	0.0420	0.0047

Note: distributions include Beta (B), Gamma (G), Inverse Gamma (I) and Normal (N). "StD" for standard deviation.

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