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# The Contribution of Food Subsidy Policy to Monetary Policy

William Ginn\*

Marc Pourroy†

## Abstract

Monetary policy is generally viewed in the literature as the only institution responsible for price stability. This approach overlooks the importance of food price stabilization policies, which are particularly important in low- and middle-income economies. We estimate a Bayesian DSGE model that incorporates fiscal and monetary policy tailored to India. Fiscal policy is based on a consumer food price subsidy. The empirical evidence suggests that food subsidies create a policy-induced form of food price-stickiness that operates in parallel with, yet is different to, the classic Calvo monopolistic competition framework. We find that the food price subsidy reduces CPI volatility and monetary policy reaction: following a world food price shock, interest rate volatility would be 10% higher absent food subsidies. Putting this effect aside would lead to overestimate the effectiveness of inflation targeting in EMEs. A main finding is the subsidy policy reduces aggregate welfare, albeit we find heterogeneous distributional effects by households.

**JEL Classification:** E52; E60; E30; E32.

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

## Highlights :

- Monetary policy is generally viewed as the only institution responsible for price stability, which omits the influence of food price stabilization policies in low- and middle-income economies.
- We estimate a DSGE model via Bayesian methods using Indian data that incorporates a food price stabilization policy.
- The empirical evidence suggests that food subsidies create a policy-induced food price-stickiness.
- Food subsidies reduce inflation volatility and monetary policy reaction.
- We find heterogeneous distributional effects of the subsidy policy on household welfare.

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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 9 in Appendix 8.1). This creates a challenge for the conduct of monetary policy, particularly for low- and middle-income economies with a large proportion of households that are credit constrained and share of food expenditures is large. The latter has potential repercussions on aggregate price stability, which is considered one of, if not the most important, objectives of most central banks around the world. The literature generally assumes that the central bank is responsible for price stability (Woodford, 2003). However, Ginn and Pourroy (2019) document that food subsidies are common fiscal policy instrument designed to stabilize food prices in low- and middle-income 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 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. Sdravovich et al. (2014), Koplow (2009) and Clements et al. (2013)). If such a gap exists, food prices are then considered “policy-driven”. Consequently, there are two important questions: Does fiscal policy via food subsidies create price stickiness? Does the interaction between monetary policy and fiscal policy strategic complements or substitutes?

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 consumer 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 consumer (i.e., demand) subsidies smooth consumer prices and reduce the need for monetary policy action.<sup>1</sup>

In this paper, we develop a DSGE model that incorporates fiscal and monetary policy in the presence of an international food price shock. The model is applied via Bayesian methods. Doing so serves two purposes. First, this methodology allows us to better understand the mechanisms through which food price volatility affects macroeconomic conditions. Second, our research is an empirical extension of the literature to evaluate the interrelated fiscal and monetary policy response. We develop methods to quantify the respective contribution of monetary and fiscal policy in stabilizing food price volatility. 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 advantages: first, this method does not suffer from an “identification problem” (Lubik and Schorfheide, 2007) as in single-equation estimation methods; second, 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. We apply the model using Indian data. India is an important case in point, as India 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

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<sup>1</sup>Production (i.e., supply) 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.

expenditures and where aggregate inflation expectations are anchored by food inflation ([Anand et al. \(2014\)](#) and [Anand et al. \(2016\)](#)). The Reserve Bank of India (RBI) has adopted an inflation targeting framework in May 2016 with a numerical objective for the consumer price index growth.<sup>2</sup>

Our main results are fourfold:

- We confirm the existence of a policy-induced price-stickiness for food goods due to the 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 Reserve Bank of India (RBI) does not overlook food price inflation, the weight of food inflation in the Taylor rule being close to its weight in the consumer price index;
- We show that fiscal policy via food subsidy complements the RBI with regard to price stability: absent food subsidies, assuming the same monetary policy reaction function based on the posterior values, the central bank would have to increase its interest rate by an additional 12.5 basis points, food inflation volatility would be 22.7% higher and because of second round effect non-food inflation volatility would be 5.6% higher following a one standard-deviation shock on the world food price.
- Our results indicate that fiscal intervention via a food price subsidy reduces aggregate welfare, albeit we find heterogeneous distributional effects by households. The subsidy benefits credit constrained (non-Ricardian) households with no access to financial instruments to smooth consumption.

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 [Gali \(2008\)](#)) which intersects with three features that are representative of low- and middle-income economies: a fraction of consumers have no access to financial instruments ([Anand et al., 2015](#)); there is a subsistence level of food consumption ([Portillo et al., 2016](#)); and food prices are subsidized by a fiscal authority ([Ben Aïssa and Rebei, 2012](#)). The model incorporates two sectors representative of a low- and middle-income economy. The food sector is produced using labor supplied by the non-Ricardian household and sold in a competitive environment. The non-food sector uses capital and labor technology supplied by the Ricardian household. The government intervenes following a pre-announced rule to shield the household from price fluctuations. The gap between the producer price and the consumer price is the food subsidy. Our contribution to this strand of research is twofold. First, we take stock of the previous literature to consider a large number of characteristics associated with food prices and bring them together in a single and coherent framework. Second, most of these papers are solely calibrated, not estimated. To our knowledge, this is the first paper to provide an empirical estimation of key parameters in the transmission of food price shocks such as food subsistence in consumption or food price subsidy smoothing effect via Bayesian methods.

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 middle- or low-income countries. [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

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<sup>2</sup>The inflation target is set for a period of five years, and is currently defined as 4% Consumer Price Index inflation, with a lower and upper tolerance limit of 2% and 6%, respectively.

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.<sup>3</sup> Similarly, [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. [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). Taking this evidence into account, we incorporate deviations from the law of one food price in the short-run between international and domestic prices.<sup>4</sup> The consumer food price faced by the household is based on the producer food price subject to a food subsidy to reflect fiscal intervention to shield households from food price shocks. 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, consumer 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 low- and middle-income economies 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. While our results lean towards the latter works, our research goes beyond these papers by developing an empirically-grounded framework; by showing that the optimal monetary policy is dependent on the effective subsidy 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<sup>5</sup> 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 find that the Chilean Central Bank responds to short-term developments of food inflation. They show that a food

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<sup>3</sup> 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 RBI online information.

<sup>4</sup> Our approach is similar to e.g. [Medina and Soto \(2005\)](#), [An and Kang \(2011\)](#) and [Poghosyan and Beidas-Strom \(2011\)](#) who apply a law of one price gap for oil prices as an AR(1) process.

<sup>5</sup>These include soybean oil, poultry meat, pork, beef and mutton.

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.<sup>6</sup> 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. Absent 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. By demonstrating that monetary and fiscal policy may be viewed as achieving a shared policy goal of price stabilization, our paper further offers a novel framework to view the interaction of the two policies. Finally, our paper is the first research that establishes and quantifies monetary policy and the fiscal food price stabilization policy as a strategic substitute.

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 analysis of food subsidies. Section 6 contains the welfare results. Section 7 concludes the paper to include policy implications.

## 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 \(2015\)](#) show 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.

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<sup>6</sup>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.

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.<sup>7</sup> India is no exception such that food subsidies are a persistent structural feature. The food policy objective in India is driven by food security by means of subsidizing food prices through the public distribution systems (PDS) consumer subsidy and a remunerative minimum support prices (MSP) supplier subsidy for farmers ([Ganguly and Gulati, 2013](#)). 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](#)).

PDS was introduced in the 1940s following the Bengal famine. 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. 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 1). The subsidy has increased considerably driven by food price volatility (see Figure 2). The food subsidy in India is a food security program (e.g. wheat, rice, sugar, edible oil, pulses and millet). [Sharma and Alagh \(2013\)](#) find that the rising food subsidy is determined by high domestic and world food prices. High food inflation has been chronic, particularly from 2006 to 2014 where the average food inflation was 8.4%.<sup>8</sup>

### 3 The Model

We develop an open economy DSGE model which incorporates a food and manufacturing sector as in [Catão and Chang \(2015\)](#) and [Pourroy et al. \(2016\)](#). We follow [Anand et al. \(2015\)](#), [Portillo et al. \(2016\)](#) and [Pourroy et al. \(2016\)](#) by incorporating food subsistence in utility.<sup>9</sup> We incorporate a food price subsidy as in [Ginn and Pourroy \(2019\)](#) to capture India’s fiscal policy objective of food security.

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

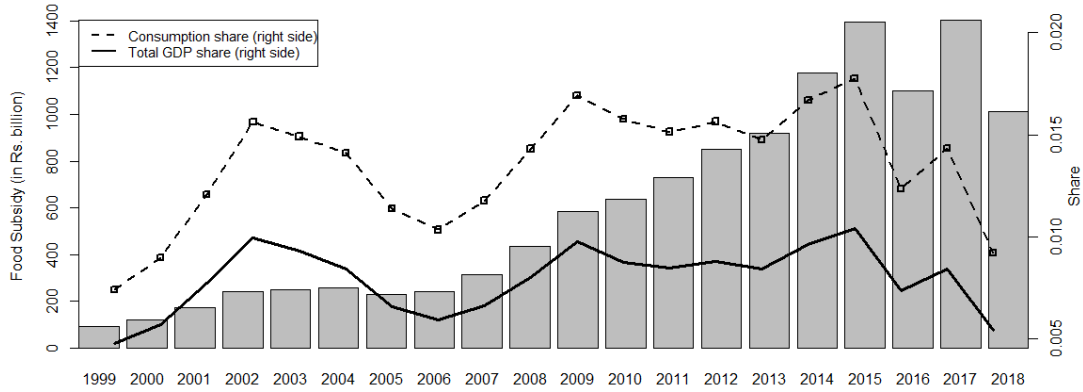
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<sup>7</sup> [Ginn and Pourroy \(2019\)](#) find that food subsidies are common in countries where the share of households living under the poverty line is higher; the share of food consumption is higher; and food access is lower.

<sup>8</sup> This is more than double the inflation rate relative to 2000 to 2005 (3.9%).

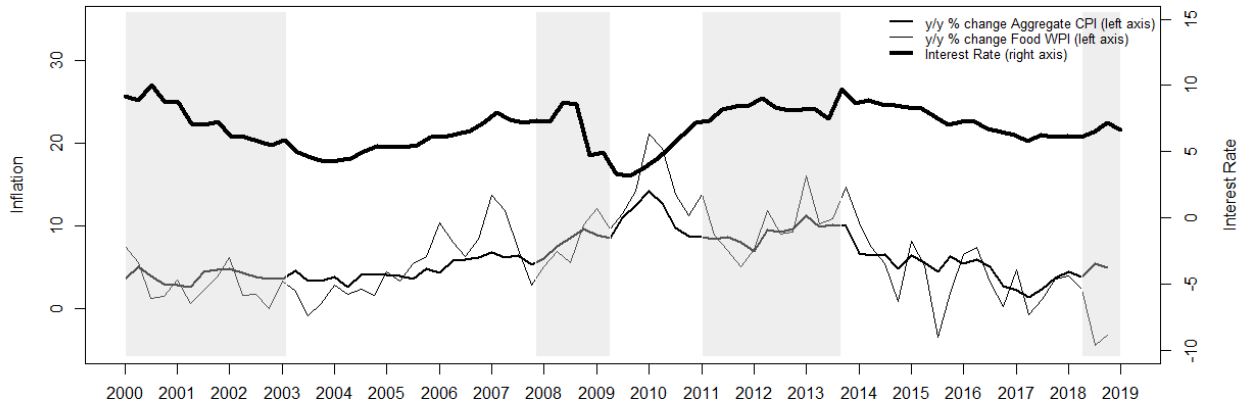
<sup>9</sup> A large share of food subsistence in the consumption bundle is a key element of the “food problem” ([Gollin et al., 2007](#)) that justifies the food security program.

Figure 1: Food Subsidy



**Sources:** author’s calculation based on 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.

Figure 2: Indian Inflation and Interest Rate



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

opportunities” (p. 102). According to the the FAO, the majority (70%) of India’s rural household’s depend mainly on agriculture for their livelihoods.<sup>10</sup> 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 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 a consumer food price subsidy.<sup>11</sup> In an RBI

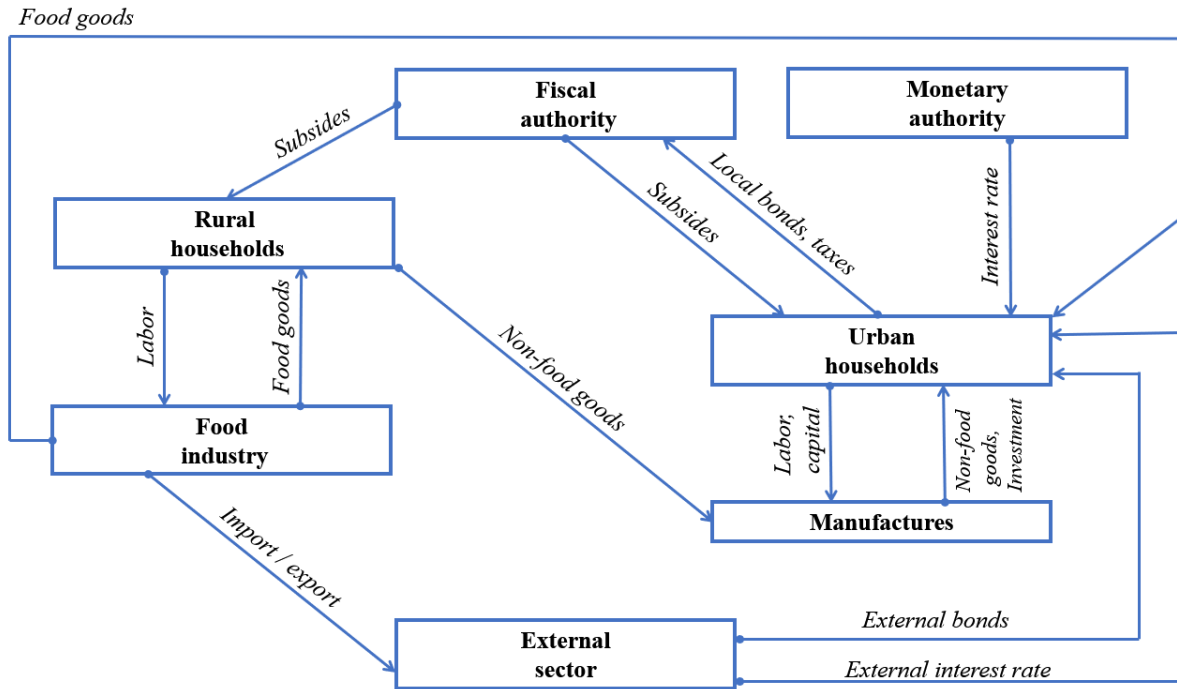
<sup>10</sup> See <http://www.fao.org/india/fao-in-india/india-at-a-glance/en/>. This phenomena is quite common relative to other non-developed countries. According to the U.N. (2003), “(t)hree quarters of the world’s poor live in rural areas of developing countries and depend mainly on agriculture and related activities for their livelihood”.

<sup>11</sup>Ginn and Pourroy (2019) show this is a key, realistic feature of MICs, considering the prevalence of food price subsidies which are an 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 2016. Such a policy can create a wedge between distorted prices faced by household and non-subsidized prices. This allows us to capture key factors to analyze fiscal and monetary policy simultaneous responses to food price volatility.



report, [Misra and Sangita \(2014\)](#) find evidence for comovement between international and domestic prices for all food groups from 2002-2008.<sup>12</sup> [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](#)).

Figure 3: The model at a glimpse



### 3.1 Households

We introduce a two-agent New Keynesian model, where home is populated by a continuum of households indexed by  $j \in [0, 1]$  ([Gali et al., 2004](#)). A share  $1 - \lambda$  represent the neo-classical Ricardian household ( $r$ ), who has access to asset markets (i.e., bonds, capital) and are able to smooth consumption. The rest  $\lambda$  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 (two-agent New Keynesian) model in the literature, as opposed to single-agent RANK (representative agent New Keynesian) model and diverse-agents HANK (Heterogeneous Agent New Keynesian) model. See [Gali \(2018\)](#), among others.<sup>13</sup>

<sup>12</sup> 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>.

<sup>13</sup> [Bilbiie \(2017\)](#) and [Kaplan et al. \(2018\)](#), among others, 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 Heterogeneous Agent New Keynesian (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 (different assets with different yields, borrowing constraint not always binding, etc.). 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 for the household, let  $i \in (r, n)$ . Household member  $i$  is assumed to have symmetric consumption preferences for food ( $C_{i,t}^F$ ) and manufacturing ( $C_{i,t}^M$ ) goods combined in a CES basket:

$$C_{i,t} = \left[ \varphi^{\frac{1}{\theta}} \left( C_{i,t}^F - \overline{C}_i^F \right)^{\frac{\theta-1}{\theta}} + (1-\varphi)^{\frac{1}{\theta}} \left( C_{i,t}^M \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \quad (1)$$

where  $\varphi$  relates to the share of food in consumption and  $\theta$  is the elasticity of substitution between food and non-food goods. We incorporate food subsistence consumption ( $\overline{C}_i^F$ ) in utility, a threshold of food required for survival. We assume this threshold is binding in the model. The CES basket implies the following consumer price index per unit of consumption:

$$P_t = \left[ \varphi \left( P_t^F \right)^{1-\theta} + (1-\varphi) \left( P_t^M \right)^{1-\theta} \right]^{\frac{1}{1-\theta}} \quad (2)$$

We incorporate an international linkage between the domestic ( $P_t^F$ ) and foreign food price ( $P_t^{F*}$ ) at the prevailing exchange rate, i.e.  $P_t^F = e_t P_t^{F*} / \Psi_t$ .<sup>14</sup> Variable  $\Psi_t$  corresponds with deviations in the law of one food price (Monacelli, 2005).<sup>15</sup>

We introduce a simple way to capture a price subsidy:<sup>16</sup>

$$\overrightarrow{P}_{i,t}^F = \kappa_i \overrightarrow{P}_{i,t-1}^F + (1-\kappa_i) P_t^F \quad (3)$$

with  $0 \leq \kappa_i \leq 1$ . As  $\kappa_i$  approaches zero (unity), household  $i$  effectively pays the market (fully subsidized) price. This mechanism generates a policy-induced form of price stickiness determined by the degree ( $\kappa_i$ ) to which the fiscal authority subsidizes food consumption to shield consumers from changing food prices. Because different household types may face different food price subsidies, the aggregate price index is defined at the household level ( $i$ ) and is given by:

$$\overrightarrow{P}_{i,t} = \left[ \varphi \left( \overrightarrow{P}_{i,t}^F \right)^{1-\theta} + (1-\varphi) \left( P_t^M \right)^{1-\theta} \right]^{\frac{1}{1-\theta}} \quad (4)$$

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

$$C_t^{i,F} = \varphi \left( \frac{\overrightarrow{P}_{i,t}^F}{\overrightarrow{P}_{i,t}} \right)^{-\theta_F} C_{i,t} + \overline{C}_i^F, \quad C_{i,t}^M = (1-\varphi) \left( \frac{P_t^M}{\overrightarrow{P}_{i,t}} \right)^{-\theta_M} C_{i,t} \quad (5)$$

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.

<sup>14</sup> Our approach is similar to e.g. Medina and Soto (2005), An and Kang (2011) and Poghosyan and Beidas-Strom (2011) who apply a law of one price gap for oil prices as an AR(1) process.

<sup>15</sup> Note that food purchasing price parity holds if  $\Psi_t$  is equal to unity. Our approach is similar to e.g. Medina and Soto (2005), An and Kang (2011) and Poghosyan and Beidas-Strom (2011) who apply a law of one price gap for oil prices as an AR(1) process.

<sup>16</sup>Our assumption is similar to Ben Aïssa and Rebei (2012) and Ginn and Pourroy (2019). An alternative approach is to assume households receive a government transfer as in García and Mejía (2018). Korir et al. (2020) show that price subsidies are less efficient than income transfer when a large share of the population relies on the informal market for food consumption. However, we follow the approach by Ben Aïssa and Rebei (2012) and Ginn and Pourroy (2019), as we believe consumer price smoothing to match with India's food price stabilisation policy presented in Section 2.

### 3.1.1 Ricardian Household

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

$$U_{r,t} = E_t \sum_{t=0}^{\infty} \beta^t \zeta_{r,t} \left( \ln(C_{r,t}) - \psi \frac{N_{r,t}^{1+\chi}}{1+\chi} \right) \quad (6)$$

where  $\zeta_{r,t}$  represents an intertemporal preference shock (e.g., [Coenen and Straub \(2004\)](#)) and  $\psi$  is a scale parameter related to the Frisch elasticity. Ricardians solely owns financial and physical assets. Financial assets include domestic ( $B_t$ ) and foreign ( $B_t^*$ ) bonds, which pay a return of  $(1 + i_{t-1})$  and  $e_t (1 + i_{t+1}^*) \Theta(B_t)$ , 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.  $i_{t+1}^*$  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:

$$\Theta(B_t) = \exp \left( \frac{-\zeta e_t B_t^*}{P_t Y_t} \right) \quad (7)$$

We incorporate investment adjustment costs and utilization costs ([Christiano et al., 2005](#)). The law of motion for capital accumulation and capital utilization evolve as follows:

$$k_t = (1 - \delta)k_{t-1} + \left[ 1 - \Psi \left( \frac{I_t}{I_{t-1}} \right) \right] I_t \quad (8)$$

$$a[u_t] = \epsilon_1(u_t - 1) + \frac{\epsilon_2}{2}(u_t - 1)^2 \quad (9)$$

where  $\delta$  is the depreciation rate,  $I_t$  is investment and  $\Psi \left( \frac{I_t}{I_{t-1}} \right)$  is investment adjustment costs. The representative Ricardian agent faces the following intertemporal budget constraint:

$$\begin{aligned} \frac{(1 + i_{t-1}) B_{t-1}}{\vec{P}_{r,t}} + \frac{e_t (1 + i_{t+1}^*) \Theta(B_t) B_t^*}{\vec{P}_{r,t}} + (1 - \tau_t)(W_t N_{r,t} + \Pi_{r,t}) + ((1 - \tau_t)r_t u_t + \delta \tau_t - a[u_t])k_{t-1} = \\ \frac{B_t}{\vec{P}_{r,t}} + \frac{e_t B_t^*}{\vec{P}_{r,t}} + (1 + \tau_t)(C_{r,t} + \overline{C}_r^F) + I_t \end{aligned} \quad (10)$$

where  $\Pi$   $\tau$  denote profit and the tax rate.

The representative Ricardian household maximizes utility as in equation (6) subject to the resource constraint (10) and capital constraint (8) with respect to  $C_{r,t}$ ,  $B_{r,t}$ ,  $B_t^*$ ,  $k_t$ ,  $I_t$ ,  $u_t$  and  $N_{r,t}$ . The first order conditions (FOC) can be found 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:

$$U_{n,t} = \ln(C_{n,t}) - \psi \frac{N_{n,t}^{1+\chi}}{1+\chi} \quad (11)$$

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

$$(1 + \tau_t) \vec{P}_{n,t} C_{n,t} + \vec{P}_{n,t}^F \overline{C}_n^F = (1 - \tau_t) W_t N_{n,t} \quad (12)$$

The FOC can be found in the Appendix.

## 3.2 Production

Production is based on food ( $Y_t^F$ ) and manufacturing ( $Y_t^M$ ) sectors. The food sector is based on labor technology, while the manufacturing sector is based on capital and labor.

### 3.2.1 Food Firms:

A representative food firm output is based on labor and aggregate productivity:

$$Y_t^F = A_t^F N_t^F \quad (13)$$

Food firms optimally allocate labor resources by minimizing costs subject to technology:

$$\min_{N_t^F} W_t^F N_t^F + \varphi_t^F (Y_t^F - A_t^F N_t^F) \quad (14)$$

where  $\varphi_t^F$  can be interpreted as the marginal cost for the respective firm. Assuming an interior solution, the first order condition yields:  $\varphi_t^F = \frac{W_t^F}{A_t^F}$

### 3.2.2 Manufacturing Firms:

The manufacturing sector is capital intensive depending on the degree of  $\alpha \in (0, 1)$ .

$$Y_t^M = A_t^M (u_t k_{t-1})^\alpha (N_t^M)^{1-\alpha} \quad (15)$$

Manufacturing firms optimally allocate labor and capital resources by minimizing costs subject to output, however there is an additional step involving pricing decisions. The first stage consists in minimizing cost to maximize profit based on perfectly competitive factor markets:

$$\min_{N_t^M, \hat{k}_{t-1}} W_t^M N_t^M + r_t \hat{k}_{t-1} + \varphi_t^M (Y_t^M - A_t^M (\hat{k}_{t-1})^\alpha (N_t^M)^{1-\alpha}) \quad (16)$$

Note that we made a change of variable to simplify notation:  $\hat{k}_{t-1} = u_t k_{t-1}$ . Optimization yields the marginal cost:

$$N_{r,t} = (1 - \alpha) mc_t \frac{Y_t^M}{W_t^M} \quad (17)$$

$$\hat{k}_{t-1} = \alpha \cdot mc_t \frac{Y_t^M}{r_t} \quad (18)$$

The two previous equations yields the optimal factor demands:

$$\frac{\hat{k}_{t-1}}{N_{r,t}} = \frac{\alpha}{(1 - \alpha)} \frac{W_{r,t}}{r_t} \quad (19)$$

And the marginal cost is defined as:

$$mc_t = \frac{1}{(1 - \alpha)^{1-\alpha}} \frac{1}{\alpha^\alpha} \frac{(W_{r,t})^{1-\alpha} r_t^\alpha}{A_t^M} \quad (20)$$

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  $\phi_M > 0$  of not being able to re-optimize its

price charged from the previous period. This can be expressed in the following optimization process:

$$\max_{P_{j,t}^M} E_t \sum_{s=0}^{\infty} \phi_M^s \Xi_{t+s} \left\{ \left( \frac{P_{j,t}^M}{P_{t+s}^M} - mc_{t+s}^M \right) Y_{j,t+s}^M \right\} \quad (21)$$

subject to sector specific demand:

$$Y_{j,t}^M = \left( \frac{P_{j,t}^M}{P_t^M} \right)^{-\epsilon_M} Y_t^M \quad (22)$$

The pricing kernel is equivalent to the marginal utility of consumption, i.e.  $\Xi_{t+s} = \Lambda_{t+s}/\Lambda_t$ . Inserting demand in (24) into the maximization process (23) simplifies the optimization from a constrained maximization to an unconstrained one:

$$\max_{P_{j,t}^M} E_t \sum_{s=0}^{\infty} \beta^s \phi_M^s \Xi_{t+s} \left( \frac{P_{j,t}^M}{P_{t+s}^M} - mc_{t+s}^M \right) \left( \frac{P_{j,t}^M}{P_t^M} \right)^{-\epsilon_M} Y_t^M \quad (23)$$

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

$$\frac{\tilde{P}_t^M}{P_t^M} = \frac{\epsilon_M}{\epsilon_M - 1} \frac{E_t \sum_{s=0}^{\infty} (\beta \phi_M)^s \Xi_{t+s} Y_{t+s}^M mc_{t+s}^M \left( \frac{P_{t+s}^M}{P_t^M} \right)^{\epsilon_M}}{E_t \sum_{s=0}^{\infty} (\beta \phi_M)^s \Xi_{t+s} Y_{t+s}^M mc_{t+s}^M \left( \frac{P_{t+s}^M}{P_t^M} \right)^{\epsilon_M - 1}} \quad (24)$$

Note that if prices are completely flexible (i.e.,  $\phi_M = 0$ ), equation (23) simplifies to  $\frac{\tilde{P}_t^M}{P_t^M} = \frac{\epsilon_M}{\epsilon_M - 1} mc_t^M$ . We work with the condition of symmetric prices where  $\tilde{P}_t^M = P_t^M$ , implying marginal cost would be equivalent to the inverse mark-up, i.e.  $mc_t^M = \frac{\epsilon_M - 1}{\epsilon_M}$ . It is convenient to express (26) recursively, which simplifies to  $\epsilon_M \times f_{1,t}^M = (\epsilon_M - 1) f_{2,t}^M$  where:

$$f_{1,t}^M = \Xi_t Y_t^M mc_t^M + (\beta \phi_M)^s E_t \left( \frac{P_{t+1}^M}{P_t^M} \right)^{\epsilon_M + 1} f_{1,t+1}^M \quad (25)$$

$$f_{2,t}^M = \Xi_t Y_t^M + (\beta \phi_M)^s E_t \left( \frac{P_{t+1}^M}{P_t^M} \right)^{\epsilon_M} f_{2,t+1}^M \quad (26)$$

Manufacturing prices can be expressed as a weighted average of the fraction of firms which optimized its price and those that did not optimize prices as follows:

$$P_t^M = \left[ (1 - \phi_M) \left( \tilde{P}_t^M \right)^{1 - \epsilon_M} + \phi_M \left( P_{t-1}^M \right)^{1 - \epsilon_M} \right]^{\frac{1}{1 - \epsilon_M}} \quad (27)$$

### 3.3 Fiscal Policy

The government's inter-temporal budget constraint is funded via domestic ( $B_t^G$ ) debt and tax revenues to finance a stream of food price subsidies.<sup>17</sup>

$$B_t^G - (1 + i_{t-1}) B_{t-1}^G = \vec{S}_t - \tau_t (C_{n,t} + \bar{C}_n^F + C_{r,t} + \bar{C}_r^F + W_t^F N_t^F + W_t^M N_t^M + r_t u_t k_t + \Pi_t) \quad (28)$$

$$\vec{S}_t = (P_t^F - \vec{P}_{n,t}^F) C_{n,t}^F + (P_t^F - \vec{P}_{r,t}^F) C_{r,t}^F \quad (29)$$

<sup>17</sup> See e.g. [Stähler and Thomas \(2012\)](#) and [Ginn and Pourroy \(2019\)](#).

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  $\phi$ . As  $\phi$  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:<sup>18</sup>

$$\frac{1+r_t}{1+r} = \left( \frac{1+r_{t-1}}{1+r} \right)^{\psi_r} \left[ \left( (\pi_t^M)^{1-\varrho} (\pi_t^F)^\varrho \right)^{\omega_\pi} (\Delta y_t)^{\omega_y} \right]^{1-\psi_r} e^{\varepsilon_t^{MP}} \quad (30)$$

The Taylor Rule incorporates interest rate smoothing depending on the degree of inertia  $0 < \psi_r < 1$ . The policy weights with respect to deviations from the inflation rule and output are denoted  $\omega_\pi$  and  $\omega_y$ , respectively. The inflation rule makes an assignment on non-food ( $\pi_t^M$ ) and food sector ( $\pi_t^F$ ) consumer price inflation which is governed by  $0 \leq \varrho \leq 1$ . This allows a simple framework to evaluate whether the central bank pursues core inflation ( $\varrho=0$ ) versus a policy response that responds to food inflation ( $\varrho < 1$ ).<sup>19</sup>  $\varepsilon_t^{MP}$  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:

$$e_t B_t^* = e_t (1 + i_{t-1}^*) \Theta(B_t) B_{t-1}^* + TB_t \quad (31)$$

$$TB_t = P_t^F (Y_t^F - C_t^F) \quad (32)$$

Equation (32) represents the position on foreign bond holdings ( $B_t^*$ ). Equation (33) shows that the trade balance depends on domestic absorption.

### 3.6 Aggregation

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

$$C_t = (1 - \lambda) C_t^M + \lambda C_t^F \quad (33)$$

$$N_t = (1 - \lambda) N_{r,t}^M + \lambda N_{n,t}^F \quad (34)$$

<sup>18</sup> 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 8.3.2.

<sup>19</sup> The assignment  $\varrho$  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.

GDP is equal to consumption, food price subsidy, investment (including adjustment costs) and the trade balance:

$$\vec{P}_t Y_t = \vec{P}_t^F C_t^F + P_t^M C_t^M + \vec{S}_t + Q_t I_t + a[u_t]k_t + TB_t \quad (35)$$

In the absence of fiscal policy (i.e.,  $\kappa_i=0$ ), the price level becomes non-distorted:

$$P_t Y_t = P_t^F C_t^F + P_t^M C_t^M + Q_t I_t + a[u_t]k_t + TB_t \quad (36)$$

## 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)).

### 4.1 Data

The model is based on seven observable variables (see Table 1). The variables include real GDP<sup>20</sup>, CPI inflation, WPI food inflation<sup>21</sup>, international food inflation (proxied via FAO international food price), real effective exchange rate (REER), the policy rate and an international interest rate<sup>22</sup>. The sample period covers 1999:Q1 to 2018:Q4. With the exception of the interest rate, all variables are seasonally adjusted and computed as a quarter-to-quarter log-difference.<sup>23</sup> 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)). Prior to estimation, growth and inflation are linearly detrended.

### 4.2 Calibrated Parameters

The model parameters are summarized in Table 2. The discount factor ( $\beta$ ) is set to 0.9830, which corresponds with the observed data over the sample period. The share of food in aggregate consumption is set to 0.45.<sup>24</sup> The share of non-Ricardian household ( $\lambda$ ) is set to 0.4.<sup>25</sup>

<sup>20</sup> 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>.

<sup>21</sup> 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.

<sup>22</sup> 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.

<sup>23</sup> 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.

<sup>24</sup> According to the World Bank (Global Consumption database), food represents 44.63% of total household expenditures in India.

<sup>25</sup> According to the World Bank (ILOSTAT database), agriculture represents 43.86% of employment for 2018 in India. 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).

Table 1: Variable Selection

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

The capital ratio in the manufacturing sector is set to a third. Quarterly depreciation ( $\delta$ ) is set to 0.025, implying an annual depreciation rate of 10%. The investment adjustment cost ( $\psi$ ) is set to 1.3.<sup>26</sup> The capital utilization process satisfies  $a[1] = 1$ . Capital utilization is normalized to unity in the steady state, i.e. we set  $\epsilon_1 = \frac{1}{\beta} - (1 - \delta)$  and  $\epsilon_2 = 0.01$ .

Table 2: Calibrated Parameters

Description	Symbol	Value
Discount factor	$\beta$	0.9830
Share of food in consumption	$\varphi$	0.45
Non-Ricardian (food labor supply)	$\lambda$	0.4
Capital share	$\alpha$	0.33
Manufacturing sector monopoly power	$\epsilon_M$	6
Capital utilization	$\epsilon_1$	0.0423
Capital utilization	$\epsilon_2$	0.01
Capital Depreciation	$\delta$	0.025
Leverage Response (ensures stability)	$\phi$	0.15

### 4.3 Prior Distributions:

The prior distributions of the estimated parameters are summarized in the Table 3. The inverse Frisch parameter ( $\chi$ ) is set unity. We set the elasticity of food ( $\theta$ ) to 0.75.<sup>27</sup>

Following [Ginn and Pourroy \(2020\)](#), we assume the central bank targets aggregate headline inflation, hence  $q$  has a prior set to the ratio of the aggregate food expenditure (i.e.,  $q = 0.45$ ) consistently with the RBI mandate.<sup>28</sup> The prior for the interest rate smoothing parameter ( $\psi$ ) is set to 0.7. The priors for the policy weights with respect to deviations from the inflation rule ( $\omega_\pi$ ) and output ( $\omega_Y$ ) are set to 1.5 and 0.5, respectively.

<sup>26</sup> Investment adjustment costs are supported empirically, see e.g. [Peiris and Saxegaard \(2007\)](#) for Mozambique and [Aguilar and Gopinath \(2007\)](#) for Mexico.

<sup>27</sup> 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.

<sup>28</sup> Theoretically, 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 a non-developed country. In practice, since May 2016 the RBI has adopted an inflation targeting framework, where the inflation target is set by the Government of India, in consultation with the Reserve Bank, once in every five years. The current inflation target definition is a 4% annual growth of the Consumer Price Index.



Table 3: Prior and Posterior Distributions

		Density	Prior		Posterior			
			Mean	StD	Mean	90% interval	StD	
$\chi$	Inverse Frisch	G	1	0.1	0.9702	0.7987	1.0930	0.0974
$\zeta$	Bond adjustment costs	I	0.01	1	0.0242	0.0148	0.0361	0.0061
$\theta$	Elasticity of substitution F and M	G	0.75	0.05	0.7917	0.7173	0.8616	0.0474
$\kappa_n$	Policy intensity	B	0.3	0.1	0.3078	0.2309	0.3992	0.0819
$\kappa_r$	Policy intensity	B	0.15	0.1	0.2256	0.1461	0.2999	0.0868
$\overline{C^F}$	Food subsistence	I	0.084	1	0.0501	0.0188	0.0904	0.0131
$\phi_M$	Calvo signal	B	0.66	0.05	0.5753	0.5111	0.6248	0.0371
$\psi$	Capital adjustment costs	N	1.3	0.2	1.2937	1.0030	1.5468	0.2001
$\varrho$	Policy price index	B	0.45	0.05	0.4555	0.4104	0.5079	0.0328
$\psi_S$	Interest rate smoothing	B	0.7	0.1	0.7913	0.7461	0.8346	0.0276
$\omega_\pi$	TR response: Inflation	N	1.5	0.1	1.6229	1.4769	1.7658	0.0916
$\omega_Y$	TR response: GDP	N	0.5	0.1	0.1617	0.0557	0.2892	0.0652
$\rho^{AM}$	AR on manufacturing productivity	B	0.8	0.05	0.9297	0.9041	0.9521	0.0161
$\rho^{AF}$	AR on food productivity	B	0.5	0.05	0.7371	0.6909	0.7901	0.0370
$\rho^{F^*}$	AR on food price	B	0.85	0.05	0.9246	0.9039	0.9450	0.0131
$\rho^{MP}$	AR monetary policy	B	0.5	0.05	0.3112	0.2667	0.3619	0.0317
$\rho^{i^*}$	AR foreign interest rate	B	0.46	0.05	0.6441	0.5941	0.6993	0.0404
$\rho^\Psi$	AR law of one food price gap	B	0.85	0.05	0.9542	0.9398	0.9668	0.0088
$\rho^{\zeta}$	AR preference	B	0.85	0.05	0.8594	0.7988	0.9154	0.0429
$\sigma^{AM}$	StD manufacturing productivity	I	0.01	2	0.0341	0.0279	0.0418	0.0051
$\sigma^{AF}$	StD food productivity	I	0.01	2	0.0250	0.0200	0.0294	0.0026
$\sigma^{MP}$	StD monetary policy	I	0.01	2	0.0036	0.0030	0.0043	0.0004
$\sigma^{p^{F^*}}$	StD food price	I	0.01	2	0.0639	0.0552	0.0729	0.0049
$\sigma^{i^*}$	StD foreign interest rate	I	0.01	2	0.0023	0.0021	0.0027	0.0002
$\sigma^\Psi$	StD law of one food price gap	I	0.01	2	0.0732	0.0634	0.0834	0.0056
$\sigma^{\zeta}$	StD preference	I	0.01	2	0.0341	0.0237	0.0423	0.0055

Note: distributions include Beta (B), Gamma (G) and Inverse Gamma (I). "StD" for standard deviation. Based on 100,000 draws generated using the Metropolis-Hastings algorithm.

We derive the share of the weight in food expenditure ( $\varphi$ ) based on the subsistence level. We set food subsistence to 20% of households' steady state food consumption. This implies a non-subsistence food share of approximately 0.40.<sup>29</sup>

Following [Schmitt-Grohé and Uribe \(2003\)](#), we incorporate a bond adjustment cost; the prior is set to  $\zeta=0.01$ .

The Calvo price signal ( $\phi_M$ ) in the manufacturing sector is assumed to be two-thirds (see e.g. [Anand et al. \(2015\)](#)). The intensity of food intervention ( $\kappa_n$  and  $\kappa_r$ ) is assumed to 0.30 and 0.15, respectively, to reflect fiscal authorities' propensity to subsidize food prices by household type<sup>30</sup>, which may be poorly targeted (e.g., [Ramaswami and Balakrishnan \(2002\)](#), [Jha and Ramaswami \(2010\)](#) and [Sharma and Alagh \(2013\)](#)).

We incorporate seven 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. \(2014\)](#)); a global

<sup>29</sup> To see this, let  $C_{SS}^F = \varphi C_{SS}$  be the steady state food expenditure in the absence of food subsistence. In the presence of food subsistence, steady state food becomes  $C_{SS}^F = \varphi_{adj}(C_{SS} - \overline{C_{SS}^F}) + \overline{C_{SS}^F}$ , where the adjusted share of non-subsistence food share becomes  $\varphi_{adj} = \frac{C_{SS}^F - \overline{C_{SS}^F}}{1 - \overline{C_{SS}^F}}$ .

<sup>30</sup> According to [OECD \(2018\)](#), those households in the lowest decile received 45% and 38% of their rice and wheat consumption from TPDS in 2011-2012 vs. 13% and 16% for the highest decile.

food price shock (e.g., [Catão and Chang \(2015\)](#), [Pourroy et al. \(2016\)](#) and [Ginn and Pourroy \(2019\)](#)); a law of one food price gap (e.g., [Monacelli \(2005\)](#), [Medina and Soto \(2005\)](#) and [Ginn and Pourroy \(2020\)](#)); a monetary policy shock ([Smets and Wouters, 2007](#)); a foreign interest rate shock ([Devereux et al., 2006](#)); and labor supply shock (e.g., [Coenen and Straub \(2004\)](#)).

## 4.4 Empirical Findings

### 4.4.1 Posterior Distributions

The prior and posterior distributions are summarized in Table 3.

Parameter  $\theta$  is estimated to be 0.79, hence food has an inelastic demand. The posterior for food consumption subsistence is estimated to be 0.05 (with a range of 0.02 and 0.09), which translates to circa 12% of steady state food consumption.

The interest rate smoothing parameter  $\rho$  has a posterior mean of 0.79, suggesting presence of policy inertia. The policy coefficients on the inflation ( $\omega_\pi$ ) and output deviations ( $\omega_Y$ ) are estimated to be 1.62 and 0.16, respectively.

The posterior Calvo probabilities for the manufacturing sector ( $\phi_M$ ) is estimated to be 0.58. The posterior policy intervention  $\kappa_n$  and  $\kappa_r$  is estimated to be 0.31 and 0.23, respectively. We view monetary policy in India unique such that the size and persistence of fiscal policy via food subsidy, which consequently leads to a case of policy-driven price stickiness. Essentially, during periods of high food inflation, a fiscal policy which reduces food inflation makes it easier for monetary policy, but the subsidy increases the debt level and taxes. It transfers one problem (curtailing food inflation, depending on the intensity  $\kappa_i$ ) for another (debt).

The posterior for the policy price index reaction ( $\varrho = 0.46$ ) is marginally higher than share of food in aggregate consumption price index ( $\varphi = 0.45$ ). We compare the fit of three models where monetary policy targets core inflation ( $\mathcal{M}_1$ ) as a baseline model relative to headline inflation ( $\mathcal{M}_2$ ) and an empirical-based ( $\mathcal{M}_3$ ) inflation target. The criteria is based on the log marginal data density and the corresponding Bayes factor summarized in Table 4. Based on the Bayes factor derived from the empirical estimation suggests the empirical-based inflation target rule ( $\mathcal{M}_3$ ) is more strongly favored by the data (see Figure 4).<sup>31</sup> Overall, the empirical evidence suggests that the RBI pursues inflation targeting that responds to food price deviations in the short run, consistent with RBI’s CPI objective.

Table 4: Model Comparison

Model	Inflation Target Model	$\ln p(Y \mathcal{M}_i)$	Bayes Factor vs. $\mathcal{M}_1$
$\mathcal{M}_1$	Core ( $\varrho = 0$ )	1429.02	1
$\mathcal{M}_2$	Headline ( $\varrho = \varphi = 0.45$ )	1513.81	$\exp(84.80)$
$\mathcal{M}_3$	Empirical Model ( $\varrho = 0.4555$ )	1514.79	$\exp(85.77)$

Note:  $\mathcal{M}_3$  is the empirical model used in this paper. The log data density for the three models is computed using the modified harmonic mean ([Geweke, 1999](#)).

<sup>31</sup> The Bayes factor is an empirical test to quantify the support of one model relative to an alternative model. According to [Kass and Raftery \(1995\)](#), values between 1-3 implies “not worth more than a bare mention”, between 3-20 “positive” evidence, between 20-150 “strong” evidence and greater than 150 “very strong” evidence.

#### 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 5). The model tends to overpredict the volatility of output growth, inflation, the policy rate and the exchange rate (Table 5). The persistence between the data and estimated model for output, inflation and interest rate are similar at order 1. The model struggles to capture the autocorrelation of the exchange rate. Overall, the model is able to replicate the key features in the data reasonably well.

Table 5: Business Cycle Statistics

	Growth ( $\Delta \ln Y_t$ )	Inflation ( $\pi_t$ )	Interest rate ( $R_t$ )	Exchange rate ( $\Delta \ln e_t$ )
Standard Deviation				
Data	0.0192	0.0096	0.0041	0.0257
Empirical Model	0.0241	0.0177	0.0102	0.0651
Autocorrelation (order=1)				
Data	0.2686	0.3640	0.8743	0.0180
Empirical Model	0.1291	0.3303	0.8749	-0.0226

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 2018:Q4.

We report the conditional variance decomposition (Table 6) at different time horizons (quarters 1, 4 and 8). Technology shocks (food and non-food) account for the majority of output fluctuations. A shock to the policy rate has a significant effect on inflation. Inflation and the exchange rate are 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 30% and 43% of domestic inflation and the policy rate, which diminishes in quarter 8 to 27% and 33%, respectively.

## 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 ( $\kappa_i$ ) that may be used to circumvent a food price shock. The second analyzes the effect of the policy response type ( $q$ ).

### 5.1 International Food Price Shock and Fiscal Policy

We conduct three experiments to better understand how fiscal intervention affects the model. The first experiment (Model I.a) relates to no fiscal intervention ( $\kappa_n = \kappa_r = 0$ ). The second experiment (Model II.a) is the estimated model ( $\kappa_n = 0.3078$ ,  $\kappa_r = 0.2256$ ) and the third experiment (Model III.a) is a "strong policy" response for both household types ( $\kappa_n = \kappa_r = 0.5$ ). The IRFs are provided in Figure 4. 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.

Table 6: Conditional Variance Decomposition (in %)

	Productivity		World	World	Monetary	Food	Shift in
	$A^F$	$A^M$	$i^*$	$P^{F*}$	Policy	LOPG	Pref.
Quarter 1							
Growth ( $\Delta \ln Y_t$ )	47.22	38.42	0.07	1.85	7.87	1.08	3.49
Inflation ( $\pi_t$ )	1.16	1.78	0.66	30.14	33.58	18.72	13.95
Exchange rate ( $\Delta \ln e_t$ )	2.38	5.47	0.25	29.42	5.77	55.53	1.19
Policy rate ( $R_t$ )	0.05	3.02	0.99	42.99	0.03	26.34	26.60
Quarter 4							
Growth ( $\Delta \ln Y_t$ )	15.07	80.15	0.02	0.68	2.23	0.44	1.42
Inflation ( $\pi_t$ )	1.38	7.75	0.66	27.43	31.62	17.01	14.15
Exchange rate ( $\Delta \ln e_t$ )	2.36	5.56	0.29	29.49	5.71	55.17	1.42
Policy rate ( $R_t$ )	0.06	10.49	0.51	34.98	0.05	22.13	31.78
Quarter 8							
Growth ( $\Delta \ln Y_t$ )	7.58	89.20	0.01	0.35	1.12	0.23	1.51
Inflation ( $\pi_t$ )	1.40	7.85	0.66	27.38	31.59	16.98	14.13
Exchange rate ( $\Delta \ln e_t$ )	2.36	5.59	0.29	29.57	5.68	55.06	1.45
Policy rate ( $R_t$ )	0.38	11.13	0.42	32.87	0.07	21.44	33.70

Note: The columns indicate the respective shock. Each shock is treated as an AR(1) process. " $A^F$ " refers to food productivity shock, " $A^M$ " non-food productivity shock, " $P^{F*}$ " the world food price, " $i^*$ " the world interest rate, food law of one price gap (LOPG) and shift in preference.

In the presence of no fiscal intervention (strong intervention) as in Model I.a (Model III.a), the peak food price occurs at  $t=0$  ( $t+5$ ). Second, subsidies reduce the magnitude of the food price shock; the "strong subsidy" (Model III.a) policy implies that the maximum price is circa two-thirds of the price without subsidies at the onset of the shock.

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. 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.<sup>32</sup>

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 II.a and III.a), a food subsidy allows food consumption smoothing.

Absent 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.

<sup>32</sup> Assuming productivity remains constant, an international food price shock can put upward pressure on non-Ricardian wages.

The last graph in Figure 5 shows the effect on public debt associated with fiscal intervention, depending on the degree of food price smoothing ( $\kappa_i$ ).

## 5.2 International Food Price Shock and Monetary Policy

We conduct three additional experiments to illustrate how the choice of monetary policy price indexation (i.e.,  $\varrho$ ) influences the model. We consider  $\varrho=0$  (Model I.b) relating to core inflation; the empirical model (Model II.b); and “strong” policy reaction scenario (Model III.b).<sup>33</sup> The corresponding IRFs are shown in Figure 5. All other parameters remain unchanged for both model experiment types, i.e. are based on the posterior mean (see Table 3).

As expected, as  $\varrho$  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 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, Ricardian food consumption falls, while non-food consumption increases.

Figure 5 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 5. 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.

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<sup>33</sup> By “strong” reaction, we assume  $\varrho=0.8$ , which is circa twice the value based on the posterior estimate (0.3957).

Figure 4: Food Price Shock and Food Subsidies

— Model I.a (No Subsidy)  $\kappa_n = \kappa_r = 0$   
- - - Model II.a (Empirical Model)  $\kappa_n = 0.3078, \kappa_r = 0.2256$   
- - - Model III.a (Strong Subsidy)  $\kappa_n = \kappa_r = 0.5$

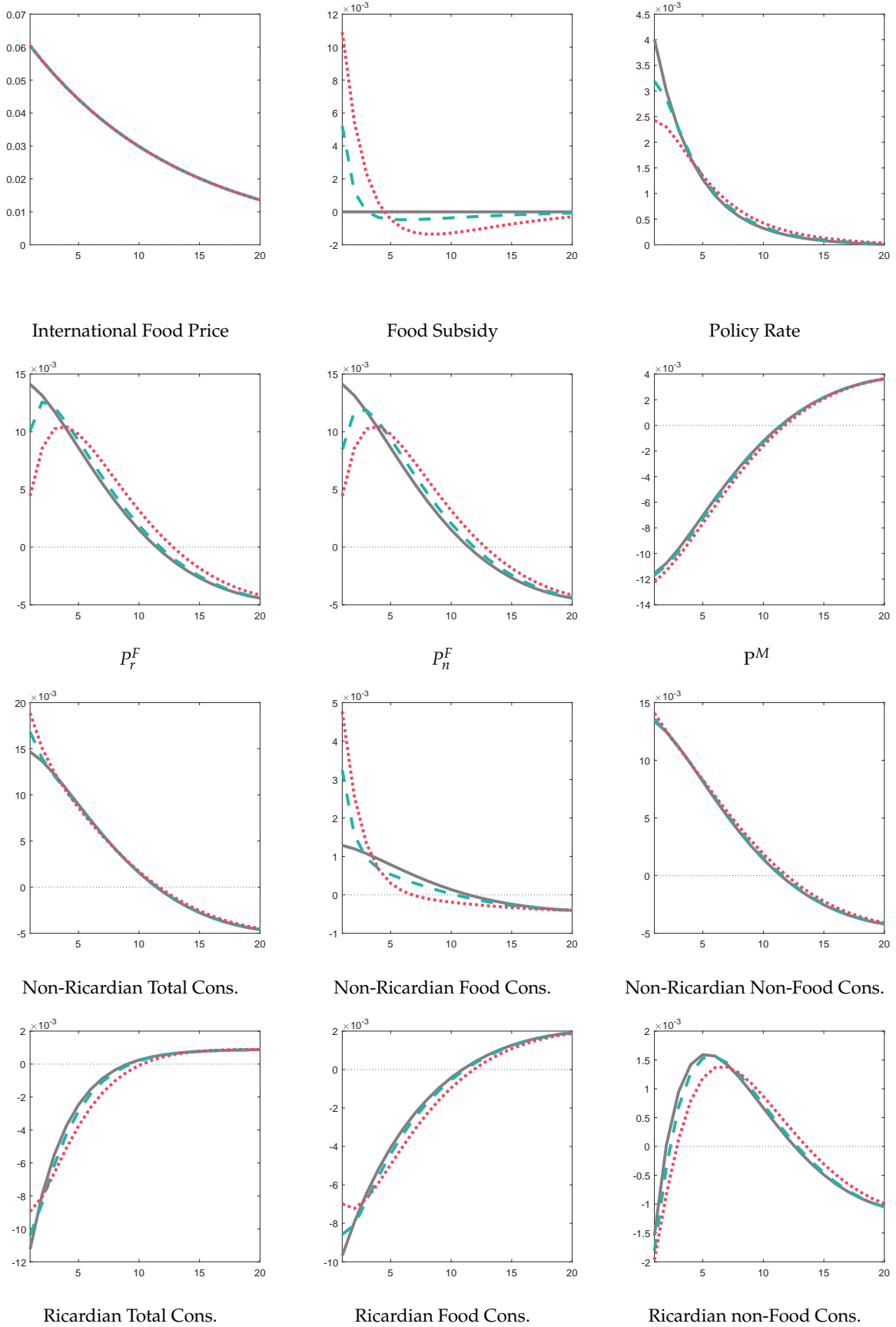


Figure 4: Food Price Shock and Food Subsidies, cont.

- Model I.a (No Subsidy)  $\kappa_n = \kappa_r = 0$
- - - Model II.a (Empirical Model)  $\kappa_n = 0.3078, \kappa_r = 0.2256$
- · · Model III.a (Strong Subsidy)  $\kappa_n = \kappa_r = 0.5$

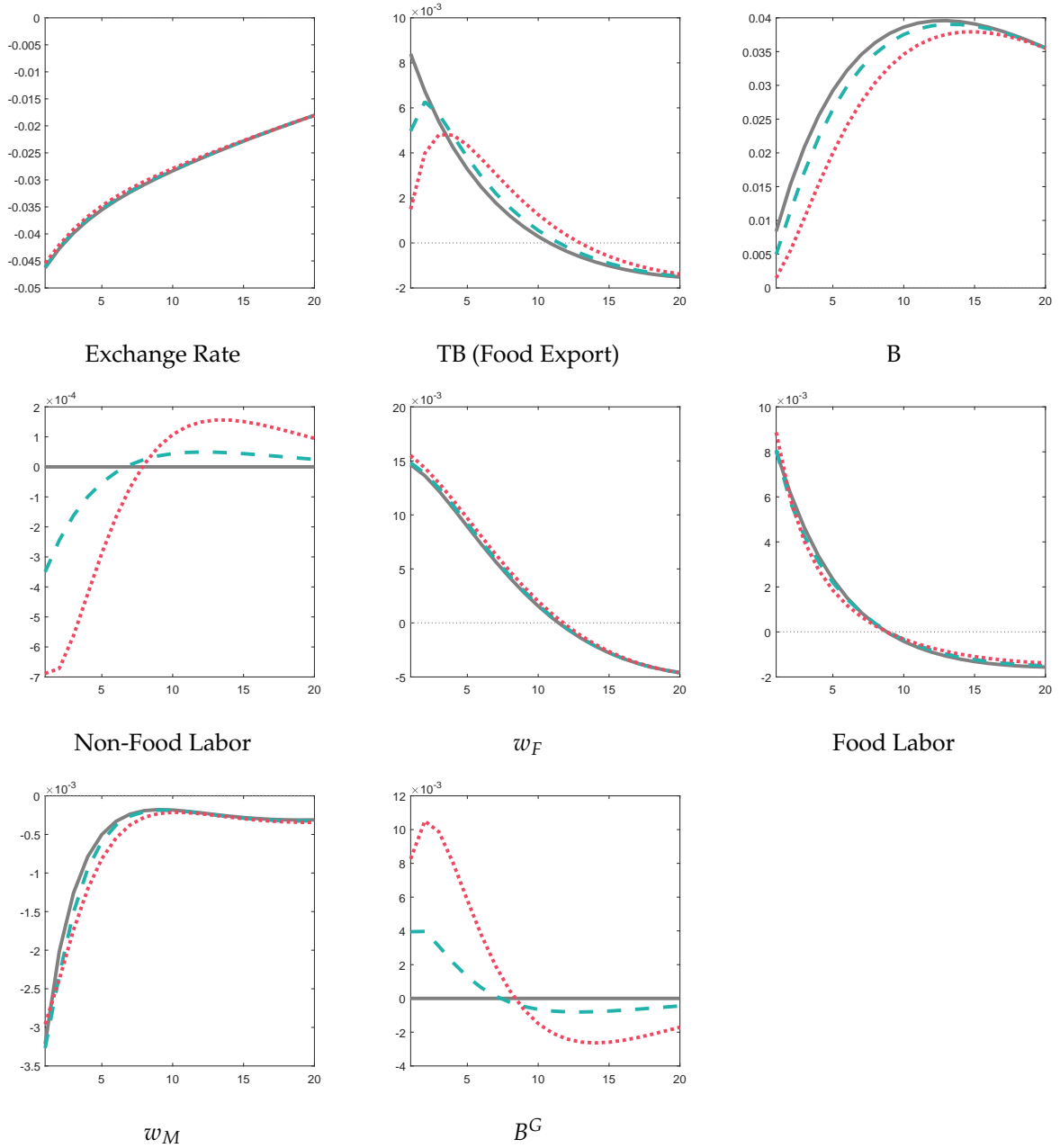


Figure 5: Food Price Shock and Monetary Policy

— Model I.b (Core Inflation)  $\rho = 0$   
- - - Model II.b (Empirical Model)  $\rho = 0.4555$   
- - - Model III.b (Strong reaction)  $\rho = 0.8$

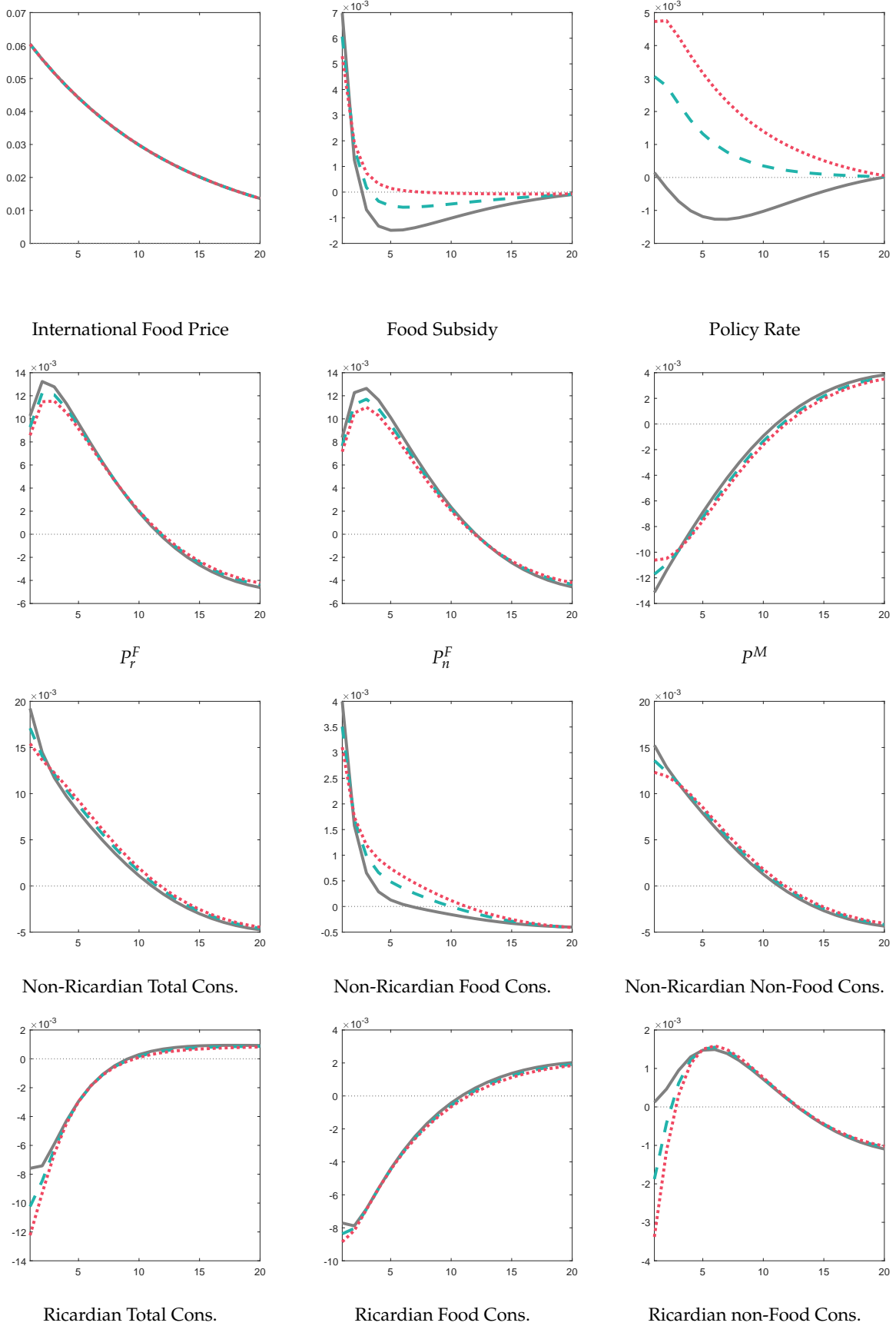
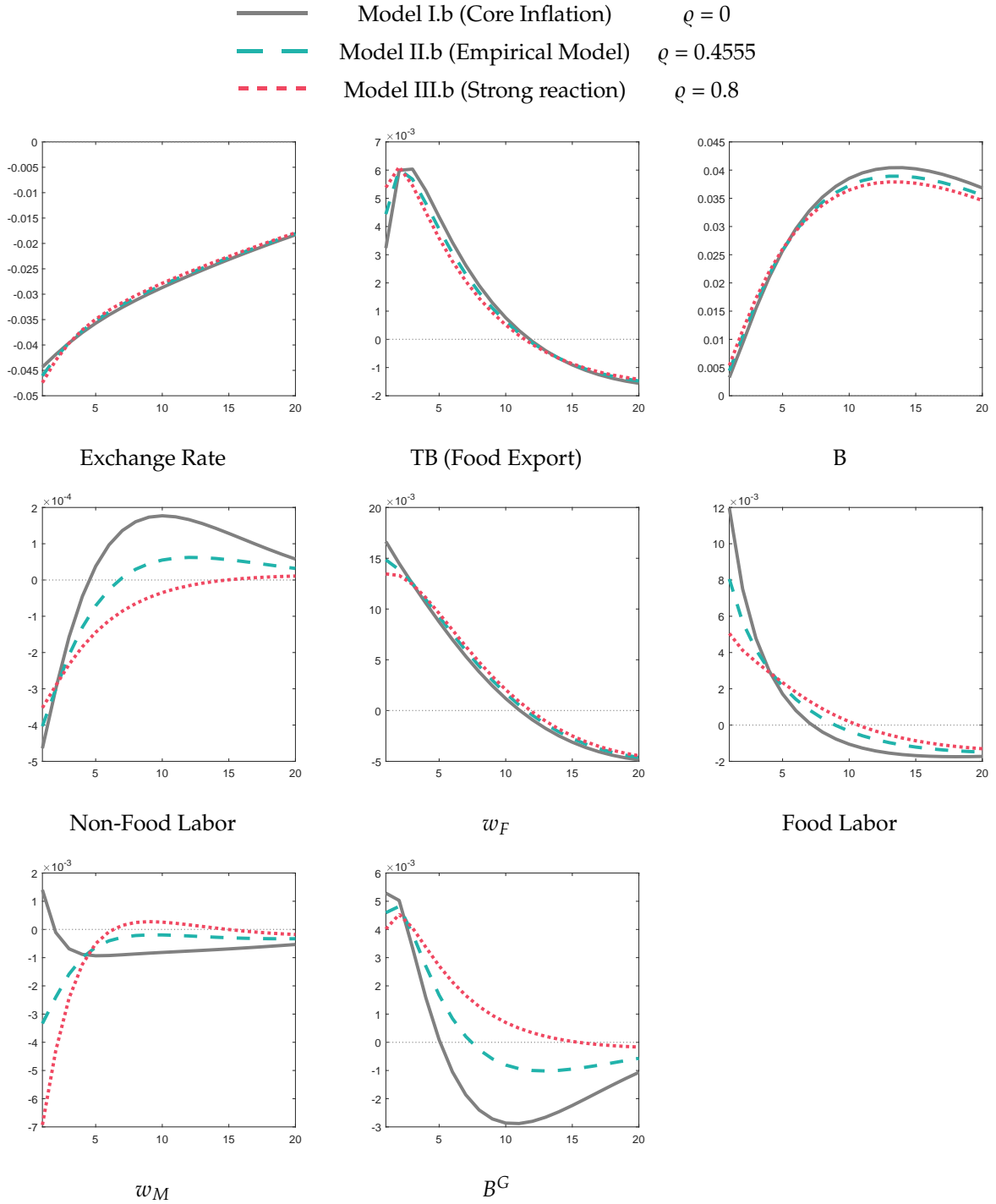




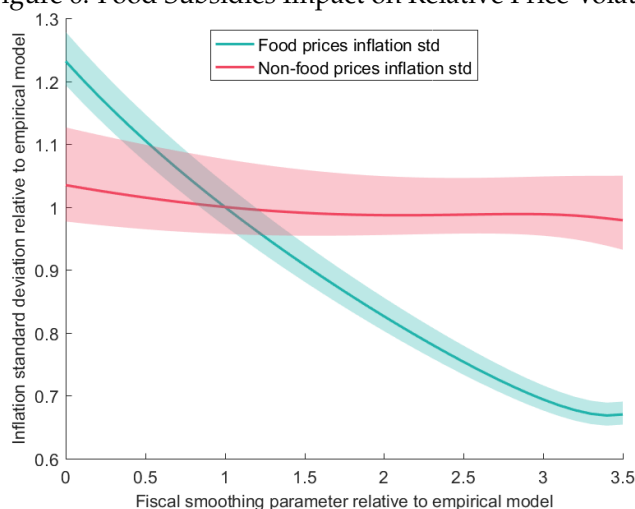
Figure 5: Food Price Shock and Monetary Policy, cont.



### 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.<sup>34</sup> The results are presented in Figure 6. The x-axis represents the coefficient applied to the food subsidy parameters. The empirical model ( $\kappa_n = 0.3078, \kappa_r = 0.2256$ ) corresponds to  $x = 1$ .<sup>35</sup> 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.

Figure 6: Food Subsidies Impact on Relative Price Volatility



We highlight four findings. First, food subsidies can reduce inflation volatility, whereas the effect on non-food prices is limited. The limitation is due to the low elasticity between the two goods. Figure 6 demonstrates 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 price subsidy stabilizes inflation, this effect disappears for food (non-food) prices when food subsidies for  $x > 3.25$  (2) to the extent that more subsidies create higher volatility.

Second, while price stability is generally considered an objective of monetary policy, we show that food 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 (non-food) inflation volatility would be 22.7% (5.6%) 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 subsidies in our model can stabilize aggregate inflation because of the sizable share of household food expenditures ( $\phi = 0.45$ ). 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.<sup>36</sup> Figure 7 demonstrates how the subsidy stabilizes aggregate and food CPI. Consistent with Figure 6, the larger the

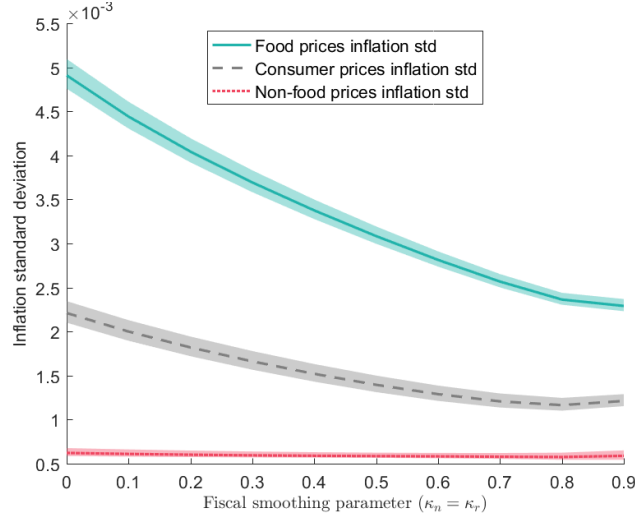
<sup>34</sup> All other parameters remain unchanged for model experiment types, i.e. are based on the posterior mean. We simulate a one standard deviation shock on the world food price.

<sup>35</sup> Similarly, if for example  $x = 2$ , then  $\kappa_n = 2 \times 0.3078$  and  $\kappa_r = 2 \times 0.2256$ . In the case of no subsidy,  $x = 0$ .

<sup>36</sup>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)

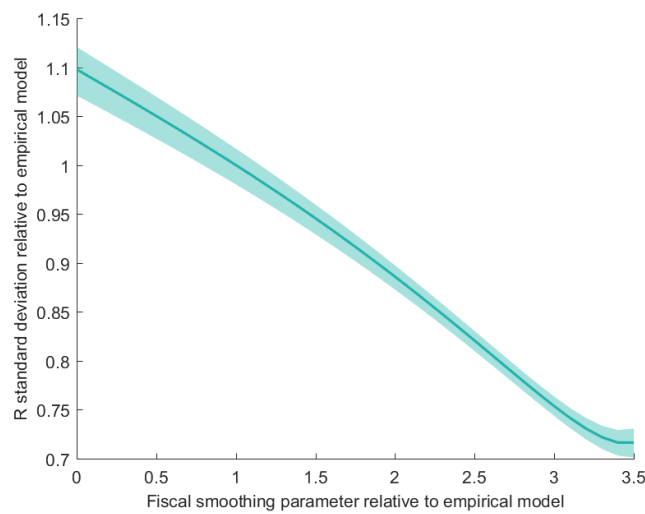
food subsidy, the lower inflation.<sup>37</sup> We estimate that absent food subsidies and assuming Taylor rule parameters remain unchanged, CPI volatility would be 8.7% higher.

Figure 7: Food Subsidies Impact on Absolute Price Volatility



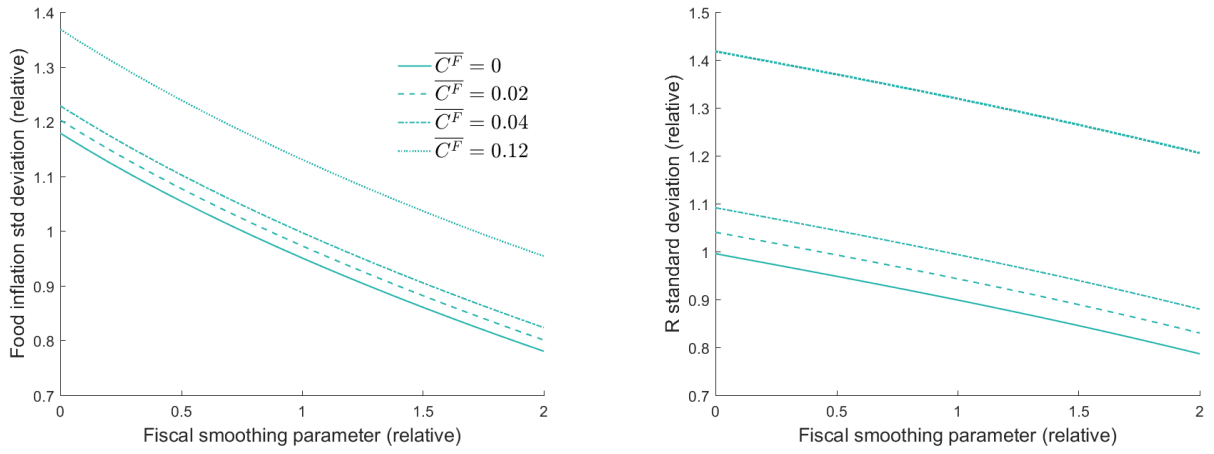
Lastly, we compute the contribution of food subsidy to the interest rate response to a food price shock. Assuming the estimated Taylor rule parameters remain unchanged, according to Figure 8 the interest rate volatility following a world food price shock would be 10.3% higher in the absence of a food subsidy, a non-negligible amount. Similarly, as shown on Figure 4 (top right graph, green and red lines), the central bank would increase the interest rate by 24% more (equivalent to 6 basis points) at the time onset of the shock ( $t=0$ ) in the absence of a food subsidy. Therefore our results show that absent food 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.

Figure 8: Food Subsidies Impact on Interest Rate Volatility

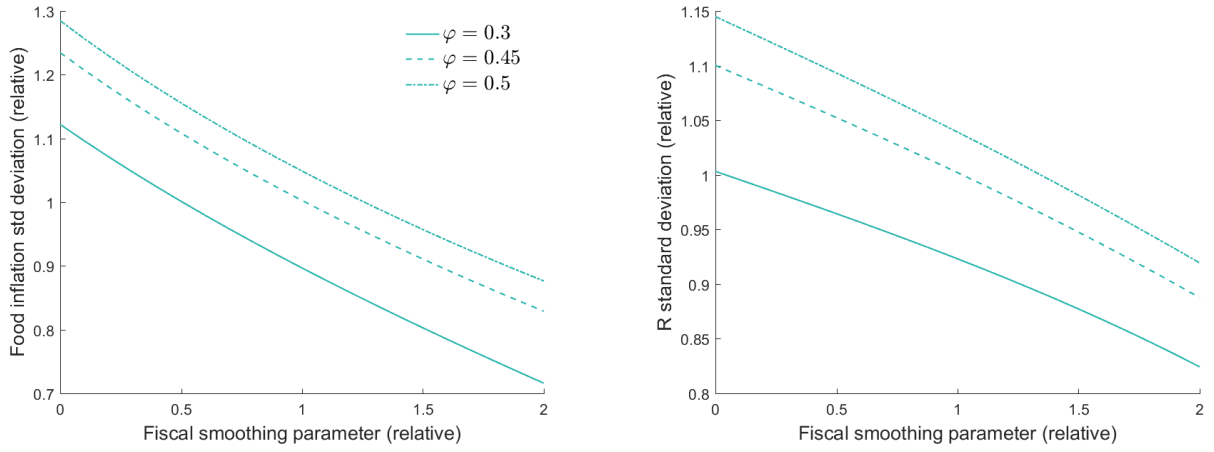


<sup>37</sup> On Figure 7, for sake of simplicity, the x-axis is based on a universal subsidy (i.e.,  $\kappa_n = \kappa_r$ ). Assuming a universal subsidy makes the computation of the CPI simpler because the two households face the same prices. Also because in the empirical model subsidies aren’t universal we can only express the results in absolute terms.

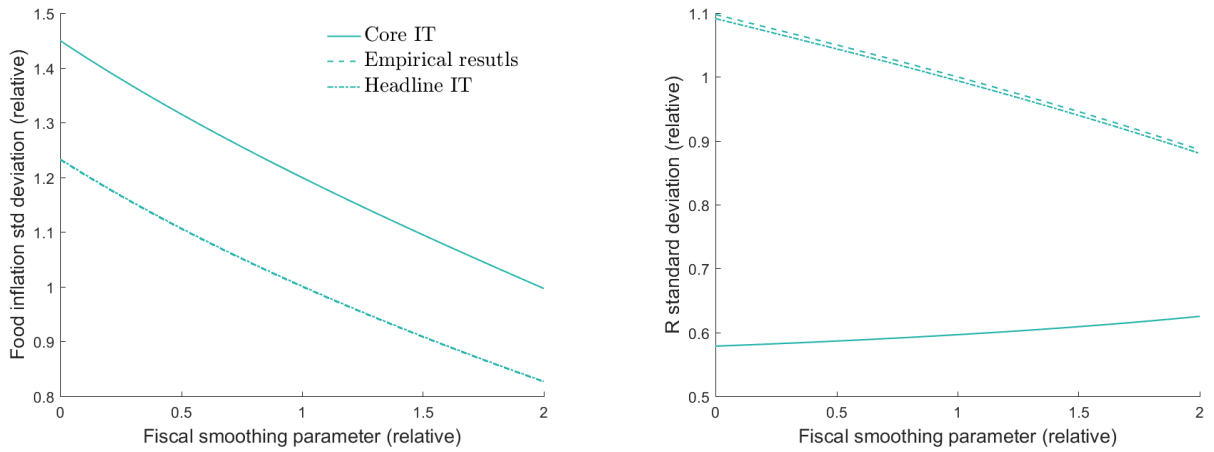
Figure 8: Food Price Intervention and Monetary Policy Interaction



Subsistence Share in Food Consumption



Food in Consumption



Monetary Policy

To further explore the conditions where food subsidies and monetary policy are complementary, we analyze the effect of a change in the subsistence share of food; 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 8).

It follows that the higher (lower) the share of food subsistence, the greater (lower) food 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 8).

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 8).

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.<sup>38</sup> 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 8).

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 find it natural to consider the stabilization properties of three policy rules based on a second-order approximation of household welfare. The first rule corresponds with no price subsidy (i.e.,  $\kappa_i = 0$ ). The second and third rules relate to targeted ( $\kappa_n > 0, \kappa_r = 0$ ) and general intervention ( $\kappa_i > 0$ ), respectively. All models have the same steady state. Following [Faia and Monacelli \(2007\)](#), we define welfare for household type as follows:

$$\mathcal{W}_{i,t} = E_t \left\{ \sum_{n=0}^{\infty} \beta^n U_i(C_{i,t+n}, N_{i,t+n}) \right\} \Big|_{x_0=x} \quad (37)$$

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

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

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 37 recursively:

$$\mathcal{W}_{i,t} = U_i(C_{i,t}, N_{i,t}) + \beta \mathcal{W}_{i,t+1} \quad (38)$$

<sup>38</sup>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:

$$\mathcal{W}_t = (1 - \lambda)\mathcal{W}_{r,t} + \lambda\mathcal{W}_{n,t} \quad (39)$$

The results of the welfare evaluation, presented in Table 7, suggest that fiscal intervention does not improve aggregate welfare, albeit we find heterogeneous distributional effects by household type. Food subsidies are welfare improving only for credit-constrained households. This household is sensitive to changes in food prices considering food represents a sizeable share of expenditures and their limited financial access to smooth consumption. The government can thus borrow for non-Ricardians, thereby decreasing non-Ricardians' vulnerability to food price shocks.

We find a polar case for the Ricardian household; any fiscal intervention reduces welfare for this household. Any price intervention results in an increase level of debt and future stream of tax liabilities. In our set up, aggregate welfare is negative, which reflects the larger share of Ricardian households in the population. Also 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 subsidy policy. However, in a Rawlsian perspective, it may be argued that the social planner should give more weight to the constrained household.<sup>39</sup> Finally, these results could also be seen in a political economy perspective as reflecting different households ability to control policy makers.

Table 7: Welfare Results

	Fiscal Intervention		Relative Welfare		
	$\kappa_n$	$\kappa_n$	$\mathcal{W}$	$\mathcal{W}_n$	$\mathcal{W}_r$
No subsidy	0.0000	0.0000	0.00	0.00	0.00
Targeted subsidy	0.3078	0.0000	-0.63	0.09	-0.11
Empirical Model	0.3078	0.2256	-0.64	0.01	-0.11

Note: all models are based on the posterior mean. Welfare results are presented in percentage changes relative to "No Subsidy".

## 7 Conclusion

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 low- and middle-income economies including food price subsidy, incomplete markets with credit-constrained consumers, food consumption subsistence and a high share of households food expenditures. The model is applied using Indian data.

Four key findings emerge from our analysis. First, the empirical evidence suggests that food 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.

<sup>39</sup>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 \(1999\)](#).

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 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 absent food subsidies, interest rate volatility would be 10.3% higher. To put it diffidently, RBI's interest rate increase to a typical food price shock would be 24% larger absent 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 diminishes the higher the degree of food price intervention, albeit there are heterogeneous distributional effects. Welfare is increasing (decreasing) the higher intensity of food price intervention for the non-Ricardian (Ricardian) household. Non-Ricardians are unable to smooth consumption, unlike the Ricardian household, however the government can do so for them by borrowing vis-à-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 products), makes monetary and fiscal policy complementary in India.

The existing literature generally relies on the assumption that monetary policy is solely charged with stabilizing inflation by setting the interest rate (Gali, 2008). In low- and middle-income countries, the transmission channel of monetary policy is weakened by the presence of non-Ricardian households who are unable to smooth consumption (Gali 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 low- and middle-income countries, contributes to the overall price stability.

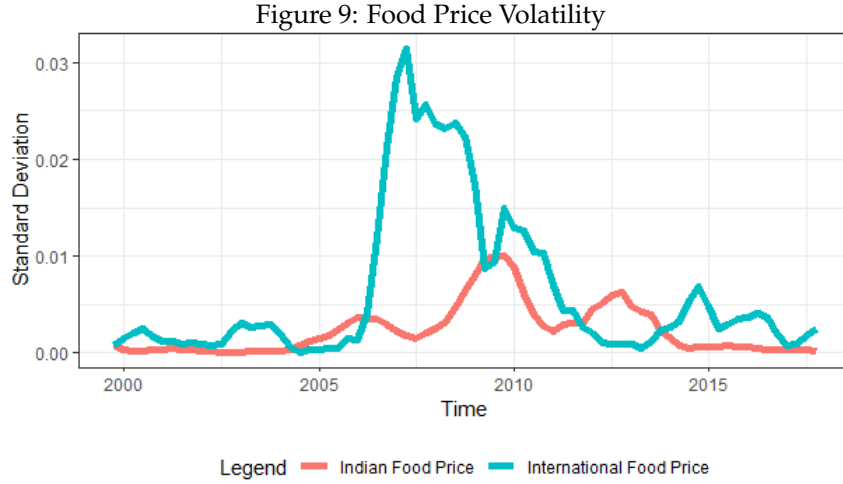
Additionally, the results have two policy implications. First, the welfare results challenge a fiscal policy response that does not conform to a policy targeting vulnerable (non-Ricardian) members of society considering a scarcity of fiscal resources, particularly in low- and middle-income economies. 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 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 9 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.



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:

$$\begin{aligned}
 L_{r,t} = & \sum_{t=0}^{\infty} \beta^t \zeta_{r,t} \left( \ln(C_{r,t}) - \psi \frac{N_{r,t}^{1+\chi}}{1+\chi} \right) + \Lambda_{r,t} \left( \frac{(1+i_{t-1})B_t}{\vec{P}_{r,t}} - \frac{e_t(1+i_{t+1}^*)\Theta(\mathcal{B})B_{t-1}^*}{\vec{P}_{r,t}} + (1-\tau_t)W_tN_t \right. \\
 & \left. + ((1-\tau_t)u_t r_t + \delta\tau_t - a[u_t])k_{t-1} + (1-\tau_t)\Pi_t^S + (1+\tau_t)C_{r,t} - I_t - \frac{B_t}{\vec{P}_{r,t}} - \frac{e_t B_t^*}{\vec{P}_{r,t}} \right) \\
 & + Q_{r,t} \left( (1-\delta)k_{t-1} + \left[ 1 - \Psi \left( \frac{I_t}{I_{t-1}} \right) \right] I_t - k_t \right)
 \end{aligned} \tag{40}$$

where  $\Lambda_{r,t}$  and  $Q_{r,t}$  represent the shadow value on the budget constraint and Lagrangian multiplier on installed capital, respectively. We describe the first order conditions below ex post allowing for a change of variables by setting  $q_{r,t} = Q_{r,t}/\Lambda_{r,t}$  as the marginal value of installed capital in terms of replacement costs which is known as Tobin's Q. Optimization yields the following first-order conditions:

$$\frac{\partial L_{r,t}}{\partial C_{r,t}} : \Lambda_{r,t} = \frac{\zeta_{r,t}}{(1+\tau_t)C_{r,t}} \tag{41}$$

$$\frac{\partial L_{r,t}}{\partial B_{r,t}} : \Lambda_{r,t} = \beta^t E_t \left[ \Lambda_{t+1} \frac{(1+i_{t+1})}{\vec{\pi}_{r,t+1}} \right] \tag{42}$$



$$\frac{\partial L_{r,t}}{\partial B_{r,t}^*} : \Lambda_{r,t} = \beta E_t \left[ \Lambda_{r,t+1} \frac{(1 + i_{t+1}^*) \Theta(\mathcal{B}) e_{t+1}}{\vec{\pi}_{r,t+1}} \frac{e_{t+1}}{e_t} \right] \quad (43)$$

$$\frac{\partial L_{r,t}}{\partial I_{r,t}} : q_t = \left( 1 - \Psi \left( \frac{I_t}{I_{t-1}} \right) + \Psi' \left( \frac{I_t}{I_{t-1}} \right) I_t + \beta^t E_t \frac{\Lambda_{t+s}}{\Lambda_t} \left[ q_{t+1} \frac{I_{t-1}^2}{I_t} \Psi' \left( \frac{I_t}{I_{t-1}} \right) \right] \right) \quad (44)$$

$$\frac{\partial L_{r,t}}{\partial k_{r,t}} : q_t = \beta E_t \left[ \frac{\Lambda_{t+s}}{\Lambda_t} (1 - \tau_t) r_t + \delta \tau_t - a[u_t + (1 - \delta)q_{t+1}] \right] \quad (45)$$

$$\frac{\partial L_{r,t}}{\partial u_t} : (1 - \tau_t) r_t = a'[u_t] \quad (46)$$

$$\frac{L_{r,t}}{\partial N_{r,t}} : \psi N_{r,t}^\chi = \frac{W_t}{(1 + \tau_t) C_{r,t}} \quad (47)$$

Equations (42) and (48) represent the inter-temporal optimization relating labor supply decisions with the marginal rate of consumption and real wage. The Euler equation is represented by equation (42) and (43). Equations (43) and (44) represents the Euler equations 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:

$$\frac{\partial L_{n,t}}{\partial C_{n,t}} : \Lambda_{n,t} = \frac{1}{(1 + \tau_t) C_{n,t}} \quad (48)$$

$$\frac{\partial L_{n,t}}{\partial N_{n,t}} : \psi N_{n,t}^\chi = \frac{(1 - \tau_t) \Lambda_{n,t} W_t}{\vec{P}_{n,t}} \quad (49)$$

## 8.3 Robustness tests

### 8.3.1 Alternative data

In order to test if our results are consistent over different measures of the world food price, we present in this section the Bayesian estimation results using the World Bank Food Price index (in place of the FAO index). Results are similar to those presented in Section 4.

### 8.3.2 Alternative Taylor rule

The RBI has adopted an inflation targeting framework in 2016. Prior to this period, consumer price stability was already monetary policy main objective. 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:

$$\frac{1 + r_t}{1 + r} = \left( \frac{1 + r_{t-1}}{1 + r} \right)^{\psi_r} \left[ \left( (\pi_t^M)^\varrho (\pi_t^F)^{1-\varrho} \right)^{\omega_\pi} (\Delta y_t)^{\omega_y} (\Delta e_t)^{\omega_e} \right]^{1-\psi_r} e^{\varepsilon_t^{MP}} \quad (50)$$

where  $\psi_r$  is the degree of interest rate smoothing and  $\omega_\pi$ ,  $\omega_y$  and  $\omega_e$  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 ( $\omega_e$ ), with a prior mean of zero set for this parameter (we keep all other priors the same). The estimates

Table 8: Prior and Posterior Distributions Using World Bank Food Price

		Density	Prior		Posterior			
			Mean	StD	Mean	90% interval	StD	
$\chi$	Inverse Frisch	G	1	0.1	0.9512	0.8038	1.1081	0.0971
$\zeta$	Bond adjustment costs	I	0.01	1	0.0299	0.0211	0.0396	0.0074
$\theta$	Elasticity of substitution F and M	G	0.75	0.05	0.8044	0.7564	0.8610	0.0470
$\kappa_n$	Policy intensity	B	0.30	0.1	0.2986	0.1966	0.3994	0.0825
$\kappa_r$	Policy intensity	B	0.15	0.1	0.2183	0.1425	0.3038	0.0890
$\overline{C^F}$	Food subsistence	I	0.08	1	0.0462	0.0230	0.0675	0.0120
$\phi_M$	Calvo signal	B	0.66	0.05	0.5892	0.5427	0.6429	0.0371
$\psi$	Capital adjustment costs	N	1.30	0.2	1.2158	0.8522	1.5281	0.1993
$\varrho$	Policy price index	B	0.45	0.05	0.4720	0.4290	0.5352	0.0331
$\psi_S$	Interest rate smoothing	B	0.70	0.1	0.8059	0.7712	0.8408	0.0274
$\omega_\pi$	TR response: inflation	N	1.50	0.1	1.5912	1.4408	1.7510	0.0913
$\omega_Y$	TR response: GDP	N	0.50	0.1	0.2453	0.1734	0.3268	0.0650
$\rho^{AM}$	AR on manufacturing productivity	B	0.80	0.05	0.9144	0.8690	0.9418	0.0157
$\rho^{AF}$	AR on food productivity	B	0.50	0.05	0.7359	0.6868	0.7864	0.0365
$\rho^{F^*}$	AR on food price	B	0.85	0.05	0.9283	0.9079	0.9451	0.0127
$\rho^{MP}$	AR monetary policy	B	0.50	0.05	0.2829	0.2216	0.3260	0.0314
$\rho^{i^*}$	AR foreign interest rate	B	0.46	0.05	0.6062	0.5433	0.6745	0.0425
$\rho^{\Psi}$	AR law of one food price gap	B	0.85	0.05	0.9504	0.9315	0.9620	0.0092
$\rho^{\zeta}$	AR preference	B	0.85	0.05	0.8621	0.7956	0.9315	0.0442
$\sigma^{AM}$	StD manufacturing productivity	I	0.01	2	0.0344	0.0272	0.0433	0.0054
$\sigma^{AF}$	StD food productivity	I	0.01	2	0.0253	0.0218	0.0288	0.0026
$\sigma^{MP}$	StD monetary policy	I	0.01	2	0.0035	0.0032	0.0039	0.0004
$\sigma^{P^{F^*}}$	StD food price	I	0.01	2	0.0652	0.0582	0.0725	0.0052
$\sigma^{i^*}$	StD foreign interest rate	I	0.01	2	0.0022	0.0021	0.0026	0.0002
$\sigma^{\Psi}$	StD law of one food price gap	I	0.01	2	0.0748	0.0651	0.0842	0.0060
$\sigma^{\zeta}$	StD preference	I	0.01	2	0.0323	0.0252	0.0414	0.0054

Note: distributions include Beta (B), Gamma (G) and Inverse Gamma (I). "StD" for standard deviation. Based on 100,000 draws generated using the Metropolis-Hastings algorithm.

of this alternative model are presented in Table 9. We obtain a low posterior mean ( $\omega_e = 0.12$ ), where most of the posteriors are similar to the baseline model (see Table 3).

We provide the welfare results for the alternative Taylor-like rule (see Table 10), which is similar to the baseline model (Table 7).

Lastly, we demonstrate the effect that fiscal price intervention has on the volatility of the interest rate based on the alternative Taylor-like rule (see Figure 10) is similar to the baseline model (Figure 8).

Table 9: Prior and Posterior Distributions via Alternative Taylor Rule

		Density	Prior		Posterior			
			Mean	StD	Mean	90% interval	StD	
$\chi$	Inverse Frisch	G	1	0.1	0.9965	0.8427	1.1357	0.0975
$\zeta$	Bond adjustment costs	I	0.01	1	0.0315	0.0197	0.0451	0.0060
$\theta$	Elasticity of substitution F and M	G	0.75	0.1	0.8428	0.7655	0.9260	0.0470
$\kappa_n$	Policy intensity	B	0.3	0.1	0.2940	0.2159	0.3643	0.0481
$\kappa_r$	Policy intensity	B	0.15	0.1	0.1884	0.1279	0.2618	0.0540
$\overline{C^F}$	Food subsistence	I	0.084	1	0.0507	0.0228	0.0791	0.0132
$\phi_M$	Calvo signal	B	0.66	0.05	0.5938	0.5224	0.6602	0.0376
$\psi$	Capital adjustment costs	N	1.3	0.2	1.3948	1.1388	1.6660	0.2009
$\varrho$	Policy price index	B	0.45	0.05	0.4679	0.4187	0.5173	0.0313
$\psi_S$	Interest rate smoothing	B	0.7	0.1	0.7990	0.7661	0.8327	0.0260
$\omega_e$	TR response: Exchange Rate	N	0	0.1	0.1152	0.0331	0.1859	0.0525
$\omega_\pi$	TR response: inflation	N	1.5	0.1	1.6312	1.5012	1.7758	0.0937
$\omega_\gamma$	TR response: GDP	N	0.5	0.1	0.2369	0.1376	0.3476	0.0676
$\rho^{AM}$	AR on manufacturing productivity	B	0.8	0.05	0.9203	0.8886	0.9514	0.0166
$\rho^{AF}$	AR on food productivity	B	0.5	0.05	0.7267	0.6743	0.7856	0.0363
$\rho^{F^*}$	AR on food price	B	0.85	0.05	0.9171	0.8948	0.9329	0.0142
$\rho^{MP}$	AR monetary policy	B	0.5	0.05	0.2939	0.2413	0.3373	0.0302
$\rho^{i^*}$	AR foreign interest rate	B	0.46	0.05	0.6411	0.5936	0.6982	0.0405
$\rho^\Psi$	AR law of one food price gap	B	0.85	0.05	0.9450	0.9298	0.9611	0.0097
$\sigma^{AM}$	StD manufacturing productivity	I	0.01	2	0.0385	0.0270	0.0528	0.0052
$\sigma^{AF}$	StD food productivity	I	0.01	2	0.0242	0.0207	0.0280	0.0026
$\sigma^{MP}$	StD monetary policy	I	0.01	2	0.0039	0.0031	0.0048	0.0004
$\sigma^{P^{F^*}}$	StD food price	I	0.01	2	0.0607	0.0544	0.0683	0.0049
$\sigma^{i^*}$	StD foreign interest rate	I	0.01	2	0.0023	0.0021	0.0026	0.0002
$\sigma^\Psi$	StD law of one food price gap	I	0.01	2	0.0747	0.0679	0.0843	0.0057
$\sigma^\zeta$	StD preference	I	0.01	2	0.0387	0.0293	0.0494	0.0055

Note: distributions include Beta (B), Gamma (G) and Inverse Gamma (I). "StD" for standard deviation. Based on 100,000 draws generated using the Metropolis-Hastings algorithm.

Table 10: Welfare Results for Alternative Taylor Rule

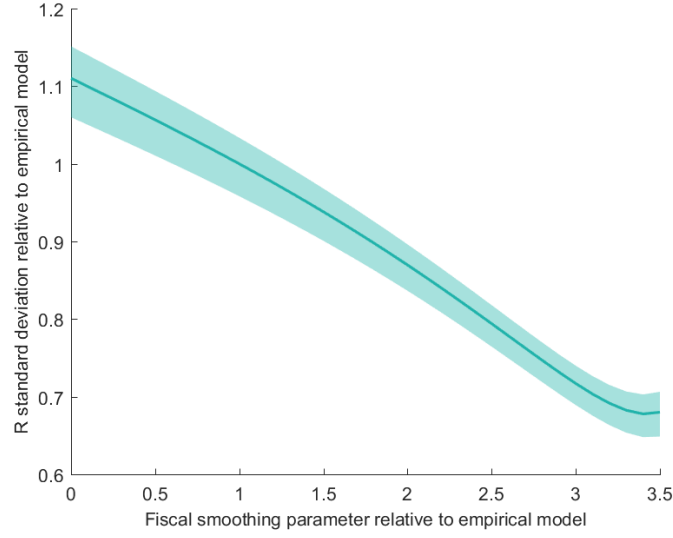
	Fiscal Intervention		Relative Welfare		
	$\kappa_n$	$\kappa_r$	$\mathcal{W}$	$\mathcal{W}_n$	$\mathcal{W}_r$
No Subsidy	0.0000	0.0000	0.0000	0.0000	0.0000
Targeted Subsidy	0.226	0.0000	-0.5577	0.2628	-0.1105
Empirical Model	0.226	0.1148	-0.5539	0.2746	-0.1106

Note: all models are based on the posterior mean. Welfare results are presented in percentage changes relative to "No Subsidy".

### 8.3.3 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 relatively 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.

Figure 10: Robustness: Alternative Taylor Rule



In our baseline framework, we present a number of tax instruments based on a single tax rate.<sup>40</sup> 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:

$$\begin{aligned}
 L_{r,t} = & \sum_{t=0}^{\infty} \beta^t \zeta_{r,t} \left( \ln(C_{r,t}) - \psi \frac{N_{r,t}^{1+\chi}}{1+\chi} \right) + \Lambda_{r,t} \left( tax_t + \frac{(1+i_{t-1})B_t}{\vec{P}_{r,t}} - \frac{e_t(1+i_{t+1}^*)\Theta(B)B_{t-1}^*}{\vec{P}_{r,t}} + W_t N_t \right. \\
 & + (u_t r_t + \delta - a[u_t])k_{t-1} + \Pi_t^S + C_{r,t} - I_t - \frac{B_t}{\vec{P}_{r,t}} - \left. \frac{e_t B_t^*}{\vec{P}_{r,t}} \right) \\
 & + Q_{r,t} \left( (1-\delta)k_{t-1} + \left[ 1 - \Psi \left( \frac{I_t}{I_{t-1}} \right) \right] I_t - k_t \right)
 \end{aligned} \tag{51}$$

where  $\Lambda_{r,t}$  and  $Q_{r,t}$  represent the shadow value on the budget constraint and Lagrangian multiplier on installed capital, respectively.

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

$$B_t^G - (1+i_{t-1})B_{t-1}^G = \vec{S}_t - tax_t \tag{52}$$

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

We provide the results corresponding with the Bayesian estimation in Table 11. The results are closely aligned with the baseline model (see Table 5). We highlight that while the estimated posteriors for the food price intensity for the non-Ricardian ( $\kappa_n$ ) and Ricardian ( $\kappa_r$ ) household is lower in the baseline model, the baseline model and lump sum model 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 0.4 and 0.46 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.

We provide the welfare results for the alternative Taylor-like rule (see Table 10), which is consistent with the baseline model (Table 7).

<sup>40</sup> The baseline model contains eight taxes on consumption, income and capital (see equation 28).

Lastly, we demonstrate the effect that fiscal price intervention has on the volatility of the interest rate based on the alternative Taylor-like rule (see Figure 11) is similar to the baseline model (Figure 8).

Table 11: Prior and Posterior Distributions via Lump Sum Tax Model

		Density	Prior		Posterior			
			Mean	StD	Mean	90% interval	StD	
$\chi$	Inverse Frisch	G	1	0.1	0.9881	0.8561	1.1077	0.0978
$\zeta$	Bond adjustment costs	I	0.01	1	0.0215	0.0142	0.0304	0.0070
$\theta$	Elasticity of substitution F and M	G	0.75	0.05	0.8071	0.7304	0.8834	0.0468
$\kappa_n$	Policy intensity	B	0.3	0.1	0.2709	0.1666	0.3748	0.0828
$\kappa_r$	Policy intensity	B	0.15	0.1	0.2098	0.1213	0.3107	0.0533
$\overline{C^F}$	Food subsistence	I	0.084	1	0.0415	0.0220	0.0581	0.0152
$\phi_M$	Calvo signal	B	0.66	0.05	0.5791	0.5276	0.6314	0.0387
$\psi$	Capital adjustment costs	N	1.3	0.2	1.2269	0.9127	1.5455	0.1992
$\varrho$	Policy price index	B	0.45	0.05	0.4559	0.4007	0.4977	0.0273
$\psi_S$	Interest rate smoothing	B	0.700	0.1	0.8015	0.7708	0.8425	0.0201
$\omega_\pi$	TR response: inflation	N	1.500	0.1	1.6228	1.5030	1.7351	0.0930
$\omega_Y$	TR response: GDP	N	0.500	0.1	0.1860	0.0919	0.2791	0.0682
$\rho^{AM}$	AR on manufacturing productivity	B	0.8	0.05	0.9264	0.8987	0.9524	0.0182
$\rho^{AF}$	AR on food productivity	B	0.5	0.05	0.7313	0.6779	0.7869	0.0376
$\rho^{F^*}$	AR on food price	B	0.85	0.05	0.9241	0.9018	0.9460	0.0144
$\rho^{MP}$	AR monetary policy	B	0.5	0.05	0.2899	0.2261	0.3375	0.0296
$\rho^{i^*}$	AR foreign interest rate	B	0.46	0.05	0.6382	0.5961	0.6995	0.0410
$\rho^\Psi$	AR law of one food price gap	B	0.85	0.05	0.9511	0.9369	0.9674	0.0096
$\sigma^{AM}$	StD manufacturing productivity	I	0.01	2	0.0325	0.0273	0.0423	0.0050
$\sigma^{AF}$	StD food productivity	I	0.01	2	0.0256	0.0223	0.0313	0.0026
$\sigma^{MP}$	StD monetary policy	I	0.01	2	0.0035	0.0029	0.0041	0.0004
$\sigma^{P^{F^*}}$	StD food price	I	0.01	2	0.0604	0.0545	0.0665	0.0048
$\sigma^{i^*}$	StD foreign interest rate	I	0.01	2	0.0022	0.0020	0.0026	0.0002
$\sigma^\Psi$	StD law of one food price gap	I	0.01	2	0.0706	0.0625	0.0816	0.0056
$\sigma^\zeta$	StD preference	I	0.01	2	0.0329	0.0276	0.0428	0.0055

Note: distributions include Beta (B), Gamma (G) and Inverse Gamma (I). "StD" for standard deviation. Based on 100,000 draws generated using the Metropolis-Hastings algorithm.

Figure 11: Robustness: Lump Sum Tax Model

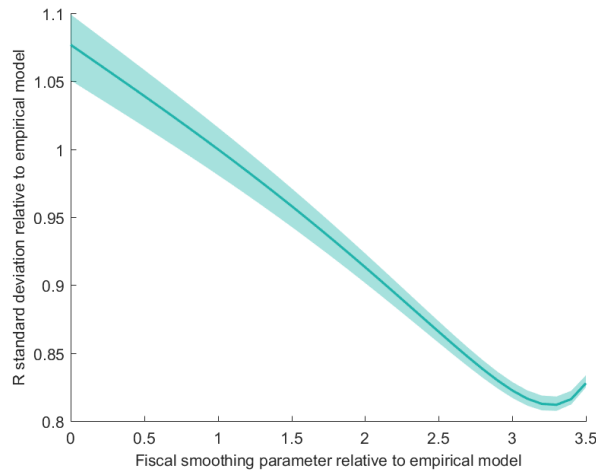


Table 12: Welfare Results for Alternative Tax Model

	Fiscal Intervention		Relative Welfare		
	$\kappa_n$	$\kappa_n$	$\mathcal{W}$	$\mathcal{W}_n$	$\mathcal{W}_r$
No Subsidy	0.0000	0.0000	0.0000	0.0000	0.0000
Targeted Subsidy	0.3078	0.0000	-0.8658	0.4148	-0.1719
Empirical Model	0.3078	0.2256	-0.1021	0.1347	-0.1792

Note: all models are based on the posterior mean. Welfare results are presented in percentage changes relative to “No Subsidy”.

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