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Food Prices and Inflation Targeting in Emerging Economies

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Abstract

The two episodes of food price surges in 2007 and 2011 have been particularly challenging for developing and emerging economies' central banks and have raised the question of how monetary authorities should react to such external relative price shocks. We develop a new-Keynesian small open-economy model and show that non-food inflation is a good proxy for core inflation in high-income countries, but not for middle-income and low-income countries. Although, in these countries we find that associating non-food inflation and core inflation may be promoting badly-designed policies, and consequently central banks should target headline inflation rather than non-food inflation. This result holds because non-tradable food represents a significant share in total consumption. Indeed, the poorer the country, the higher the share of purely domestic food in consumption and the more detrimental lack of attention to the evolution in food prices.

Keyword: Monetary Policy, Commodities, Food prices, DSGE models.

JEL: E32, E52, O23.

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1 Introduction

The last few years have been intensely challenging for central bankers. The financial crisis has had tremendous negative effects on developed economies and major spillover effects on emerging economies (large capital inflows and outflows). At the same time central bankers had to manage the dramatic rise in food prices. According to the United Nations Food and Agriculture Organization (FAO), in the period 1996 to 2006, world food prices rose on average by only 0.05% per semester in real terms; from 2007 to 2011 they have risen by an average of 2% per semester, that is, by 25 times more. The period beginning in 2006 (or post-great moderation) has been characterized by two price surges: the FAO price index increased by 54% between January 2006 and June 2008, declined of 34% between June 2008 and December 2008, then rose by 53% before stabilizing in December 2010.

The most frequently mentioned causes of food price volatility include: extreme weather conditions, increased demand from emerging countries caused by growth in incomes, increased costs to farmers due to high oil prices, rapid development of biofuels, adoption of restrictive trade policies by major net exporters of key foods products such as rice, and speculation in commodity markets. So, for the monetary authorities of almost all small open economies, these shocks were perfectly exogenous from their policies or their own country situations, and were unanticipated.

The high fluctuation in food prices is questioning how monetary policy should react to these external shocks. The present paper tries to find some answers. Specifically, we examine how monetary authorities in developing countries should respond to food price shocks. The case of developing countries is interesting for two main reasons.

First, in low-income and emerging economies, food consumption represents a significant share of household expenditure. Table 1 shows that food budgets represent around 50%, 30% and 20% of the household budgets in low-income, middle-income and high-income countries respectively. Therefore, in these countries, changes in food prices will induce significant variations in their headline inflation.

Second, low and middle-income countries are characterized by a large share of non-tradable products in their food consumption. For instance, even if a country is an exporter of a given agricultural product, the domestically consumed variety is often of a different (e.g. lower) quality, is produced in different fields and does not share the logistics infrastructure of the exported variety. Different cultures induce different diets, some cereals and tubers are country specific and not traded. Even if volumes of agricultural imports are large, they represent at most half of the country's food consumption (see Table 1).

Thus, developing economies are characterized by a large domestic food sector. This is a crucial aspect of this analysis of the effects of a world price shock on a small open economy. Since the domestic food sector is country specific, it evolves with the domestic environment.

Pricing strategies do not reflect directly the world market. But since domestic and tradable food goods are highly substitutable, the domestic food sector is impacted on by the evolution in the world market. So, in studying the pass-through from the world market price to the domestic overall consumer price index (CPI), a major issue is the passage from the tradable food goods price to the non-tradable food goods price. This channel is a striking feature of developing economies and a major concern for monetary authorities.

Table 1: Food budget shares

	Low-income	Middle-income	High-income
Food in consumption	48%	31%	20%
Tradables in food	37%	59%	81%

Source: International Comparison Program (ICP) (World Bank, 2005), tradable shares (FAO, 2007) and own calculations. Note: Tradable share is defined as the percentage of the food products documented by the 2007 FAO Food Balance Sheet database for which the sum of import and export is less than 5 % of domestic consumption. The 144 countries covered by the 2005 ICP and The 162 countries covered by the 2007 FAO Food Balance Sheet database are divided into low-, middle-, and high-income countries, based on their income relative to that of the United States. Low-income, middle-income and high-income countries represent those with real per capita income less than 15 percent, between 15 and 45 percent, and greater than 45 percent of the U.S. level, respectively.

In this study, we examine particularly the performance of an inflation targeting framework to manage food price shocks in developing countries. By definition, an inflation targeting framework requires the choice of a measure of inflation as the target. Targeting countries generally use core inflation as the target. There are several methods used to compute core inflation. The most common approach, which is exploited by many countries, is the exclusion method, which computes core inflation by removing the prices of a fixed, pre-specified set of items from the CPI basket. The excluded components are chosen because they are considered either volatile or susceptible to supply disturbances; they typically consist of food and energy items. The exclusion method is based on the idea that these excluded items are prone to supply shocks that are beyond the control of the central bank, and is used by Canada, New Zealand, Peru, Thailand and the United Kingdom among others. The other approach is a statistically-based method that removes extreme price changes or outliers (both positive and negative) from the overall inflation rate. In the statistics-based method, the set of excluded items changes each period, depending on which items show extreme price movements. For example, Chile uses a statistics-based approach and computes its core inflation by excluding the 20 percent largest negative price changes and the 8 percent largest positive price changes. This method is more sophisticated but is also more costly to implement, since the list of the goods included in core inflation need continuous updating.

In order to analyze the response of monetary policy to food price shocks, we construct a small open economy model where food can be produced domestically or imported. More precisely, the consumption bundle consists of food and manufactured goods, where each kind of good consists of two varieties: one is non-tradable (domestically-produced and sold in a monopolistic competition market) and one is tradable (both imported and produced at home, and sold in a competitive market under the law of one price). This allows us to assume that food price volatility is related to both technological shocks (such as weather) and imported price shocks (such as world price hikes). Therefore our model allows us to decompose the channel from the world price to the overall CPI, through the effects on domestic food prices, food and non-food substitutability, and exchange rate effects on non-food tradable goods competitiveness.

We consider three important issues:

- Firstly, we model an economy in which the non-tradable food share in consumption is large, implying a non-negligible part of non-tradable food prices in the CPI. Thus, monetary authorities cannot look at food price shocks as short term volatility only. World food price movements impact on domestic non-tradable sticky prices in food and non-food sectors, implying long-run effects.
- Secondly, our model allows us to distinguish three price indices: overall consumer price inflation, true core inflation index based on sticky prices, and a proxy core inflation index based on non-food prices (as in the exclusion method). Therefore, we estimate the welfare cost of confusing non-food inflation and core inflation.
- Thirdly, we examine whether the fact that food is a first necessity matters for the ranking of monetary policy rules. In this case, we employ a Klein-Rubin form with minimum amount of consumption.

We show that food prices should not be entirely excluded from the core inflation index. This implies not distinguishing between non-food inflation and core inflation may result in ill-designed policies, especially in countries with large food domestic sectors. Thus our results suggest that in low-income and emerging countries central bank should target CPI rather than core inflation index based on the method of exclusion of food prices. We demonstrate that this result does not hold for high-income countries where the share of food prices in core inflation is low enough to make non-food inflation a good proxy for core inflation.

Many studies focus on oil price rather than food price shocks. Some analyze the choice of index (core or headline inflation) to target in the presence of oil price shocks. Bodenstein et al. (2008) use a stylized Dynamic stochastic general equilibrium (DSGE) model with an energy sector to study the optimal monetary policy response to an adverse energy supply. They find that policies that react to a forecast of headline inflation following a temporary energy shock induce different effects from policies that react to a forecast of core inflation, with the former causing greater volatility in core inflation and the output gap. Batini & Tereanu (2009), using a small open-economy DSGE model to design an appropriate response from inflation targeting countries to oil price shocks, find that the optimal response of inflation targeting central banks is an aggressive increase in real interest rates in order to close the inflation gap with the minimum efficient policy horizon. This focus on oil price shocks (see e.g. Blanchard & Galí (2007), Gomez-Lopez & A.Puch (2008) or Schubert & Turnovsky (2011); **?** among other) is of limited help in an analysis of food price shocks. They focus mainly on shocks to the input price, while food price shocks are more likely to be shocks to consumption goods with extremely low elasticity of substitution with other goods. This applies to the paper by Anand & Prasad (2010) which proposes a model of a closed developing economy in which food producers are credit constraints. Anand & Prasad (2010) show that overall CPI targeting is the best policy in the presence of financial restrictions. Since they model a closed economy, the volatility of food prices is due only to technological shocks. Thus, their model does not allow analysis of the monetary policy response to a world price shock. Our paper is related also to the study by Catao & Chang (2010) which examines how monetary policy should react to imported food price shocks. Similar to our approach, they assume that food price shocks are relative price shocks. These authors propose a small open economy in which all food is imported. They find that broad CPI targeting is welfare-superior to alternative policy rules once the variance in food price shocks is as large as in real world data. The restriction that food is only imported (and not domestically produced) does not capture the pass-through mechanism from the world to the domestic food price, as is the case in our paper. Moreover, low and middle-income countries are sometimes importers and sometimes exporters, but there is no net trend in the data to characterize them as net food importers.

The remainder of the paper is organized as follows. Section 2 describes the model whose calibration is presented in Section 3. The simulation results are presented in Section 4. Section 5 introduce fixed consumption. Finally, Section 6 sums up the results and discusses some policy implications.

2 The model

The small open economy is populated by infinitely-lived households. They consume C and supply labor L. The consumption bundle consists of food F and non-food M. Each kind of good consists of two varieties: a non-tradable one N (domestically-produced and sold in a monopolistic competition market) and a tradable good T (both imported and produced at home, and sold in a competitive market under the law of one price). Households can own domestic firms and can accumulate foreign assets in the form of one-period risk-free bonds in the world currency. Domestic bonds are available but are not internationally traded.

2.1 Households

The representative household maximizes the following utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t) \qquad \text{with} \qquad U(C,L) \equiv \frac{C^{1-\rho}}{1-\rho} - \psi \frac{L^{1+\chi}}{1+\chi}$$

where $0 < \beta < 1$, $\mathbb{E}$ is the expectation operator, $\rho > 0$ is the inverse of intertemporal elasticity of substitution, $\chi > 0$ the inverse of elasticity of labor supply and$\psi > 0$ is a scale parameter.

The consumption bundle can be written as (we skip the t subscript for simplicity)

$$C \equiv \left[(1-\gamma)^{\frac{1}{\theta}} (C^M)^{\frac{\theta-1}{\theta}} + (\gamma)^{\frac{1}{\theta}} (C^F)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \tag{1}$$

where θ is the intratemporal elasticity of substitution between food and non-food goods, and γ is the share of food in consumption. C^M and C^F can be written as

$$C^M \equiv \left[(1-\gamma_M)^{\frac{1}{\theta_M}} C^{MN\frac{\theta_M-1}{\theta_M}} + \gamma_M{}^{\frac{1}{\theta_M}} C^{MT\frac{\theta_M-1}{\theta_M}}\right]^{\frac{\theta_M}{\theta_M-1}}, \tag{2}$$

$$C^F \equiv \left[(1-\gamma_F)^{\frac{1}{\theta_F}} \left(C^{FN}\right)^{\frac{\theta_F-1}{\theta_F}} + \gamma_F{}^{\frac{1}{\theta_F}} \left(C^{FT}\right)^{\frac{\theta_F-1}{\theta_F}}\right]^{\frac{\theta_F}{\theta_F-1}}. \tag{3}$$

Given the price of each good P^{FN}, P^{FT}, P^{MN} and P^{MT}, and introducing the convenient aggregate prices relative to food P^F, non-food P^M and aggregate consumption P,

$$P^F \equiv \left[(1-\gamma_F) P^{FN^{1-\theta_F}} + \gamma_F P^{FT^{1-\theta_F}}\right]^{\frac{1}{1-\theta_F}}, \tag{4}$$

$$P^M \equiv \left[(1-\gamma_M) P^{MN^{1-\theta_M}} + \gamma_M P^{MT^{1-\theta_M}}\right]^{\frac{1}{1-\theta_M}}, \tag{5}$$

$$P \equiv \left[(1-\gamma) P^{M^{1-\theta}} + \gamma P^{F^{1-\theta}}\right]^{\frac{1}{1-\theta}}. \tag{6}$$

The demand for food and non-food goods is given as

$$C^F = \gamma \left(\frac{P^F}{P}\right)^{-\theta} C \tag{7}$$

$$C^M = (1-\gamma) \left(\frac{P^M}{P}\right)^{-\theta} C \tag{8}$$

Then, the demand for each variety is given by

$$C^{FT} = \gamma_F \left(\frac{P^{FT}}{P^F}\right)^{-\theta_F} C^F \tag{9}$$

$$C^{FN} = (1-\gamma_F) \left(\frac{P^{FN}}{P^F}\right)^{-\theta_F} C^F \tag{10}$$

$$C^{MT} = \gamma_M \left(\frac{P^{MT}}{P^M}\right)^{-\theta_M} C^M \tag{11}$$

$$C^{MN} = (1-\gamma_M) \left(\frac{P^{MN}}{P^M}\right)^{-\theta_M} C^M \tag{12}$$

The non-tradable (food and non-food) good is assumed to be a composite of a continuum of differentiated goods, $c_t(i)$ with $i \in [0,1]$, via the aggregative CES function

$$C^N \equiv \left(\int_0^1 c^N(i)^{1-\frac{1}{\eta_N}} \mathrm{d}i\right)^{\frac{1}{1-\frac{1}{\eta_N}}}, \tag{13}$$

where $N = FN$ (for non-tradable food) or $N = MN$ (for non-tradable non-food), η_N is the elasticity of substitution across varieties. Let $P_t^N(i)$ be the nominal price of variety i at time t. The aggregate price in the sector is defined by

$$P^N = \left(\int_0^1 P^N(i)^{1-\eta_N} \mathrm{d}i\right)^{\frac{1}{1-\eta_N}}. \tag{14}$$

The consumer minimizes its total expenditure for any given level of consumption of the composite good, subject to the aggregation constraint. The optimal level of $c^N(i)$ is then given by

$$c^N(i) = \left(\frac{P^N(i)}{P^N}\right)^{-\eta_N} C^N. \tag{15}$$

The representative household enters each period with holdings of domestic bonds, denoted by B_{t-1}, and foreign bonds denominated in units of foreign currency, denoted by B^*_{t-1}, purchased from the previous period, and purchases the respective amounts B_t and B^*_t. To avoid a multiplicity of steady-states, the household is assumed to face an interest rate that is increasing in the country's net foreign debt (following Schmitt-Grohé & Uribe (2003)). The interest rate perceived by the household, denoted by $i^\star_t$ is the sum of the world interest rate, i^w_t, and a risk premium that depends on the net foreign asset position:

$$i^\star_t = i^w_t + \zeta(e^{-B^*} - 1)$$

where $\zeta > 0$ is a parameter of bond adjustemnt cost.

Let S denotes the nominal exchange rate, the representative household faces the following budget constraint, expressed in units of domestic currency

$$\begin{aligned} & S_t B_t^* + B_t + P_t C_t \\ & \quad = S_t \left(1 + i_{t-1}^{\star}\right) B_{t-1}^* + (1 + i_{t-1}) B_{t-1} + W_t L_t + \Pi_t. \end{aligned} \tag{16}$$

where Π_t denotes profit. Let $d_{t,t+k}$ be the nominal stochastic discount factor between dates t and $t+k$, which is given by

$$d_{t,t+k} = \beta^k \frac{P_t}{P_{t+k}} \left(\frac{C_{t+k}}{C_t}\right)^{-\rho}. \tag{17}$$

Therefore, the first order conditions related to domestic and foreign bonds holdings and labor supply are given by

$$1 = \mathbb{E}_t \left\{(1 + i_t) d_{t,t+1}\right\} \tag{18}$$

$$1 = \mathbb{E}_t \left\{\frac{S_{t+1}}{S_t} \left(1 + i_t^{\star}\right) d_{t,t+1}\right\} \tag{19}$$

$$\frac{W_t}{P_t} = \psi L_t^{\chi} C_t^{\rho} \tag{20}$$

2.2 Firms

Firms produce according to a decreasing return to scale function. Non-wage income implicitly remunerates land (in the food sector) or capital (in the non-food sector).

2.2.1 Tradable goods producers

The production technology for tradable goods is given by

$$Y_t^T = A_t^T \left(L_t^T\right)^{1-\alpha_T} \tag{21}$$

where $T = FT$ (for tradable food) or $T = MT$ (for tradable non-food), L_t^T is the unit of labor employed and A_t^T is the level of technology.

The firm takes the price and the wage as given, and chooses the quantity produced and the labor required to maximize its profit.

$$\Pi_t^T = P_t^T Y_t^T - W_t L_t^T \tag{22}$$

The optimal condition of this program implies the usual equation that links labor productivity and real wages

$$W_t L_t^T = (1-\alpha_T) P_t^T Y_t^T. \tag{23}$$

Together with the production function we get demand for labor

$$L_t^T = \left((1-\alpha_T) A_t^T \frac{P_t^T}{W_t} \right)^{1/\alpha_T} \tag{24}$$

2.2.2 Non-tradable goods producers

In the non-tradable sector, the variety i of each good is produced by a single firm according to a technology common across sector firms and using labor as the only input. The production technology is given by

$$Y_t^N(i) = A_t^N \left(L_t^N(i) \right)^{1-\alpha_N}, \tag{25}$$

where $N = FN$ (for non-tradable food) or $N = MN$ (for non-tradable non-food) and A_t^N is productivity in the non-tradable sector N.

Firms are allowed to set prices according to a stochastic time-dependent rule as in Calvo (1983): in each period, a firm faces a probability ϕ_N of not being able to re-optimize its price. All firms that reset their price at t will choose the same $P_{t|t}^N$ in order to maximize the expected present discounted value of profits, under the constraint that the firm must satisfy demand at the posted price. Thus, the firm program is given by

$$\max_{P_{t|t}^N} \quad \mathbb{E}_t \sum_{k=0}^{\infty} d_t^{t+k} {\phi_N}^k \left[P_{t|t}^N Y_{t+k|t}^N - \Psi_{t+k|t}^N \right]$$

$$\text{subject to} \quad \begin{cases} Y_{t+k|t}^N = \left(\frac{P_{t|t}^N}{P_{t+k}^N} \right)^{-\eta_N} C_{t+k}^N & \text{(demand)} \\ \Psi_{t+k|t}^N = W_{t+k} \left(\frac{Y_{t+k|t}^N}{A_{t+k}^N} \right)^{\frac{1}{1-\alpha_N}} & \text{(cost)} \end{cases}$$

The first order conditions, optimal price setting, evolution of inflation and aggregate production function in the non-tradable food and the non-tradable manufactured sectors are set out in the Appendix B.

2.3 The balance of payments

The trade balance is given by the sum of food tradable and manufacture tradable exports. The balance of payments is obtained by

$$P_t^{FT}(Y_t^{FT} - C_t^{FT}) + P_t^{FT}(Y_t^{FT} - C_t^{FT}) - S_t \left(B_t^\star - i_{t-1}^w B_{t-1}^\star \right) = 0 \tag{26}$$

2.4 Monetary policy

Since our focus is on the performance of inflation targeting to deal with food price shocks, we consider monetary policy rules in which central bank moves interest rates systematically as a function of price inflation. These interest rate rules take the following forms:

- Headline inflation targeting: $log\left(i/\bar{i}\right) = \Phi \log\left(\Pi\right)$
- Non-food inflation targeting: $log\left(i/\bar{i}\right) = \Phi_M \log\left(\Pi^M\right)$
- Core inflation targeting: $log\left(i/\bar{i}\right) = \Phi_{FN} \log\left(\Pi^{FN}\right) + \Phi_{MN} \log\left(\Pi^{MN}\right)$

where $\bar{i}$ is steady-state level of interest rate i.

For each interest rate rule, the value of the parameters is set in order to maximize the welfare associated with this rule (see Section 4). Note that the second rule corresponds to what is generally used by central banks as a proxy for core inflation: excluding food prices from the CPI. This proxy for core inflation is the inflation of non-food goods. In the third rule the target is the exact definition of core inflation, which is an index of sticky prices.

2.5 Shocks

There are two kinds of perturbations: shocks to productivities, A^{FT}, A^{FN}, A^{MT} and A^{MN} and shocks to foreign prices, $P^{FT\star}$, $P^{MT\star}$ and i^w.

- Productivity shocks are assumed to evolve exogenously over time, following an AR(1) process $x_t = \rho^x x_{t-1} + \epsilon_t^x$, where $0 < \rho^x < 1$ and $\epsilon^x \sim N(0, \sigma_\epsilon)$, for $x = A^{FT}$, A^{FN}, A^{MT}, A^{MN}.
- Foreign variables $(P^{FT\star}, P^{MT\star}, i^w)$ follow a VAR(2) process (see Appendix C).

3 Calibration

Most of the parameters are set according to the typical values in the literature; some are set in order to reproduce some basic ratios, mainly food sector size (see Table 2). The model is solved numerically up to second-order approximation using DYNARE (see Adjemian et al. (2011)).

The representative household is assumed to have no foreign debt at equilibrium ($B^* = 0$). We assume also that both the food and the manufacturing sectors have a closed economy steady-state ($Y^{FT} = C^{FT}$ and $Y^{MT} = C^{MT}$).[1] All relative prices are set to 1 at the steady-state

[1] In low-income and middle-income group, countries can experience surplus or deficit in the agricultural balance. On average, the data know no systematic imbalance.

Table 2: Parameters calibration

Description	Symbol	Value
Utility function		
Discount factor	β	0.99
Inverse of intertemporal elasticity of substitution	ρ	2
Inverse of elasticity of labor supply	χ	0.83
Share of tradable in non-food consumption	γ^M	0.5
Elasticity of substitution between food and non-food good	θ	0.3
Elasticity of substitution between food T and N	θ^F	1.4
Elasticity of substitution between non-food T and N	θ^M	1.4
Food sector		
Probability of domestic food price non-adjustment	ϕ^F	0.5
Monopoly power	η^F	6
Scale effect on labor, non-tradable	α^{FD}	0.25
Scale effect on labor, tradable	α^{FT}	0.35
Non-food sector		
Probability of non-food price non-adjustment	ϕ^M	0.75
Monopoly power	η^M	6
Scale effect on labor, non-tradable	α^{MD}	0.25
Scale effect on labor, tradable	α^{MT}	0.25
Adjustment cost		
Parameter of bonds adjustment cost	ζ	0.001
Shocks persistence		
Productivity, domestic food sector	$\rho, \sigma_{\epsilon}^{a^{FD}}$	$0.25, 0.03$
Productivity, tradable food sector	$\rho, \sigma_{\epsilon}^{a^{FT}}$	$0.25, 0.03$
Productivity, domestic non-food sector	$\rho, \sigma_{\epsilon}^{a^{MD}}$	$0.8, 0.02$
Productivity, tradable non-food sector	$\rho, \sigma_{\epsilon}^{a^{MT}}$	$0.8, 0.02$

Table 3: Calibration per country type

Description	Symbol	Value
Low-income Countries		
Share of food in consumption	γ	0.48
Share of tradable in food consumption	γ^F	0.37
Middle-income Countries		
Share of food in consumption	γ	0.31
Share of tradable in food consumption	γ^F	0.59
High-income Countries		
Share of food in consumption	γ	0.20
Share of tradable in food consumption	γ^F	0.81

($P^s = 1, \forall s$). Similarly, the parameter that weights labor in utility (ψ) is set such that total values for labor and consumptions at the steady-state are equal to unity ($L = 1$ and $C = 1$).

The quarterly discount factor β is set equal to 0.99 which implies a yearly real world interest rate of 4% at the steady-state. The risk-aversion parameter is set to $\rho = 2$, which means an intertemporal elasticity of substitution of 0.5, as is usual in the literature (see for instance Devereux et al. (2006), Schmitt-Grohé & Uribe (2007) and De Paoli (2009)).

The share of food in consumption, γ, is calibrated according to International Comparison Program (ICP) data that cover 144 countries. Depending on the group to which the country belongs (low-, middle- or high-income countries) it is set to 48%, 31% and 20% respectively (see Table 3) and the share of tradable goods in food consumption is set to 37%, 59% and 81%.

The elasticity of substitution between food and non-food goods, θ, is a key parameter in our model. Because the demand for food is inelastic, θ is lower than 1. To our knowledge Anand & Prasad (2010) is the only study to provide a clear calibration [2]. We follow Anand & Prasad (2010) and set elasticity in utility at $\theta = 0.3$. The elasticity of substitution between tradable and non-tradable goods θ^F and θ^M, is set to 1.4, as estimated for developing countries by Ostry & Reinhart (1992).

At the steady-state, agricultural sector value added represents around one-third of total GDP (which is a key feature of emerging economies, as seen in Table 4). Labor in the agricultural sector represents around one-third of total employment.

Table 4: Sectors shares

	Value added (% of total)			Employment (% of total)		
	Agriculture	Industry	Services	Agriculture	Industry	Services
Low income	23	29	48	40	18	42
Middle income	7	35	59	16	26	58
High income	2	32	66	4	26	69
All countries	14	31	56	16	24	60

Source: World Bank. Note: Calculations form the authors of the mean for 144 countries, divided into low-, middle-, and high-income countries, based on their income relative to that of the United States. Low-income countries represent those with real per capita income less than 15 percent of the U.S. level, middle-income countries are those with real per capita income between 15 and 45 percent of the U.S. level, and high-income countries with have per capita income equal to or greater than 45 percent of the U.S. level.

Generally, the literature on Calvo-style pricing behavior sets the probability of price non-adjustment at around $\phi = 0.75$, which implies that on average price adjustments occur every four quarters. Empirical studies show that food prices are less sticky than the prices of

[2] Anand & Prasad (2010) write page 26: *Since the demand for food is inelastic, we set [elasticity of substitution] = 0.6 as the baseline case. With a subsistence level of food consumption, this parameter choice implies a price elasticity in demand for food of about -0.3 at the steady-state, which is close to the USDA estimate.* In our case, we have no subsistence level of food consumption as a baseline (this assumption is removed in section 5). Thus, for this parameter we set the elasticity in utility at $\theta = 0.3$.

manufactured goods (see Loupias & Ricart (2004), Bils & Klenow (2004) and Baudry et al. (2005)). Thus, we set $\phi^F = 0.5$ for the food sector and $\phi^M = 0.75$ for the manufactured sector. The scale effect on labor equals 0.75 for each sector ($\alpha^s = 0.25$).

The persistence of shocks on productivity in the non-food sectors (ρ^{MT} and ρ^{MN}) is set at 0.8. The associated standard deviation (σ_ϵ) is set at 0.02. These values are in line with those in Ravenna & Natalucci (2008) or Gali & Monacelli (2005), and average those in the international business cycle literature. Productivity shocks in the food sectors (mainly weather events) are calibrated following Anand & Prasad (2010): persistences (ρ^{FT} and ρ^{FN}) are set at 0.25, and standard deviation (σ_ϵ) at 0.03.

We estimate a VAR model in order to calibrate variances and covariances in world food price shocks, the world manufacturing (non-food) price shocks and the world interest rate shocks. The results are given in appendix C.

For the described structure of shocks and the low-income countries calibration, the variance decomposition of the main variables of the model is given in Table D.8 in Appendix D.

4 Welfare and model's response under alternative monetary policy rules

4.1 Welfare calculation

Monetary policy analysis based on a welfare criterion has improved dramatically in recent years. In most studies of optimal monetary policy in economies with nominal rigidities, it is assumed that government can access a subsidy to factor inputs, financed from lump-sum taxes, aimed at dismantling the inefficiency introduced by imperfect competition. Since this assumption is clearly unrealistic we do not introduce this mechanism in our model. It follows that the solution to the model is a distorted steady-state equilibrium (Schmitt-Grohé & Uribe, 2007). In this case, a second-order welfare approximation is needed.

Because the solution to our model is a distorted steady-state equilibrium, calculation of a Ramsey policy would imply re-writing the model without inefficiency. There is no reason to believe that a comparison between our model and such a corrected copy would make sense. In our case, no policy is a good benchmark. Thus our purpose is not to measure the distance of a given policy from the benchmark, but to rank different policies.

To our knowledge, Faia & Monacelli (2007) is the only reference that gives the exact criterion underlying the welfare computation. We use the following criterion:

$$\mathcal{W} = \mathbb{E}_{-1} \left\{ \sum_{t=0}^{\infty} \beta^t u(C_t, L_t) \right\} \Bigg|_{x_0=\bar{x}}$$

where x denotes the set of predetermined variables. Following Schmitt-Grohé & Uribe (2004) and Adjemian et al. (2011) the second-order welfare approximation takes the form of the following conditional expectation:

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

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

We present the results in terms of the percentage conditional welfare gains associated with each policy choice. Welfare gains are defined as additional perpetual consumption needed to make the level of welfare under strict non-food price inflation targeting identical to that under the evaluated policy. Thus, a positive number indicates that welfare is higher under the alternative policy than under strict non-food price inflation targeting policy.

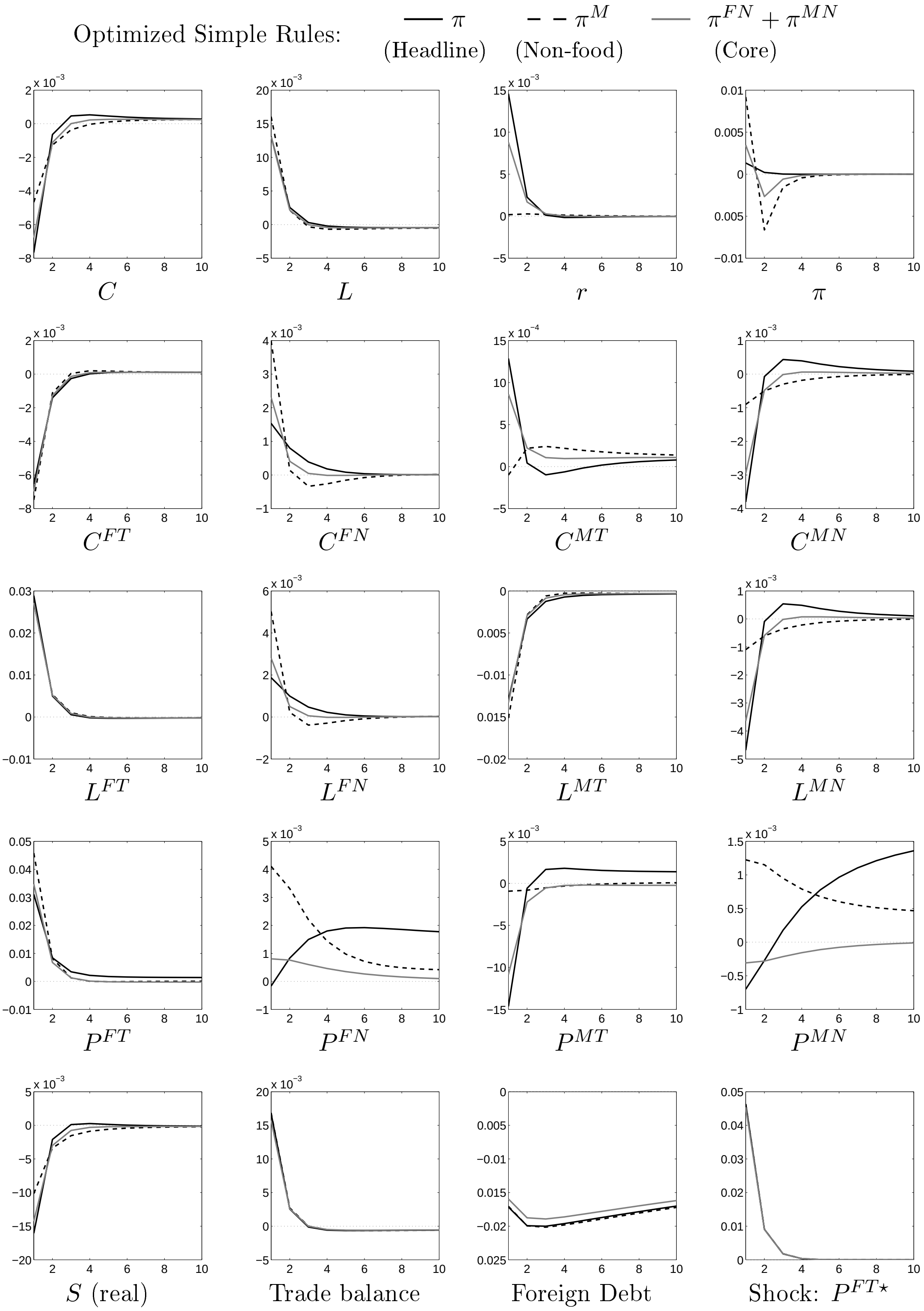
Table 5: Taylor Rules: calibration that maximizes welfare

Target	Optimal Rule	$\mathcal{W}$	Rank
Low-income Countries			
Headline inflation	$log\,(i/\bar{i}) = 56\ log\,(\Pi)$	0.03	2
Non-food inflation	$log\,(i/\bar{i}) = 52\ log\,(\Pi^M)$	0.00	3
Core inflation	$log\,(i/\bar{i}) = 712\ log\,(\Pi^{FN}) + 287\ log\,(\Pi^{MN})$	0.11	1
Middle-income Countries			
Headline inflation	$log\,(i/\bar{i}) = 115\ log\,(\Pi)$	0.01	2
Non-food inflation	$log\,(i/\bar{i}) = 58\ log\,(\Pi^M)$	0.00	3
Core inflation	$log\,(i/\bar{i}) = 882\ log\,(\Pi^{FN}) + 117\ log\,(\Pi^{MN})$	0.08	1
High-income Countries			
Headline inflation	$log\,(i/\bar{i}) = 151\ log\,(\Pi)$	-0.01	3
Non-food inflation	$log\,(i/\bar{i}) = 66\ log\,(\Pi^M)$	0.00	2
Core inflation	$log\,(i/\bar{i}) = 963\ log\,(\Pi^{FN}) + 36\ log\,(\Pi^{MN})$	0.09	1

4.2 Discussion over alternative monetary-policy rules

Figure 1 displays the model's response to a shock to the world food price for a typical low-income country. We consider an unanticipated one percentage point transitory increase in the world food price. Inflationary pressure leads the central bank to tighten its monetary policy. Aggregate consumption drops and the currency appreciates. Whatever the monetary policy rule, around two-third of the shock passes through domestic prices, while one-third is absorbed by exchange rate appreciation. The increase in the domestic price of tradable food leads to a large fall in domestic demand for this good. Because tradable and non-tradable food goods are substitutable ($\theta^F = 1.4$) this fall in tradable food consumption is partly

Figure 1: IRF under alternative monetary policy rules: low-income countries



compensated for by an increase in non-tradable food consumption. Thus the price of non-tradable food also increases despite the monetary policy. Appreciation of the currency makes the tradable non-food goods cheaper, and causes demand for them to rise. Consumption of non-tradable non-food goods decreases while consumption of tradable non-food goods rises. The increase in food exports dominates the fall in non-food exports such that the trade balance becomes positive, and the net foreign position is cleared through ownership of more foreign assets.When the central bank targets the overall CPI, the interest rate increases at the time of the shock. The price of non-tradable goods does not increase, firstly because wages are a constraint, secondly because the exchange rate appreciation reduces the pass-through. During the transition, the interest rate decreases, and global demand, wages and prices rise. Thus non-tradable prices increase progressively, and domestic inflation is spread over a long period.

When the central bank excludes food prices from its target, the interest rate does not move with world food price hikes. Thus, the food price shock heats the domestic economy more heavily. The shock is absorbed less by the exchange rate appreciation. Wages and non-tradable goods prices increase dramatically. During the transition, the relative price of tradable food falls gradually because of nominal rigidity. Since our model includes tradable food and non-food goods, the exchange rate turns to be a key channel for the transmission of monetary policy. If the central bank raises its interest rates following a world food price shock, this will cause appreciation of the domestic currency and will reduce the relative price of tradable non-food goods. This keeps inflation in non-food goods at a low rate.

The result in Table 5 show that for any country category, the best policy is to target sticky prices (in other words, the exact core inflation index). This result is consistent with previous studies and especially with Aoki (2001). Table 5 presents the weights that maximize each policy rule. Note that the poorer the country, the bigger the weight on non-tradable food in core inflation. These weights reflect the relative sizes of the two sticky price sectors in the economy. The share of non-tradable food in core inflation is around 4% in high-income countries, 12% in middle-income countries and 30% in low-income countries. This explains the ranking of the other rules: in high income countries, the optimal share of non-tradable food in core inflation is extremely low, thus it can be virtually neglected by the monetary authorities with the consequence that targeting non-food inflation is more effective than targeting headline inflation. Thus, in high income countries, non-food inflation, the proxy for core inflation calculated with the exclusion method, is a better target than headline inflation. However, in middle income countries, the optimal share of non-tradable food in core inflation is higher than in high-income countries, and thus it cannot be neglected by the monetary authorities. Consequently, in middle-income countries targeting non-food inflation is less effective than targeting headline inflation. This result is even stronger in low-income countries, where the gap between the welfare cost of shocks under headline inflation and the welfare cost of shocks under non-food inflation represents a perpetual utility loss of 0.03% of consumption. Our results suggest that the confusion between non-food inflation and core inflation may be causing badly designed policies in low and middle-income countries. This result implies that central bank would do better to target CPI than to target a proxy core inflation index based on non-food prices.

When the non-tradable food share in consumption is large, core inflation must include food as well as non-food sticky prices. Therefore, the relative share of the two indexes in the monetary-relevant inflation is far from obvious. Many central banks use a proxy for core inflation that is based on non-food prices rather that the true core index. As Table 5 shows, this is justified in high-income countries where the share of food in consumption is low and consist mainly of tradable goods. However, in low and middle-income countries targeting non-food inflation leads to ill-designed policies. Food prices are more volatile, which explains their exclusion from the measure of core inflation. Nevertheless, in low and middle-income countries, a surge in imported food prices generates inflationary pressures in the large non-tradable food sector. Thus, the trade-off between headline and non-food inflation differs for middle and high-income countries. This results is robust to changes in the calibration of the main parameters of the model (see Table E.9 in Appendix E).

5 Fixed consumption and monetary policy

Food is not a good like other goods: it is basic consumption need. Some might argue that because food is a good of first necessity, a food price shock will not spread to the economy in the same ways as other relative price shocks. Consumption cannot decrease freely. A part of consumption is not related to relative prices and thus is inelastic. In this section, we examine whether the fact that food is a first necessity influences the ranking of monetary rules. We can conclude that our results are robust to a change in the definition of food in the utility function.

Following Anand & Prasad (2010), to account for food being a necessity, households must consume a minimum amount of each kind of food in order to survive, denoted $\bar{C}^{FN}$ and $\bar{C}^{FT}$, respectively. We assume also that the household always has enough income to buy the subsistence level of food. Thus, the food index in utility is given by a generalized Klein-Rubin utility function (see e.g. Gollin et al. (2002)). Therefore, the consumption bundle given in equation (3) becomes:

$$C^F \equiv \left[(1-\gamma_F)^{\frac{1}{\theta_F}} \left(C^{FN} - \bar{C}^{FN}\right)^{\frac{\theta_F - 1}{\theta_F}} + \gamma_F{}^{\frac{1}{\theta_F}} \left(C^{FT} - \bar{C}^{FT}\right)^{\frac{\theta_F - 1}{\theta_F}}\right]^{\frac{\theta_F}{\theta_F - 1}}. \qquad (27)$$

Notice that C_t^F is not the amount of food consumed by the household, but the household's utility value of food consumption. The household consumes C_t^{FN} and C_t^{FT}. But since food is a necessity, we considerer that consumption does not deliver pleasure (or utility) to the household before the *minimum* level is reached. This means that its utility starts to increase only when food consumption overtakes this *subsistence* level.

Demand for each food variety (previously given by equation (9) and (10)) can be rewritten as

$$C^{FT} = \gamma_F \left(\frac{P^{FT}}{P^F}\right)^{-\theta_F} C^F + \bar{C}^{FT} \tag{28}$$

$$C^{FN} = (1{-}\gamma_F) \left(\frac{P^{FN}}{P^F}\right)^{-\theta_F} C^F + \bar{C}^{FN} \tag{29}$$

Thus, in this case, the total consumption expenditure is given by

$$P_t C_t + P_t^{FN} \bar{C}^{FN} + P_t^{FT} \bar{C}^{FT}$$

The representative household now faces the following budget constraint (previously given by equation (16)) expressed in units of domestic currency

$$\begin{aligned} S_t B_t^* + B_t + P_t C_t + P_P^{FD} \bar{C}^{FD} + P_P^{FT} \bar{C}^{FT} \\ = S_t \left(1 + i_{t-1}^{\star}\right) B_{t-1}^* + (1 + i_t) B_t + W_t L_t + \Pi_t. \end{aligned} \tag{30}$$

We introduce fixed consumption in food and restrict the change in the utility function such that the economy's steady-state is maintained. This implies introducing minimum consumption in Equation (27) and rescaling the share of food in the consumption bundle in Equation (1) according to $\bar{\gamma} = \gamma(1 - \mathcal{A})$ with $\mathcal{A}$ the food subsistence level in proportion to total food consumption at the steady-state.

Even with the introduction of fixed consumption, ceteris paribus, it has a major effect on the elasticity of substitution between goods. The model's elasticity, denoted by θ, is no longer the perceived elasticity of substitution, denoted by $\mathcal{E}$. The perceived elasticity of substitution is a linear function of the model's elasticity of substitution and fixed consumption: $\mathcal{E} = \mathcal{A}\theta$. This means that when fixed consumption rises to near 100 % of consumption, the elasticity of substitution falls to zero.

The model described in Section 2 is taken as a baseline. In order to add the subsistence amount of food consumption, we need to redefine all the variables that are dependent on the utility function, as described above. We add subsistence levels of 5, 10, 15, etc. up 95% of the food consumption. We repeat the tasks described in Section 4 for welfare.

The welfare cost of shocks obtained by a given rule for a given value of fixed food consumption should not be compared to the welfare value obtained by the same rule for another value of fixed consumption, because it does not come from the same utility function. Since the utility function has changed, it does not allow for welfare comparison. However, for a given value of fixed consumption we can compare different policies and rank them according to their welfare. We can also compare the rankings from one fixed consumption value to another. Our main

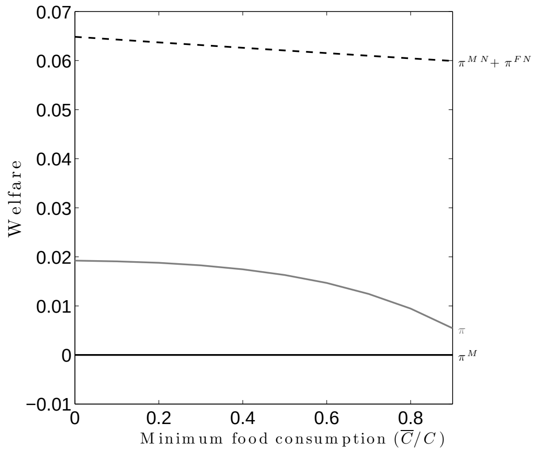


Figure 2: Welfare associated to the main policy rules for different subsistence level

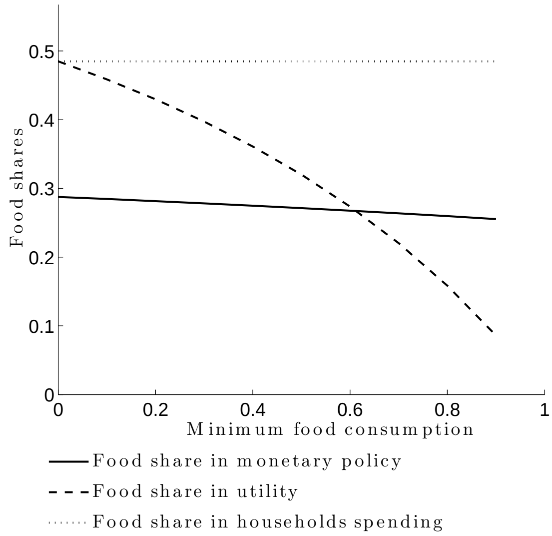


Figure 3: Variations of food shares in consumption, utility and monetary policy.

result is that the rankings do not change. Graphically this is represented by the fact that in Figure 3 the lines never cross. Thus the results described in Section 4 are ongoing: (i) targeting sticky prices is the best option; (ii) targeting overall CPI is better than targeting a proxy for core inflation given by non-food inflation.

If we examine the best monetary policy more closely, that is, the rule combining inflation in non-tradable food and non-tradable non-food sectors, we can define the relative weight of food in the optimized policy rule. For any subsistence level we can calculate the weighting that minimizes the welfare cost of shocks. We find that the relative weight of the two inflation indexes does not change while the subsistence levels of food increase. On the graph in 3 we plot the food share according to this rule, which is the weight associated with non-tradable food inflation divided by the sum of the weights of non-tradable food and non-tradable non-food inflation. Once again, the ranking of monetary policy rules does not change whatever the subsistence level. Therefore, the fact that food is a necessity does not change the way monetary policy should react to food prices.

6 Conclusion

In this paper, we examine how central banks react to food price shocks. In particular, we analyze the performance of an inflation targeting regime to deal with a shock to the world price of food products. We developed a small open economy New Keynesian model. We consider that both food and non-food goods are made of tradable and non-tradable goods, and we calibrate our model on real data. We defined a non-tradable food good as a product that is produced at home and whose price does not depend directly upon the world market. This set up allowed us to describe the channel between the world market and domestic consumer prices, through the relative demand for tradable goods and purely domestic varieties. It is well-known that central banks cannot calculate the exact core inflation indices of their economies because they generally lack micro level data on prices behaviors, particularly in less-developed and emerging economies. They tend to use a proxy for core inflation that is based on excluding oil and food prices from the CPI.

We showed how confusion between core inflation and non-food inflation can lead to badly formulated policies. This result holds for low-income and middle-income countries, where the share of food goods in the CPI, and particularly the share of non-tradable food goods, is large. In high-income countries, the share of non-tradable food in consumption is small enough to be ignored by central banks in their definition of core inflation. Thus, our results suggest that in low and middle income countries central banks should target headline inflation rather than a core inflation index that excludes food prices.

This finding holds not because food is a first necessity, but because non-tradable food represents a significant share in total consumption. When food is described as a first necessity good the ranking of monetary rules does not change. In fact, a high share of non-tradable food in consumption, implies a non-negligible part of sticky food prices in the CPI, giving room for monetary policy action toward food price shocks.

Therefore, the results from our work provide important policy recommendation for countries that are inflation targeting and intend to implement such policies in the future. For high-income countries, food prices can be virtually ignored in the target index. For low and middle income countries where non-tradable food is not negligible, central bank should not ignore food price evolution and should target headline inflation .

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A Food consumption and economic development

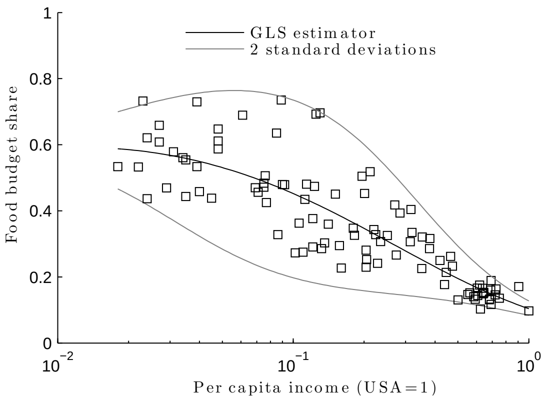

Figure A.4: Food in households basket.

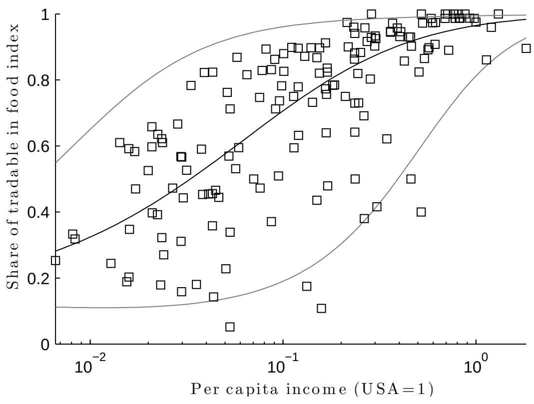

Figure A.5: Share of tradable goods in food consumption.

We estimate the equation

$$\log\left(\frac{S_i}{1-S_i}\right) = \alpha_1 \log(GDP_i) + \alpha_2 \log(GDP_i)^2 + \alpha_3$$

where S is either the share of food in the consumption bundle or the share of tradable goods in food consumption, using GLS (to take into account heteroscedasticity).

B Non-tradable food and manufactured goods sectors

B.1 Optimal price setting and inflation dynamic

We skip the s superscript for convenience (i.e. P_t denotes P_t^s and π_t denotes π_t^s). From the demand function, Equation (15), one has $\frac{\partial Y_{t+k|t}}{\partial P_{t|t}} = -\eta \frac{Y_{t+k|t}}{P_{t|t}}$. The first order condition is given by

$$\mathbb{E}_t \sum_{k=0}^{\infty} d_t^{t+k} \phi^k Y_{t+k|t} \left[P_{t|t} - \frac{\eta}{\eta-1} \frac{\partial \Psi_{t+k|t}}{\partial Y_{t+k|t}}\right] = 0.$$

Let $\mathrm{mc}_t = \frac{1}{1-\alpha} A_t^{\frac{-1}{1-\alpha}} Y_t^{\frac{\alpha}{1-\alpha}} \frac{W_t}{P_t}$. One has

$$\frac{1}{P_{t+k}} \frac{\partial \Psi_{t+k|t}}{\partial Y_{t+k|t}} = \mathrm{mc}_{t+k} \left(\frac{Y_{t+k|t}}{Y_{t+k}}\right)^{\frac{\alpha}{1-\alpha}}.$$

The FOC is given by

$$\left(\frac{P_{t|t}}{P_t}\right)^{\frac{1-\alpha+\eta\alpha}{1-\alpha}} = \frac{\eta}{\eta-1} \frac{\mathbb{E}_t \sum_{k=0}^{\infty} d_t^{t+k} \phi^k Y_{t+k} \left(\frac{P_{t+k}}{P_t}\right)^{\frac{1-\alpha+\eta}{1-\alpha}} \mathrm{mc}_{t+k}}{\mathbb{E}_t \sum_{k=0}^{\infty} d_t^{t+k} \phi^k Y_{t+k} \left(\frac{P_{t+k}}{P_t}\right)^{\eta}} = \frac{\eta}{\eta-1} \frac{\mathcal{X}_t}{\mathcal{Y}_t}.$$

$\mathcal{X}_t$ and $\mathcal{Y}_t$ have the following recursive expressions

$$\mathcal{X}_t = Y_t \mathrm{mc}_t + \phi \mathbb{E}_t \left\{ d_t^{t+1} \pi_{t+1}{}^{\frac{1-\alpha+\eta}{1-\alpha}} \mathcal{X}_{t+1} \right\}, \tag{31}$$

$$\mathcal{Y}_t = Y_t + \phi \mathbb{E}_t \left\{ d_t^{t+1} \pi_{t+1}{}^{\eta} \mathcal{Y}_{t+1} \right\}. \tag{32}$$

Given the definition of the consumption bundle, inflation dynamic in the sector is given by

$$\pi_t^{1-\eta} = \phi + (1-\phi) \left(\frac{P_{t|t}}{P_t} \right)^{1-\eta}. \tag{33}$$

B.2 Price dispersion and aggregate production function

Price dispersion in a given sector induces misallocation of factors and decreases the productivity at the aggregate level comparing to productivity at the firm level. Schmitt-Grohé & Uribe (2006) develops the calculus in the constant return to scale case. We propose here the decreasing return to scale case. Labor demand from firm i is given by

$$L_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{\frac{-\eta}{1-\alpha}} \left(\frac{Y_t}{A_t} \right)^{\frac{1}{1-\alpha}}.$$

Integrating over firms of the sector gives

$$L_t = \left(\frac{Y_t}{A_t} \right)^{\frac{1}{1-\alpha}} \int_0^1 \left(\frac{P_t(i)}{P_t} \right)^{\frac{-\eta}{1-\alpha}} \mathrm{d}i$$

The effect of price dispersion on productivity, given by the term $\mathcal{S}_t = \int_0^1 \left(\frac{P_t(i)}{P_t} \right)^{\frac{-\eta}{1-\alpha}} \mathrm{d}i$, is given by

$$\begin{aligned} \mathcal{S}_t &= (1-\phi) \left(\frac{P_{t|t}}{P_t} \right)^{\frac{-\eta}{1-\alpha}} + \int_{P_t(i)=P_{t-1}(i)} \left(\frac{P_t(i)}{P_t} \right)^{\frac{-\eta}{1-\alpha}} \mathrm{d}i \\ &= (1-\phi) \left(\frac{P_{t|t}}{P_t} \right)^{\frac{-\eta}{1-\alpha}} + \phi \left(\frac{P_{t-1}}{P_t} \right)^{\frac{-\eta}{1-\alpha}} \mathcal{S}_{t-1} \\ &= (1-\phi) \left(\frac{P_{t|t}}{P_t} \right)^{\frac{-\eta}{1-\alpha}} + \phi \pi_t{}^{\frac{\eta}{1-\alpha}} \mathcal{S}_{t-1} \end{aligned} \tag{34}$$

C Estimation of exogenous shocks

We estimated a VAR model on the three exogenous variables of our model which values are given by shocks on "the world economy".

- tradable food goods price, $P_t^{FT\star}$, proxied by Reuter's DataStream food commodities composite price index.

- tradable non-food goods price, $P_t^{MT\star}$, proxied by Reuter's DataStream world export index.

- world interest rate, i_t^w, proxied by the yield on one year US tresory bonds.

Datas range from 1980 first quarter to 2011 last quarter. We consider two lags, according to the correlograms shape. We have also estimated other models, like VARMA, and had similar results.

Table C.6: Estimated VAR

	i_t^w	$P_t^{FT\star}$	$P_t^{MT\star}$
i_{t-1}^w	0.99	-1.64	
	(11.3)	(-2.7)	
i_{-2}^w	-0.20	1.76	
	(-2.7)	(2.9)	
$P_{t-1}^{FT\star}$	0.03	1.03	
	(2.5)	(12.6)	
$P_{t-2}^{FT\star}$	-0.02	-0.42	
	(-1.9)	(-5.16)	
$P_{t-1}^{MT\star}$			1.11
			(13.5)
$P_{t-2}^{MT\star}$			-0.42
			(-5.07)
R-2	0.71	0.60	0.68
D-W	2.00	1.81	1.91
Obs.	126	126	126

t-stat in parenthesis.

Table C.7: Estimated Residuals Matrix

	i^w	$P^{FT\star}$	$P^{MT\star}$
Shocks correlation			
i^w	1		
$P^{FT\star}$	0.089	1	
$P^{MT\star}$	-0.023	0.56	1
Shocks covariance			
i^w	3.8e-5		
$P^{FT\star}$	2.4e-5	1.8e-3	
$P^{MT\star}$	-3.4e-6	5.7e-4	5.6e-4

D Main statistics of the model

Table D.8: Variance decomposition (in percent)

Variables	A^{FN}	A^{FT}	A^{MT}	A^{MN}	i^w	$P^{FT\star}$	$P^{MT\star}$
C	0.24	0.10	1.78	3.43	37.30	45.86	11.28
L	0.04	2.73	7.66	0.54	37.51	40.66	10.87
Y	0.67	8.05	25.15	5.10	26.04	27.43	7.57
Y^{FN}	29.50	0.82	7.50	2.47	11.04	11.62	37.06
Y^{FT}	0.01	29.23	6.41	0.12	8.20	50.05	5.98
Y^{MT}	0.03	3.30	54.22	0.31	15.46	1.35	25.33
Y^{MN}	0.42	0.19	2.39	42.89	10.55	41.72	1.84
Π	0.19	0.01	0.07	0.33	33.30	55.61	10.49
Π^F	2.14	0.01	0.01	1.12	10.18	57.11	29.43
Π^M	1.67	0.01	0.04	0.60	11.18	65.39	21.10

E Impulse-response function

Figure E.6: IRF under alternative monetary policy rules: middle-income countries

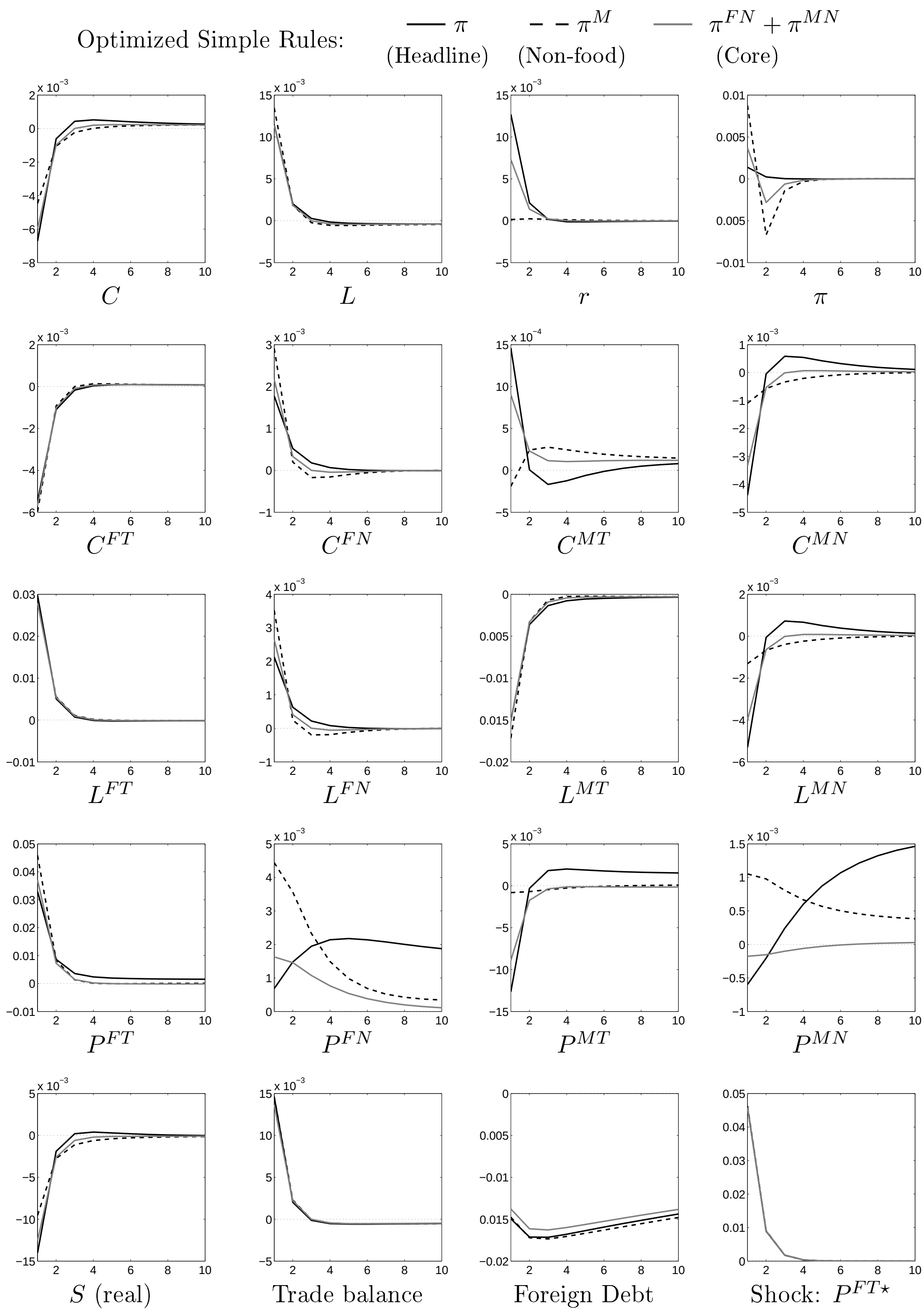

Figure E.7: IRF under alternative monetary policy rules: high-income countries

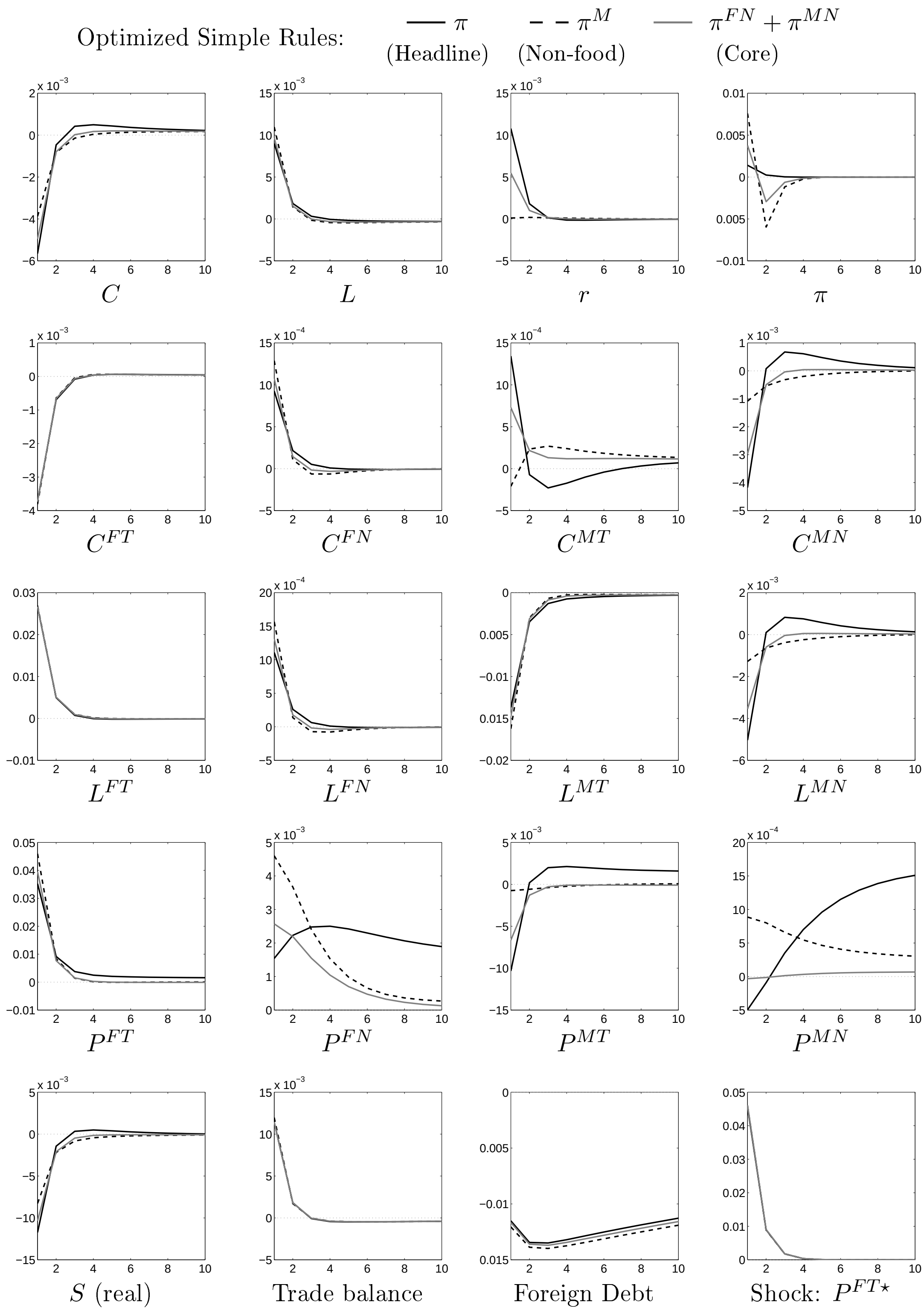

Table E.9: Rubustess test: static comparative on welfare maximizing' Taylor Rules

(low income countries case)

Optimal Rule	$\mathcal{W}$	Rank
Baseline		
$log\,(i/\bar{i}) = 56\ log\,(\Pi)$	0.03	2
$log\,(i/\bar{i}) = 52\ log\,(\Pi^M)$	0.00	3
$log\,(i/\bar{i}) = 712\ log\,(\Pi^{FN}) + 287\ log\,(\Pi^{MN})$	0.11	1
Share of food in consumption $\gamma = 0.2$		
(Baseline = 0. 48)		
$log\,(i/\bar{i}) = 61\ log\,(\Pi)$	0.01	2
$log\,(i/\bar{i}) = 81\ log\,(\Pi^M)$	0.00	3
$log\,(i/\bar{i}) = 901\ log\,(\Pi^{FN}) + 99\ log\,(\Pi^{MN})$	0.10	1
Share of tradable in food consumption $\gamma^F = 0.1$		
(Baseline = 0.37)		
$log\,(i/\bar{i}) = 28\ log\,(\Pi)$	0.09	2
$log\,(i/\bar{i}) = 114\ log\,(\Pi^M)$	0.00	3
$log\,(i/\bar{i}) = 646\ log\,(\Pi^{FN}) + 354\ log\,(\Pi^{MN})$	0.16	1
Probability of domestic food price non-adjustment $\phi^F = 0.75$		
(Baseline = 0.5)		
$log\,(i/\bar{i}) = 80\ log\,(\Pi)$	0.03	2
$log\,(i/\bar{i}) = 189\ log\,(\Pi^M)$	0.00	3
$log\,(i/\bar{i}) = 460\ log\,(\Pi^{FN}) + 526\ log\,(\Pi^{MN})$	0.13	1
Inverse of the intertemporal elasticity of substitution $\rho = 0.5$		
(Baseline = 2)		
$log\,(i/\bar{i}) = 19\ log\,(\Pi)$	0.05	2
$log\,(i/\bar{i}) = 1001\ log\,(\Pi^M)$	0.00	3
$log\,(i/\bar{i}) = 708\ log\,(\Pi^{FN}) + 292\ log\,(\Pi^{MN})$	0.21	1
Elasticity of substitution between F and non-F $\theta = 0.9$		
(Baseline = 0.3)		
$log\,(i/\bar{i}) = 59\ log\,(\Pi)$	0.03	2
$log\,(i/\bar{i}) = 49\ log\,(\Pi^M)$	0.00	3
$log\,(i/\bar{i}) = 715\ log\,(\Pi^{FN}) + 285\ log\,(\Pi^{MN})$	0.11	1
Elasticity of substitution between food T and N $\theta^F = 2.5$		
(Baseline = 1.4)		
$log\,(i/\bar{i}) = 53\ log\,(\Pi)$	0.04	2
$log\,(i/\bar{i}) = 38\ log\,(\Pi^M)$	0.00	3
$log\,(i/\bar{i}) = 701\ log\,(\Pi^{FN}) + 299\ log\,(\Pi^{MN})$	0.11	1
Scale effect on labor $\alpha^{FT,FN,MT,MN} = 0.01$		
(Baseline = 0.25)		
$log\,(i/\bar{i}) = 155\ log\,(\Pi)$	0.03	2
$log\,(i/\bar{i}) = 19\ log\,(\Pi^M)$	0.00	3
$log\,(i/\bar{i}) = 733\ log\,(\Pi^{FN}) + 267\ log\,(\Pi^{MN})$	0.06	1