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Implications of Structural Transformation for Monetary Policy and Inflation
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ABSTRACT

We introduce subsistence requirements in food consumption in a simple new–Keynesian model with two sectors, one with flexible prices (food) and one with sticky prices (non–food). We study how structural transformation—endogenous changes in the structure of the economy as aggregate productivity increases and which result from the presence of subsistence—affects the dynamics of the model, the design of monetary policy and the properties of inflation. We calibrate the model so that it encompasses a typical rich country (the US) and a typical poor country (a sub-Saharan African country). The model replicates the properties of inflation across the development spectrum: inflation is dominated by changes in non–food inflation in rich countries and by changes in the relative price of food in poor countries. The model also replicates the co-movement between inflation and output: from zero (or negative) in poor countries, it gradually becomes positive as the economy develops. The model also predicts that inflation should be more volatile in poor countries than in rich countries, although it falls short of the inflation volatility observed in the data. Finally we discuss the macroeconomic implications of alternative policy regimes depending on the level of development.

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I. INTRODUCTION

Low–income countries find themselves at a crossroad.[1] In the case of sub-Saharan Africa, with a few exceptions, these countries were tremendously successful in bringing inflation down to single digits (or near single digits) since the late 1990s/early 2000s, in the context of fiscal–based stabilization efforts and policy regimes centered, at least de jure, on money targets. Having stabilized inflation and curtailed fiscal pressures to al large extent, many of these countries are looking to modernize their monetary policy frameworks. Some have moved toward explicit inflation targeting (IT) (Ghana) and others have announced their intention to adopt that regime in the near future (Uganda). Others are adopting elements of IT (Kenya, Rwanda), such as signalling the policy stance via changes in the policy rate, greater emphasis on the communication strategy of the central bank and improving in–house capacity to forecast inflation and assess the state of the economy.

Advanced and emerging economies went through a similar process, starting in the late 1970s with the Bundesbank, and especially with the introduction of IT in New Zealand and Canada in the 1990s.[2] This resulted in greater focus on anchoring inflation expectations, on understanding the sources of inflation to distinguish inflationary increases stemming from aggregate demand from the effects of supply–side shocks (and react accordingly), while also allowing to respond to deviations in output from its potential. The transformation of policy was accompanied, though with a lag, by advances in macro theory, namely the emergence of the new-Keynesian macro literature, which helped lay the the theoretical foundations for the new regimes.[3]

The questions we address in this paper is the following: do the lessons from advanced and emerging markets extend to developing countries, so that these countries should follow the same monetary policy prescription? or are there structural features, that distinguish low–income from middle and high–income countries, that call for a different monetary policy? More generally, as developing countries modernize their policy framework, what can we expect about the properties of inflation in these countries? Will inflation behave in similar ways to those observed in other countries, or will they have different properties because of the different structure of these economies?

We are particularly interested in the role of food prices. One of the insights of the new-Keynesian literature is that policy should concern itself with stabilizing inflation, because movements in inflation reflect real distortions stemming from nominal rigidities.[4] Specifically, the central bank should focus on the inflation rate of goods and services in which prices are sticky. This lends support to the view that core inflation, rather than

[1]Our focus here is on countries with an independent monetary policy.

[2]See Bernanke et al (2001).

[3]See Clarida, Gali and Gertler (1998) and Goodfriend and King (1997).

[4]See Woodford (2003).

headline, should be the primary concern of policy makers.[5] By extension, real shocks that result in movements in goods with flexible prices (food, fuel) should be accommodated, even if they result in increases in headline inflation. In addition, in the canonical new–Keynesian model, there is a "divine coincidence" between the objective of core inflation stabilization and the objective of stabilization output at its potential value, thus eliminating any potential conflict between these two objectives of policy.[6] Many caveats have emerged, e.g., stemming from the presence of nominal or real wage rigidities, or in the open economy context from potential trade externalities. Yet these are of general importance and not specific to low–income countries.

One of the main differences, if not the main difference, between low– and middle– and high–income countries, is the observation that the food sector (agriculture) represents a larger share of the economy and that consumers spend a larger share of their total expenditure on food consumption. This is related to existence of a subsistence level of food consumption, a minimum level below which food consumption cannot decline. When countries are poor, i.e., they have a low level of aggregate productivity, they must allocate a larger fraction of their labor (and capital) to help satisfy the subsistence need for food. As countries develop, and move away from subsistence, the economy is able to allocate a smaller fraction of total resources to the food sector, thus allowing the relative expansion of other sectors (manufacture and services). This is the process of structural transformation.

Structural transformation has potential implications for inflation and monetary policy, which we study here. First, because the food sector is a flexible price sector, structural transformation affects the aggregate importance of sticky prices in the economy: the sticky price sectors tends to be smaller. Second, subsistence lowers the economy–wide substitutability between food and other sectors, so that potentially larger changes in relative prices (in this case the relative price of food) are needed. Third, depending on the monetary policy regime, inflation in low–income countries is likely to be more volatile than in developed countries, with a larger share of that volatility coming from movements in the relative price of food and arising from shocks to productivity in the agricultural sector. Fourth, the supply–sided nature of inflation at earlier stages of inflation is also likely to imply a negative correlation between inflation and output. Finally, alternative policy prescriptions may have radically different macroeconomic implications at different stages of development.

To address these questions, we introduce subsistence in a simple new-Keynesian model with a flexible price sector (food) and a sticky price sector (non–food), an extension we believe has not received sufficient attention in the macro literature, and study its properties. The only real disturbance is a shock to productivity in the food sector. The model features structural transformation (at the steady state): changes in aggregate productivity result in both an increase in income and a decrease in the share of the food sector in the economy (employment) and in consumption. In addition to its effects on consumption and employment shares, subsistence also affects several elasticities in the model. First, it lowers (increases)

[5]See Aoki (2001).

[6]See Blanchard and Gali (2007).

the income and price elasticity in the food (non–food) sector. Second, it reduces the inter–temporal elasticity of substitution. Third, it reduces the effects of changes in food prices on household behavior (labor supply and inter-temporal decisions). All of these features contribute to amplifying the effects of productivity shocks in the food sector on the relative price of food, at earlier stages of development.

We then calibrate the model, and run simulations to study the properties of inflation across the development spectrum. The calibration of the subsistence parameter is such that the model encompasses the US and a group of African countries (to match the (income per capita, food share) pair in these countries). We now assume that the economy is subject to two shocks: the food productivity shock mentioned earlier, and a shock to monetary policy that introduces a temporary deviation between the flexible and the sticky price equilibrium of the model. We calibrate the volatility of the two shocks such that it reproduces the volatility of inflation and the volatility of the relative price of food in the US. We then study what are the volatilities of these two variables when steady state aggregate productivity is such that the model mimics the structure of the African countries.

We find that a simple model of structural transformation as ours helps make sense of the stylized facts of inflation across levels of development. Simulations of the model match the relative decomposition of inflation that we observe in the data (at business cycle frequency). About 50 percent of the volatility of inflation in low–income countries is accounted for by changes in the relative price of food, compared with 3 percent in the US. We also find that the model generates the right co-movement between inflation and output. Low–income countries tend to have negative inflation/output correlations; as countries develop, the correlation becomes increasingly positive. [We need to confirm the quantitative performance of the model in this respect.]

The model also generates inflation in low–income countries that is about 60 percent higher than the volatility in the US. This falls short of the volatility observed in the data: inflation in African countries is about 300 percent more volatile than in the US. The model also predicts that changes in the relative price of food should be about 25–45 percent more volate in low–income countries; in the data for Africa, these are 200 percent more volatile. In sum, the model goes some way toward accounting for the properties of inflation in the data.

Finally, we also pursue some welfare analysis for both instrument (Taylor) and targeting rules, to study the implications of structural transformation for monetary policy design. We focus, in particular, on the issue of the appropriate measure of inflation for policy analysis in poor countries. Our analysis reveals that, despite the presence of subsistence, the appropriate measure corresponds to the non-food (sticky-price) inflation. That is, the "divine coincidence" of Blanchard and Gali (2007) still holds and therefore stabilizing this measure of inflation ensures stabilizing the welfare-relevant measure for output. However, our analysis also shows that subsistence raises the stakes for monetary policy: targeting the wrong inflation measure is more costly, from a welfare perspective, in poor countries than in rich countries.

In addition to the large literature on new–Keynesian macro in closed and open economies, our paper is related to two separate literatures. First, it is related to the literature on structural transformation: Caselli and Coleman (2001), Kongsamut et al (2001), Ngai and Pissarides (2007), Rogerson (2008), among others. It is also related to a recent body of work that focuses on inflation in emerging markets and low income countries, and the role of food: Catao and Chang ((2010) and (2012)), Anand and Prasad (201), Walsh (2010), IMF (2011), Portillo and Zanna (2012), Adam et al (2012), Andrle et al (2013). Anand and Prasad come closest to our specification, since they also study subsistence. However, in our view, they do not provide an adequate treatment of this issue.

The paper is organized as follows...

II. Stylized Facts about Food Shares, Inflation Volatility and Income

We present some evidence on the link between income per capita, food shares and the volatility of inflation and the relative price of food. To do so, we collect data for 66 countries for the period 1995–2011.[7] The data set comprises 28 OECD countries, 23 sub–Saharan African countries and 15 non–OECD countries (mostly emerging markets).

Figure (1) plots the weight of food in the consumer price index against the average income per capita in PPP dollars over the period 2001-2010.[8] Income per capita for the US has been normalized to one. Countries with lower income per capita have a larger share of consumer expenditure that goes to food. Note that the relation appears convex: the food share increases by more as income per capita decreases. This is captured by the good fit of the log–trend (the red dashed line). We also show the relation between income per capita and the share of food implied by the model we present below (the black dashed line).

Figure (2) plots the standard deviation of headline inflation (quarter on quarter) against income per capita. The focus here is on business-cycle frequency, and we use a band-pass filter that retains frequencies between 6 and 32 quarters.[9] Note that there is also a negative relationship: countries with lower income per capita have inflation rates that are considerably more volatile. Figure (3) plots the volatility of changes in the relative price of food (the price of food relative to the CPI), also at business–cycle frequency, against income per capita. A similar relation holds. Finally Figure(4) plots the correlation between headline inflation and output (also at business cycle frequency) against income per capita. There is a positive relation between this correlation and income per capita, starting from a negative value.

We now present a model consistent with some of these features.

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[7]The data for some countries (especially low–income countries) starts in 2000.

[8]The data is from the World Bank set of indicators.

[9]Lower frequency movements in inflation are usually interpreted as changes in the explicit or implicit inflation target of the country, the choice of which is beyond the scope of our paper. We also drop higher frequency movements to remove any noise or leftover seasonality.

III. THE MODEL

A. The consumer

The representative consumer chooses a consumption aggregate c_t^*, labor effort n_t and holdings of a nominal bond B_{t+1} to maximize lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(ln(c_t^*) - \frac{n_t^{1+\psi}}{1+\psi} \right),$$

subject to the budget constraint:

$$P_{F,t}c_{F,t} + P_{N,t}c_{N,t} + B_{t+1} = W_t n_t + \Pi_{F,t} + \Pi_{N,t} + R_{t-1}B_t,$$

and the composition of c_t^*:

$$c_t^* = Z\left(c_{F,t} - \bar{c}_F\right)^{\alpha_F} c_{N,t}^{1-\alpha_F}. \tag{1}$$

The pair ($c_{F,t}$, $c_{N,t}$) denotes consumption of food and non–food, valued at nominal prices ($P_{F,t}$, $P_{N,t}$). W_t is the nominal wage, ($\Pi_{F,t}$, $\Pi_{N,t}$) are profits from food and non–food sector, and R_{t-1} is the gross nominal interest rate paid on bond B_t. The parameter $\bar{c}_F$ indicates the subsistence level of food consumption, a threshold below which food consumption cannot decline. Z is a scaling parameter that takes the value $(\alpha_F)^{-\alpha_F}(1-\alpha_F)^{-(1-\alpha_F)}$ to simplify notation.

Utility maximization leads to the following first–order conditions:

$$c_t^{*-1} = \beta E_t\left\{\frac{R_t}{\pi_{t+1}^*} {c_{t+1}^*}^{-1}\right\}, \tag{2}$$

$$n_t^{\psi} = w_t^* {c^*_t}^{-1}, \tag{3}$$

$$c_{F,t} = \bar{c}_F + \alpha_F \left(\frac{P_{F,t}}{P_t^*}\right)^{-1} c_t^* = \bar{c}_F + \alpha_F {p_{F,t}^*}^{-1} c_t^*, \tag{4}$$

$$c_{N,t} = (1-\alpha_F)\left(\frac{P_{N,t}}{P_t^*}\right)^{-1} c_t^* = (1-\alpha_F){p_{N,t}^*}^{-1} c_t^*, \tag{5}$$

where P_t^* is a price index that arises naturally from the utility maximization:

$$P_t^* = P_{F,t}^{\alpha_F} P_{N,t}^{1-\alpha_F}, \tag{6}$$

and ($\pi_t^* = P_t^*/P_{t-1}^*$, $w_t^* = W_t/P_t^*$) are the gross inflation rate and the real wage relative to that price index.

Note that c_t^* and P_t^* do not correspond to the aggregate consumption and the consumer price index that are actually measured. We define measured consumption c_t as follows:

$$c_t = p_F c_{F,t} + p_N c_{N,t}, \tag{7}$$

where (p_F, p_N) denote the steady–state prices of food and non–food relative to the measured price index $(P_F/P, P_N/P)$. The latter is given by:

$$P_t = \left(\frac{c_{F,t}}{c_t}\right) P_{F,t} + \left(\frac{c_{N,t}}{c_t}\right) P_{N,t}. \tag{8}$$

By now the choice of notation should be clear. Variables with an asterisk (c_t^*, P_t^*, π_t^*, w_t^*, $p_{F,t}^*$, $p_{N,t}^*$) are relevant for consumer decisions but are not actually observed. We will refer to these as *notional*, in contrast with their observed counterparts (c_t, P_t, π_t, w_t, $p_{F,t}$, $p_{N,t}$), where $\pi_t = P_t/P_{t-1}$, and $w_t = W_t/P_t$.

B. The Food Sector

The food sector features perfect competition and flexible prices. Production is given by:

$$y_{F,t} = A_{F,t}(An_{F,t})^{\alpha} K_F^{1-\alpha}, \tag{9}$$

where K_F is the level of capital in the sector, chosen at the steady state, $n_{F,t}$ is the demand for labor in the food sector, α is the labor share, A is the level of labor augmenting productivity (common to the entire economy), and $A_{F,t}$ is food–sector specific productivity.[10] Profit maximization results in the following labor demand condition:

$$\frac{w_t}{p_{F,t}} = \alpha {n_{F,t}}^{\alpha-1} A_{F,t} A^{\alpha} K_F^{1-\alpha}. \tag{10}$$

C. The non–Food Sector

The non–food sector is composed of a continuum of monopolistic competitors, each providing a variety $y_{N,t}(i)$, with $i \in [0, 1]$. Varieties are combined by consumers into a Dixit–Stiglitz aggregate:

$$y_{N,t} = \left[\int y_{N,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{11}$$

where ϵ is the elasticity of substitution between varieties. Cost minimization results in the following demand for variety (i):

$$y_{N,t}(i) = \left(\frac{P_{N,t}(i)}{P_{N,t}}\right)^{-\epsilon} y_{N,t},$$

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[10]For simplicity we assume the depreciation rate is zero.

where $P_{N,t}(i)$ is the price charged by firm (i) and $P_{N,t}$ is the price index for the entire sector:

$$P_{N,t} = \left[\int P_{N,t}(i)^{1-\epsilon} di \right]^{\frac{1}{1-\epsilon}}.$$

Production of non–traded varieties is given by:.

$$y_{N,t}(i) = (An_{N,t}(i))^{\alpha} K_N^{1-\alpha}. \tag{12}$$

As in Calvo (1983), firms are not allowed to change their prices unless they receive a random signal. The probability that a given price can be re–optimized in any particular period is constant and equal to $(1-\theta)$. If firm i gets the random signal at time t, it chooses a reset price $\overline{P}_{N,t}(i)$ to maximize its discounted stream of expected profits:

$$Max\ E_t \left[\Sigma_{j=0}^{\infty} (\beta\theta)^j \lambda_{t+j} \left(\left(\frac{\overline{P}_{N,t}(i)}{P_{N,t+j}} \right)^{-\epsilon} y_{N,t+j} \left(\overline{P}_{N,t}(i) - MC_{N,t+j}(i)(1-\iota) \right) \right) \right],$$

where λ_{t+j} is the stochastic discount factor ($\lambda_{t+j} = \frac{c_t^*}{c_{t+j}^*}$), ι is an employment subsidy, and $MC_{N,t}(i)$ is firm i's nominal marginal cost of producing one additional unit of variety i:

$$MC_{N,t}(i) = \frac{W_t}{\alpha n_{N,t}(i)^{\alpha-1} A^{\alpha} K_F^{1-\alpha}}. \tag{13}$$

Profit maximization results in the following reset price (the same for all firms that are re-setting):

$$\overline{P}_{N,t} = \frac{\epsilon}{\epsilon-1}(1-\iota) \frac{E_t \left[\Sigma_{j=0}^{\infty} (\beta\theta)^j \lambda_{t+j} \left[\left(\frac{1}{P_{N,t+j}} \right)^{-\epsilon} y_{N,t+j} MC_{N,t+j}(t) \right] \right]}{E_t \left[\Sigma_{j=0}^{\infty} (\beta\theta)^j \lambda_{t+j} \left[\left(\frac{1}{P_{N,t+j}} \right)^{-\epsilon} y_{N,t+j} \right] \right]}, \tag{14}$$

where $(MC_{N,t}(t), MC_{N,t+1}(t), ...)$ denotes the sequence of expected nominal marginal costs for those firms that reset prices at time t.

The aggregate price index in the non–traded sector $P_{N,t}$ is the weighted sum of those prices that were reset (of which there is mass $(1-\theta)$) and those that were not reset (of which there is mass θ and which can be approximated with last period's price index $P_{N,t-1}$):

$$P_{N,t} = \left[(1-\theta)\overline{P}_{N,t}{}^{1-\epsilon} + \theta P_{N,t-1}{}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}. \tag{15}$$

D. Goods and labor market equilibrium

The description of the model is complete with the clearing of the food, non–food and labor markets:

$$c_{F,t} = y_{F,t}, \quad c_{N,t} = y_{N,t}, \quad n_{F,t} + n_{N,t} = n_t, \quad \text{and} \quad n_{N,t} = \int n_{N,t}(i)\, di. \qquad (16)$$

We also define a real GDP measure y_t, given by:

$$y_t = y_{F,t} + y_{N,t}. \qquad (17)$$

IV. MODEL PROPERTIES

A. The steady state

As mentioned in the introduction, the model's structural transformation features are present at the steady state. We now analyze those features and some of their implications.

First, we assume $\iota = 1/\epsilon$, which removes market power by monopolistic producers in the non–food sector. We set the relative price of food (p_F), the gross inflation rate (π), and food–sector specific total factor productivity (A_F) to 1:

$$p_F = \pi = A_F = 1.$$

Setting $p_F = 1$ implies all other relative prices (p_N, p^*_F,, p^*_N) also equal one at steady state, and it ensures notional and measured real wages are equal: $w^* = w$. Setting $\pi = 1$ implies gross notional inflation π^* is also equal to one.

The normalization of relative prices leads to a simple linear relation between c and c^*, which is given by combining equations (4), (5) and (7):

$$c = \bar{c}_F + c^*. \qquad (18)$$

Firms chose steady–state values of capital by equating the marginal value of capital with the steady state rental rate $1/\beta - 1$, which yields the following condition:

$$(1-\alpha)K_F{}^{-\alpha}A^\alpha n_F^\alpha = (1-\alpha)K_N{}^{-\alpha}A^\alpha n_N{}^\alpha = (1/\beta - 1). \qquad (19)$$

Combining condition (19) with labor demand in each sector (eqs. (10) and (13)) yields a linear relation between real wages and aggregate labor productivity, similar to the neoclassical growth model:

$$w = \left[\frac{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}{(1/\beta - 1)^{1-\alpha}} \right]^{1/\alpha} A = XA, \tag{20}$$

We combine conditions (19),(20) with equations (3), (9), (12), (16), and (18) to yield a relation between measured consumption c and aggregate labor productivity A:

$$\alpha^{\psi} c^{\psi} (c - \bar{c}_F) = X^{1+\psi} A^{1+\psi}.$$

The presence of a subsistence threshold for food consumption $\bar{c}_F$ makes the relation non–linear, though it approximates linearity as labor productivity increases. The elasticity is less than one, so that one percent increase in A results in an increase in c that is less than one percent, with the elasticity getting closer to one as A increases.

The non–linearity results from the effects of subsistence on labor supply, which can be shown by combining equations (3), (18) and (20):

$$n^{\psi} = X \frac{A}{c - \bar{c_F}}.$$

When consumption is close to subsistence, income effects dominate substitution effects in the supply of labor, and agents work more. As productivity and income increase, agents reduce their labor supply, which allows them to enjoy more leisure though at the costs of smaller increases in total consumption.

Changes in aggregate labor productivity also have implications for the share of expenditure and labor that is allocated to the food sector, which we denote as γ_F. Combining equations (4) and (18) yield the following equation for γ_F:

$$\gamma_F = \frac{n_F}{n} = \frac{c_F}{c} = \frac{(1-\alpha_F)\bar{c}_F + \alpha_F c}{c}, \quad \gamma_F > \alpha_F. \tag{21}$$

When $\bar{c}_F > 0$, γ_F converges to α_F (from above) as steady state consumption increases. Not surprisingly the relation between γ_F and c depends on the value of $\bar{c}_F$. Figure (5) shows this relation for different values of $\bar{c}_F$. The higher the level of subsistence, the greater the impact of income (consumption) on the food share. We will use this relation to calibrate $\bar{c}_F$ from the data.

Finally we define four new parameters that will be useful when presenting the log-linearized version of the model:

$$\xi = \frac{\gamma_F}{1-\gamma_F} \geq \frac{\alpha_F}{1-\alpha_F}, \quad \phi = \xi(1-\alpha_F) - \alpha_F \geq 0,$$

$$\delta = \frac{\alpha_F}{\gamma_F} \leq 1, \quad and \quad \sigma = \frac{1-\alpha_F}{1-\gamma_F} \geq 1.$$

In the presence of subsistence, as steady state consumption increases, ξ converges toward $\alpha_F/(1-\alpha_F)$ (from above), ϕ converges toward zero (from above), and δ and σ converge toward one (the former from below and the later from above).

B. Log–linear approximation to the model's solution

We now present the log-linearized version of the model. We focus on the features that are brought about by the existence of a subsistence threshold for food consumption, which in the log–linear version is captured by $\gamma_F > \alpha_F$ and the values of the related parameters (ξ, ϕ, δ, and σ). We also describe how these features change as the economy develops.

Combining equations (1), (2), (6), (7), (8), (16), and (17) we obtain a forward–looking IS equation:

$$\hat{y}_t = -\sigma^{-1}\left[\hat{R}_t - \hat{\pi}_{t+1} + \phi\Delta\hat{p}_{F,t+1}\right] + \hat{y}_{t+1}, \tag{22}$$

where a hat on top of a variable ($\hat{*}$) denotes percent deviations from steady state. The presence of subsistence introduces two modifications in this equation. First, the inter–temporal elasticity of substitution for output is given by σ^{-1}, which is less than one when $\gamma_F > \alpha_F$ ($\bar{c}_F > 0$). This is lower than the value that would obtain if $\bar{c} = 0$ (unity). This modification is related to the difference between the consumption aggregate that matters for private sector decisions (c_t^*) and measured consumption (c_t), with the former always smaller than the later. The second difference concerns the presence of the expected change in relative food prices ($\Delta\hat{p}_{F,t+1}$). When $\gamma_F > \alpha_F$, there is a difference between the inflation rate that matters for private sector decisions ($\hat{\pi}_t^*$) and the measured headline inflation rate ($\hat{\pi}_t$); this difference equals $\phi\Delta\hat{p}_{F,t}$. As the economy develops, the inter–temporal elasticity of substitution converges to one, and the direct effect of changes in expected relative food prices in inter–temporal decisions tends to disappear.

Combining equations (1), (3), (6), (7), (8), (16), and (17) we obtain the Frisch labor supply condition:

$$\psi\hat{n}_t = \hat{w}_t + \phi\hat{p}_{F,t} - \sigma\hat{y}_t \tag{23}$$

The presence of subsistence introduces the relative price of food as one of the direct determinants of labor supply, in addition to the real wage and output. This reflects the fact that it is w_t^* that matters for households and not w_t. This distinction lowers the substitution effect in labor supply relative to changes in $\hat{w}_t$: changes in $\hat{w}_t$ that are due to movements in $\hat{p}_{F,t}$ will have a smaller effect on labor supply. Subsistence also raises the elasticity of labor supply to changes in output (given by σ). As in the previous equation,the direct role of $\hat{p}_{F,t}$ tends to disappear as the economy develops.

Combining equations (1), (4), (6), (7), (8), (16), and (17) yields the demand equation for food:

$$\hat{y}_{F,t} = -\delta\hat{p}_{F,t} + \delta\hat{y}_t \tag{24}$$

The parameter δ now captures both price and income elasticity in the demand for food. Subsistence reduces both elasticities, which would equal one if $\bar{c}_F = 0$. Both parameters converge toward unity as steady state consumption increases. Similar algebra yields the demand for non–food:

$$\hat{y}_{N,t} = \delta\xi\hat{p}_{F,t} + \sigma\hat{y}_t \tag{25}$$

Price elasticity in the demand for non–food (to the relative price of food) is greater in the presence of subsistence, and income elasticity is higher than one.

The rest of the equations of the model are standard. Supply in both sectors is derived by combining equations (9) and (10), and (12) and (13):

$$\frac{1-\alpha}{\alpha}\hat{y}_{F,t} = \hat{p}_{F,t} + \frac{1}{\alpha}\hat{A}_{F,t} - \hat{w}_t, \tag{26}$$

$$\frac{1-\alpha}{\alpha}\hat{y}_{N,t} = -\xi\hat{p}_{F,t} - \hat{\mu}_{N,t} - \hat{w}_t. \tag{27}$$

where $\hat{\mu}_{N,t}$ denotes changes in markups in the non–food sector. After linearizing equations (14) and (15), inflation in the non–food sector is determined by a new–Keynesian Phillips curve:

$$\hat{\pi}_{N,t} = -\kappa\hat{\mu}_{N,t} + \beta\hat{\pi}_{N,t+1}, \tag{28}$$

where κ is given by:

$$\kappa = \frac{(1-\theta\beta)(1-\theta)\alpha}{\theta[\alpha + \epsilon(1-\alpha)]}.$$

Note that κ differs from the standard derivation found in most of the literature, e.g. in Galí (2012).[11] Overall inflation is given by:

$$\hat{\pi}_t = \hat{\pi}_{N,t} + \xi\Delta\hat{p}_{F,t}. \tag{29}$$

The model is complete with the definition of aggregate GDP and the relation between aggregate employment and output:

$$\hat{y}_t = \gamma_F\hat{y}_{F,t} + (1-\gamma_F)\hat{y}_{N,t} = \alpha\hat{n} + \gamma_F\hat{A}_{F,t}. \tag{30}$$

C. Flexible price solution and gap presentation

It is helpful to distinguish between movements in output that would hold if prices were flexible (potential output) and movements in output due to the presence of nominal rigidities (the output gap), with the latter directly related to inflationary pressures in the sticky–price sector:

$$\hat{y}_t = \hat{y}_t^{flex} + \hat{y}_t^{gap}.$$

[11] This stems from the presence of decreasing returns to scale in labor, which makes marginal costs vary across different cohorts of firms (depending on when they set their price). An adjustment is required to write the Phillips curve in terms of average marginal costs (see Sbordone 2001).

This distinction can also be extended to other real variables such as the relative price of food:

$$\hat{p}_{F,t} = \hat{p}^{flex}_{F,t} + \hat{p}^{gap}_{F,t}.$$

We first solve for $\hat{y}^{flex}_t$ and $\hat{p}^{flex}_{F,t}$, by using the system (23)-(27) and (30), and imposing $\hat{\mu}_{N,t} = 0$:

$$\hat{y}^{flex}_t = \Phi_y \hat{A}_{F,t},$$
$$\hat{p}^{flex}_{F,t} = -\Phi_{p_f} \hat{A}_{F,t},$$

where:

$$\Phi_y = \frac{\left[\gamma_F\phi + [1 + \frac{1-\alpha}{\alpha}\delta]\xi\frac{\gamma_F(1+\psi)}{\alpha}\right]}{\left[\frac{1-\alpha}{\alpha}[\sigma-1]\phi + [1+\frac{1-\alpha}{\alpha}\delta]\xi\Upsilon\right]},$$

$$\Phi_{p_f} = \frac{\frac{\gamma_F}{\alpha}\left[\Upsilon - [\sigma-1]\frac{1-\alpha}{\alpha}(1+\psi)\right]}{\left[\xi[1+\frac{1-\alpha}{\alpha}\delta]\Upsilon + [\sigma-1]\frac{1-\alpha}{\alpha}\phi\right]},$$

$$\Upsilon = \frac{\psi + 1 - \alpha}{\alpha} + \sigma.$$

The presence of subsistence raises both Φ_y and Φ_y. Note that, when $\bar{c}_F = 0$, these two terms reduce to $\Phi_y = \alpha_F$ and $\Phi_{p_f} = (1 - \alpha_F)$.

We then use the system (22)-(30) and the two flexible–price solutions to reduce the model to a system of two equations (the forward–looking IS curve and the Phillips curve) and two unknowns (the output gap and the inflation of non–food):

$$\hat{y}^{gap}_t = -\Theta[\hat{R}_t - \hat{\pi}_{N,t+1} - \hat{r}^{flex}_t] + \hat{y}^{gap}_{t+1}, \tag{31}$$

$$\hat{\pi}_{N,t} = \kappa_y \hat{y}^{gap}_{N,t} + \beta\hat{\pi}_{N,t+1}, \tag{32}$$

where:

$$\Theta = ...,$$

and

$$\kappa_y = \kappa\frac{\left[\frac{1-\alpha}{\alpha}[\sigma-1]\phi + [1+\frac{1-\alpha}{\alpha}\delta]\xi\Upsilon\right]}{\left[\gamma_F\phi + [1+\frac{1-\alpha}{\alpha}\delta]\xi(1-\gamma_F)\right]} = \kappa\Gamma.$$

The rate $\hat{r}^{flex}_t$ is the natural rate of interest, the interest rate that would hold under flexible prices. It is given by:

$$\hat{r}^{flex}_t = \Phi_{r,1}\hat{A}_{F,t} + \Phi_{r,2}\hat{A}_{F,t-1},$$

where $(\Phi_{r,1}, \Phi_{r,2})$ have been derived by assuming that technology in the food sector follows a autoregressive process of order 2:

$$\hat{A}_{F,t} = (1+\rho_A)\hat{A}_{F,t-1} - (\rho_A + \varrho)\hat{A}_{F,t-2} + \varepsilon_{A_F,t};$$

Having solved for the flexible price equilibrium and the gap presentation, we can explain headline inflation as a combination of movements in non–food inflation, movements in the gap component of relative food prices and movements in the flexible price component of the latter variable:

$$\hat{\pi}_t = \hat{\pi}_{N,t} + \xi \Delta \hat{p}_{F,t}^{gap} + \xi \Delta \hat{p}_{F,t}^{flex},$$

with $\hat{p}_{F,t}^{gap}$ related to movements in the output gap as follows:

$$\hat{p}_{F,t}^{gap} = \Omega \hat{y}_t^{gap},$$

$$\Omega = \Gamma \frac{\left[\gamma_F \Upsilon - [\sigma - 1]\frac{1-\alpha}{\alpha}(1-\gamma_F)\right]}{\left[\xi[1 + \frac{1-\alpha}{\alpha}\delta]\Upsilon + [\sigma - 1]\frac{1-\alpha}{\alpha}\phi\right]}.$$

V. MODEL SIMULATIONS

We now proceed to simulate the model to compare impulse response functions and inflation properties across the development spectrum. We limit the analysis to two polar cases: a poor and a rich country. The first case is meant to capture the US and the second one a typical African country. It is necessary to calibrate the model to undertake this analysis, which we describe in the next sub–section. Note that the calibration is the same for both country types (rich and poor). The only difference between the two specifications is the level of total factor productivity, which we adjust so that the two types have similar income per capita as in the data.

Before going further it is necessary to make an assumption about the monetary policy rule we will use when we simulate the model. We assume that the central bank follows a monetary policy rule that helps implement the flexible price equilibrium while also allowing for shocks to aggregate demand:

$$\hat{R}_t = (\hat{r}_t^{flex} + \xi \Delta \hat{p}_{F,t+1}^{flex}) + \varsigma \hat{\pi}_{N,t} + u_{MP,t}, \tag{33}$$

$$u_{MP,t} = \rho_{MP} u_{MP,t-1} + \varepsilon_{MP,t}.$$

When $u_{MP,t} = 0$, this rule helps implement the flexible price equilibrium. However, the shock $\varepsilon_{MP,t}$ will generate a shock to aggregate demand. This rule provides a simple way of disentangling the effects on inflation stemming from shocks to the supply side of the economy, which will not depend on features of the model related to sticky prices, and the effects of shocks to aggregate demand, which do depend on those features.

A. Calibration

The calibration is summarized in Table 1. The choice of $(\alpha_F, \bar{c}_F)$ is such that the model encompasses the food share observed in the US and the median food share in a group of 16 African countries for which there is data (for this share), given their differences in income per capita. This can be seen by restating equation (21) for the US (rich country) and the median African country (poor):

$$\gamma_{F,R} = (1-\alpha_F)\bar{c}_F + \alpha_F, \quad \gamma_{F,P} = \frac{(1-\alpha_F)\bar{c}_F}{y_P} + \alpha_F,$$

where we have normalized consumption (income) in the rich country to 1. Income per capita in this group of African countries over the period (2001–2010) is 2.9 percent that of the US ($c_P = y_P = 0.029$), while the food shares ($\gamma_{F,R}$, $\gamma_{F,P}$) are (0.08, 0.42), respectively. Given these values, the choice of (α_F, $\bar{c}_F$) ensures the above relation holds. The relation between food share and income generated by this calibration is shown in Figure (1). Note that it does a reasonably good job of replicating the relation found in the data, though it tends to predict a lower food share for middle income countries than what is actually observed.

The choice of (α, θ, ψ, ς) is standard in the new–Keynesian literature when these models are applied to the US.[12]. The parameters (ρ_{MP}, ρ_A) are chosen to match the observed persistence of the Fed Funds Rate and changes in the relative price of food in the US. Finally the standard deviations for the two shocks (σ_{MP}, σ_{A_f}) is chosen to match the volatility of inflation and the relative price of food in the US.

B. Impulse response Analysis

An exogenous monetary policy loosening ($\varepsilon_{MP,t} < 0$)

We first study the effect of an exogenous monetary policy loosening, which is captured by a negative shock to $\varepsilon_{MP,t}$. The effects of the shock for the poor and the rich country are shown in Figure (6). In models where one sector has flexible prices and the other has sticky prices, it is not surprisingly the sector with flexible prices that displays the biggest increase in prices following a monetary policy shock. This is reflected in the increase in the relative price of food. Note that relative food prices in the poor country increase by more than in the rich country, by about 2.5 and 2 percent, respectively. Despite the price stickiness, non–food inflation also increases. Again, the poor country experiences a larger increase in food inflation than the rich country, although the difference is small. Since the poor country has a much larger food share, headline inflation increases by almost twice as much as the rich country. Expansionary monetary policy results in an overall expansion of output. There are sectoral differences however: the increase in the relative price of food translates into an expansion of the non–food sector and a contraction of the food sector, with the expansion larger (and the contraction smaller) in the poor country. The overall expansion is higher in the rich country however, because of composition effects (larger non–food sector).

A negative shock to food production ($\varepsilon_{A_F,t} < 0$)

We now study the effect of a one percent decrease in productivity in the food sector $\varepsilon_{A_F,t}$. Note that the decrease in productivity amplifies over time: food productivity is close to 5

[12]See Gali (2008),...

percent smaller after 20 quarters. Given the reduced substitutability in the economy—because of subsistence—the relative price of food increases by more in the poor country. This reduced substitutability is also reflected at the sectoral level: food production contracts by less, at the cost of a large contraction in the non–food sector. As in this case the interest rate rule helps implement the optimal policy prescription, non–food inflation does not increase in both cases. Because of the large food share however, headline inflation increases by more in the poor country.

A negative shock to food production ($\varepsilon_{A_F,t} < 0$) under headline inflation targeting

If monetary policy targets headline inflation ($\hat{\pi}_t = 0$), then the increase in the relative price of food described above must be compensated by a decrease in non–food inflation. In the presence of sticky prices, this can only come about via a demand–driven contraction in non–traded food production, which adds to the negative effects of the lower food productivity and results in a larger decrease in overall output.

In the case of the rich country, the effect is barely noticeable because of the small size of the food sector. A smaller decrease in non–food inflation is needed, which requires a tiny non–food contraction. In the poor country instead, the effect of targeting headline inflation is much larger because of the larger weight of food in the economy. Controlling headline inflation requires a larger decline in non–food prices and a larger decline in non–food sector. The effect on aggregate output is therefore larger.

The lesson from this latter impulse response is that the choice of inflation target is more important in the poor country than in the rich country, even though price stickiness is more relevant (affects a larger share of goods) in the rich country.

C. Second order moments

We now simulate the model and compare the model–generated second order moments to those observed for the US and the median observation in our group of African countries. The data covers the period 1995:I to 2011:IV. We simulate the model for a period of 68 observations (as in the data), apply a bandpass filter to keep business–cycle frequency fluctuations, and then calculate the standard deviation for headline inflation, non–food inflation and changes in the relative price of food. We do this 100 times and keep the average value and the 95 percent confidence interval (shown in brackets).

We choose the volatility of the two shocks to match the volatility of inflation and changes in the relative price of food for the US. We then adjust steady state aggregate productivity to move the model toward the poor economy and compare the volatility figures generated by the model in that specification to the volatility figures we observe in Africa. We believe this is a straightforward way of assessing the direct effect that structural transformation has on the properties of inflation.

We proceed sequentially: we first choose the volatility of productivity in the food sector to match the volatility of relative food prices (in the US) and compare across specifications. We then choose the volatility of monetary policy shocks to match the volatility of non–food inflation. Finally, we combine both shocks.

Table 1 displays the results of the model when each type of shock is simulated separately, as well as the standard deviations found in the data. First, it is worth stressing that headline and non–food inflation is considerably more volatile in Africa than in the US. The ratio between the two standard deviations is about 4 for headline and 2.2 for non–food. Relative food prices are also more volatile with a ratio of about 3. This is consistent with the cross–country evidence observed in Figures (2) and (3).

When only food productivity shocks are included, the model predicts that relative food prices should be 45 percent more volatile in the poor country than in the rich country. This is consistent with the analysis based on the impulse response. When only monetary policy shocks are included, the model fails to generate increased volatility in either non–food inflation or relative food prices. However, different weights in the consumer price index imply that inflation in poor countries is about 30 percent more volatility. We infer from this result that while structural transformation amplifies the effects of food shocks on relative food prices, it does not have the same effect under monetary policy shocks. In both cases however, structural transformation unequivocally raises the volatility of inflation, although by less than what is observed in the data.

Table 2 shows the results of the simulation when both shocks are included. In this case, relative food prices are about 25 percent more volatile in the poor country, and headline inflation is about 57 percent more volatile. Comparing the decomposition of inflation into the two components, the model gets the relative importance of each factor about right. There is one important difference between the model and the data, however. In the data, there is a slight negative correlation between $\hat{\pi}_{N,t}$ and $\Delta\hat{p}_{F,t}$, whereas the opposite is true in the model.

A notable finding is that, when hit with both shocks, the model can replicate the correlation between output and inflation that is observed in the data (at annual frequency) for both the rich and the poor country. As inflation is driven to some extent by food supply shocks, an food prices account for a sizable share of the CPI, the correlation between output and inflation is close to zero for the median African country. In the US instead, the correlation is much higher and closer to one, as food price shocks play a negligible role in inflation dynamics and demand shocks dominate.

In sum, the model can help make sense of some of the properties of inflation that are observed in the data, although it falls short in others. This should not be considered as a failure of the model however. There are many other reasons why inflation and relative food prices are more volatile in poor countries. Some have to do with aggregate demand management: central banks in developing countries ave been less focused—at least until now—on inflation stabilization than their counterparts in developed countries. It is precisely the transition toward more active regimes that motivates the analysis in this paper, so it is not surprising that the model generates less non–food inflation volatility than what has been observed in recent history.

A different reason is that there are other aspects of structural transformation we have not analyzed. For example, technology adoption is also endogenous to the level of development. Countries at lower levels of development have production technologies in the food sector that are more vulnerable to exogenous factors such as the weather. For a given shock, the endogenous choice of technology will result in more volatile food prices. We leave the modelling of this technology adoption for future research.

VI. Welfare Analysis

In this section, we conduct some policy evaluations by computing the welfare cost of different instrument (Taylor) and targeting rules for our parameterizations of a rich and a poor country. We analyze Taylor rules and targeting rules *separately*. The main focus is to study the welfare costs that result from implementing rules that differ from each other in the dimension of the *measure* of inflation that is being targeted. Specifically, we consider Taylor rules of the type:

$$R_t = R\left(\frac{\pi_t^o}{\pi}\right)^{\phi_\pi},$$

which react actively ($\phi_\pi = 1.5$) to contemporaneous inflation, and targeting rules that enforce:

$$\pi_t^o = 1.$$

The measure of inflation in these rules corresponds to

$$\pi_t^o = (\pi_{F,t})^{\omega}(\pi_{N,t})^{1-\omega} \quad \text{with} \quad \omega \in [0,1].$$

This specification is general enough to embed the following specific cases: (i) non-food inflation $\pi_{N,t}$, when $\omega = 0$; (ii) food inflation $\pi_{F,t}$, when $\omega = 1$; and (iii) headline inflation π_t, when $\omega = \gamma_{F.}$

Following Schmitt-Grohe and Uribe (2007), we calculate the welfare cost of these policies by relying on a second-order approximation of a welfare measure associated with a particular Taylor or targeting rule. We proceed to explain how we calculate this cost for Taylor rules. A similar analysis applies to targeting rules.

For any given ω we use the following conditional welfare function:

$$V_0^{\omega} = E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(c_t^{*\omega}) - \frac{(n_t^{\omega})^{1+\psi}}{1+\psi}\right],$$

where $c_t^{*\omega}$ and n_t^{ω} denote the contingent plans for (notional) consumption and labor related to that particular rule. The benchmark for the analysis, on the other hand, corresponds to the conditional welfare associated with a Taylor rule that responds exclusively to non-food inflation, i.e., V_0^0 when $\omega = 0$. Using these welfare measures, we then calculate the welfare cost λ^ω of a particular Taylor rule as the percentage fraction of consumption that households would be willing to give up to be as well off as under the Taylor rule that responds exclusively to non-food inflation ($\omega = 0$). The results of the welfare costs associated with Taylor and targeting rules, for rich and poor economies, are presented in Figures 9 and 10.

Two results stand out from this welfare cost analysis. First, despite the presence of subsistence, it still seems appropriate for the central bank of a poor country to follow Taylor (and targeting) rules that *exclusively* respond to (or target) non-food inflation. This is reminiscent of the results of Aoki (2001): the optimal monetary policy is to target sticky-price inflation, rather than a broad inflation measure. In our model, it is precisely the non-food inflation which corresponds to that sticky-price inflation measure and, as a result, any rule deviation that involves putting some weight on food inflation will generate a relative welfare cost. This also means that the central bank of a poor economy has no need in stabilizing the relative price of food, as stabilizing non-food inflation is sufficient to keep the relative price at its efficient value. Moreover the "divine coincidence" of Blanchard and Gali (2007) still holds in our model with strong effects of subsistence, and therefore stabilizing non-food inflation is equivalent to stabilizing the welfare-relevant output gap.

Second, deviating from the policy of targeting non-food inflation in a targeting rule—or deviating from responding to non-food inflation in a Taylor rule—seems to be more costly in welfare terms in poor countries than in rich countries. This goes in line with some of the previous analysis of the impulses responses of Figures 6 and 7, where we showed that the choice of the inflation target is more important in the poor country than in the rich country. In a poor country that faces a negative productivity shock in the non-food sector and, by this means, an increase in the relative price of food, keeping broad measures of inflation stable implies engineering big drops in non-food inflation. And the size of these drops is bigger in poor countries than in rich countries, given the larger weight of food in the economy. But, because of sticky prices, this requires inducing even bigger contractions in non-food output and overall output in poor countries. This may explain the relative welfare cost differences of targeting headline inflation in poor countries versus doing so in rich countries. But why is the slope of the welfare cost curve—for targeting rules, for instance—steeper for poor countries than that for rich countries (see Figure 10 of targeting rules)? An answer can be found in the log-linearized forward-looking IS equation (22). In poor countries, with a high degree of subsistence, there is a direct effect of changes in expected relative food prices in inter-temporal decisions. As a result, expected increases of the relative price of food will have bigger contractionary effects in poor economies that in rich countries.

VII. Conclusion

We have studied the implications of structural transformation for monetary policy design and the properties of inflation across the development spectrum. We have found that structural transformation features amplifies the volatility of inflation at lower stages of development and modifies its structural properties.

Our model is very stylized. In future work we plan to incorporate other aspects of structural transformation and assess their quantitative contribution to inflation and relative price volatility. For example, the choice of technology in the agricultural sector is endogenous to the level of development; this feature is also likely to amplify the effects of shocks on food production and therefore on the relative price of food. We also plan to explore the role of structural transformation features in an open economy setting, where there can also be food shocks coming from abroad.

More generally, we are interested in understanding what economic features are necessary to make the volatility of the relative price of food an appropriate objective of monetary (and fiscal) policy? Limited risk sharing between workers in the food and non–food sector is one potential channel, which we would also like to explore in future work.

Parameter	Value	Parameter	Value
$\bar{c}_F$	0.0099	ρ_A	0.8
α_F	0.0701	ρ_{MP}	0.8
α	0.7	ξ	0.01
β	0.99	σ_{MP}	0.5
θ	0.75	σ_{A_f}	0.55
φ	1.5		
ψ	5		

Table 1: Calibration.

	Data			Model					
				$\sigma(AF) = 0.55$			$\sigma(MP) = 0.50$		
	US	Med. Afr	Ratio	Rich	Poor	Ratio	Rich	Poor	Ratio
Food share in CPI (percentage)	8.0	39.4		7.93	42.1				
GDP per capita	41.7	1.2	2.9%	1	0.03	2.6%			
PPP (thousands of dollars, avg 2001-2010)									
	Volatility (std, BP filtered quarterly data, 1995:I-2011:IV))								
Headline inflation	0.29	1.18	**4.06**	0.04	0.33		0.34	0.44	**1.30**
				(0.03, 0.06)	(0.23, 0.45)		(0.24, 0.47)	(0.32 0.62)	
Non Food inflation	0.34	0.74	**2.20**				0.33	0.32	**0.98**
							(0.22, 0.46)	(0.21, 0.43)	
Changes in the relative price of food	0.56	1.75	**3.14**	0.55	0.80	**1.45**	0.56	0.57	**1.02**
				(0.37, 0.73)	(0.54, 1.07)		(0.40, 0.82)	(0.41, 0.84)	

Table 2: Second Order Moments, Data and Model.

	Data			Model		
				σ(tf) = 0.55, σ(dev) = 0.50		
	US	Med. Afr	Ratio	Rich	Poor	Ratio
Food share in cpi	8.0	39.4				
GDP per capita	41.7	1.2	2.9%			
PPP (thousands of dollars, avg 2001-2010)						
Volatility (std deviations, BP filtered quarterly data, 1995:I-2011:IV))						
Headline inflation	0.29	1.18	4.06	0.35	0.55	1.57
				(0.25, 0.50)	(0.37, 0.66)	
Non Food inflation	0.34	0.74	2.20	0.33	0.30	0.93
				(0.23, 0.46)	(0.21, 0.43)	
Changes in the relative price of food	0.56	1.75	3.14	0.77	0.94	1.22
				(0.55, 1.04)	(0.67, 1.30)	
Inflation decomposition						
Non food	1.11	0.75		0.87	0.32	
food weight* changes in the relative pri	0.02	0.52		0.03	0.54	
Correlation (BP filtered, annual data, 1995-2011)						
Output/Inflation	0.79	0.08		0.73	0.08	

Table 3: Second Order Moments, Data and Model.

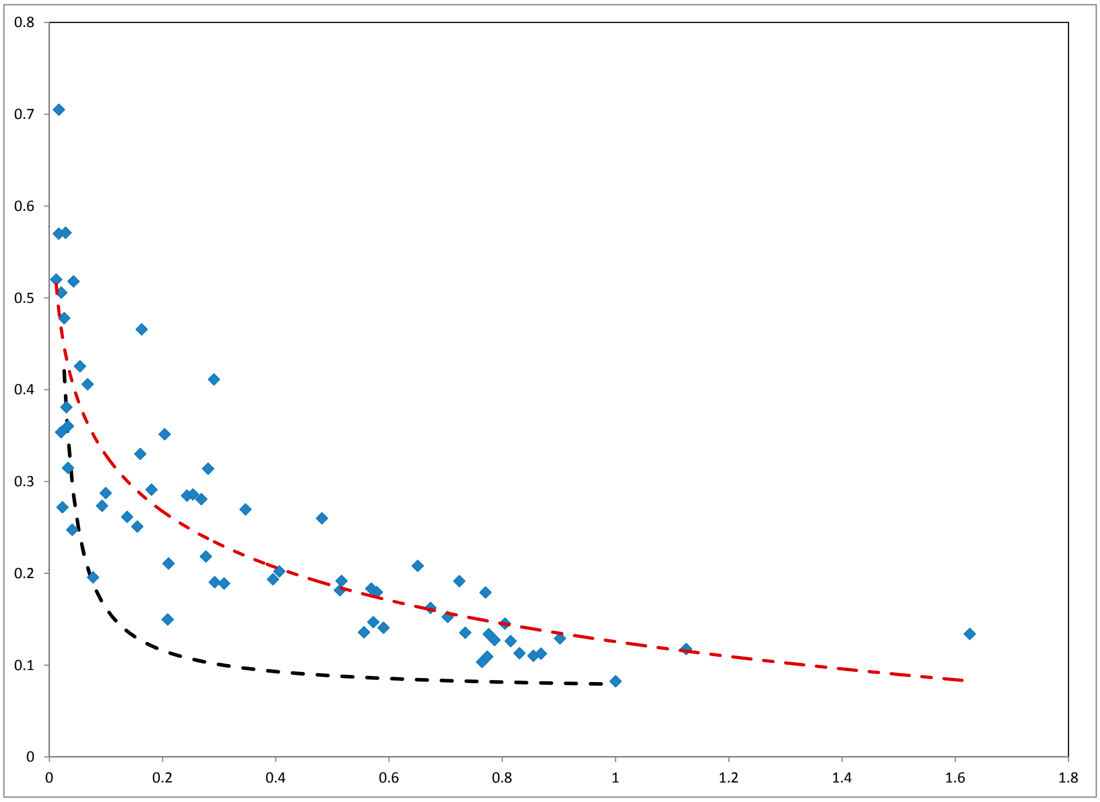

Figure 1: Food Share Against Income per Capita. Blue diamonds: countries; dashed red line: log trend; dashed blue line: model.

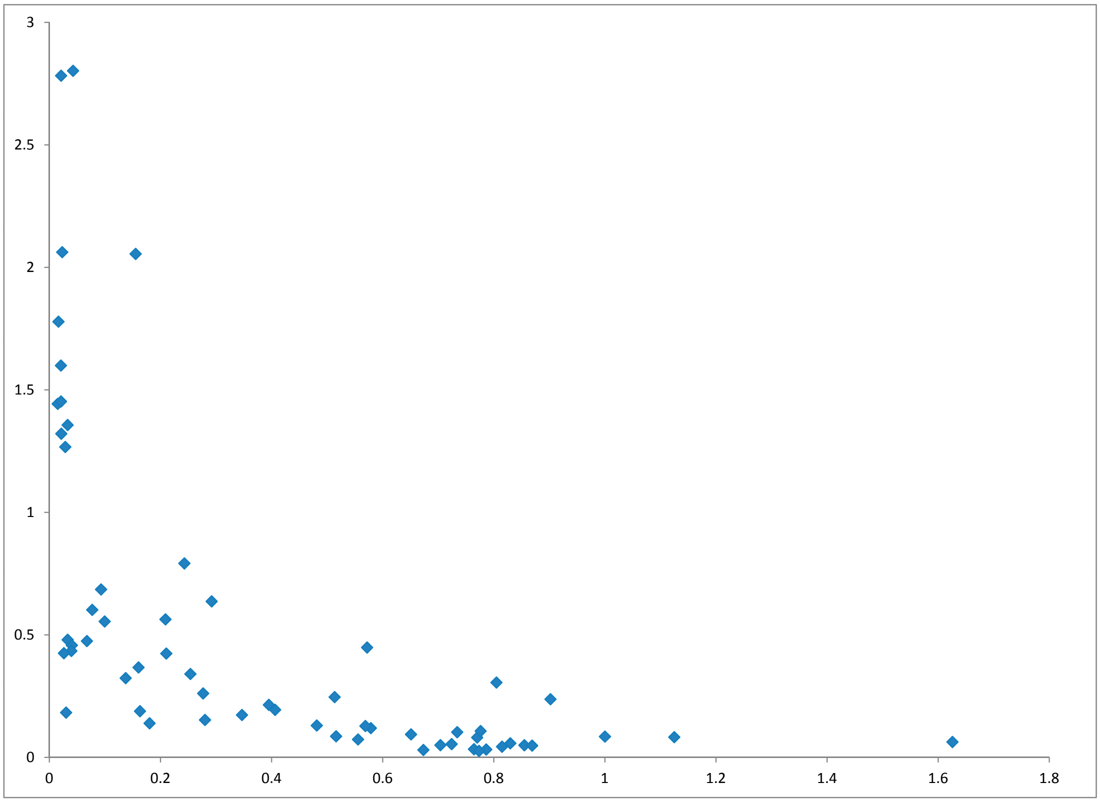

Figure 2: Inflation Volatility Against Income per Capita.Blue diamonds: countries.

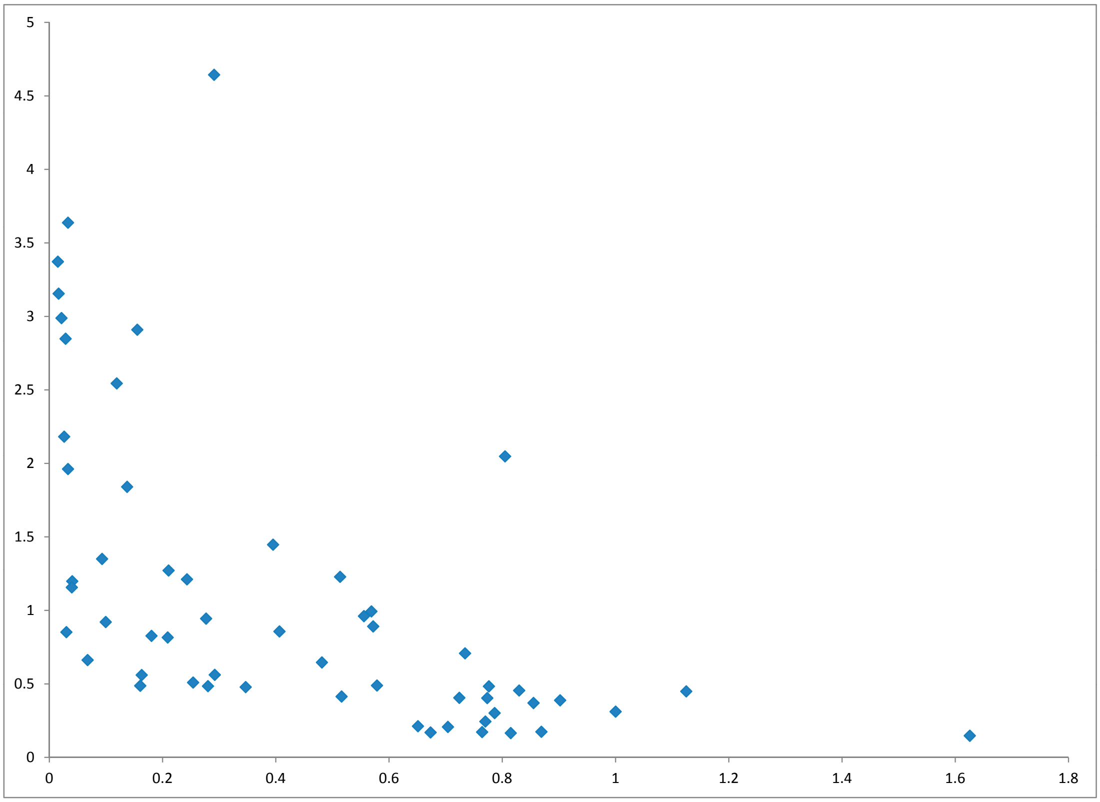

Figure 3: Relative Food Price Volatility Against Income per Capita.Blue diamonds: countries.

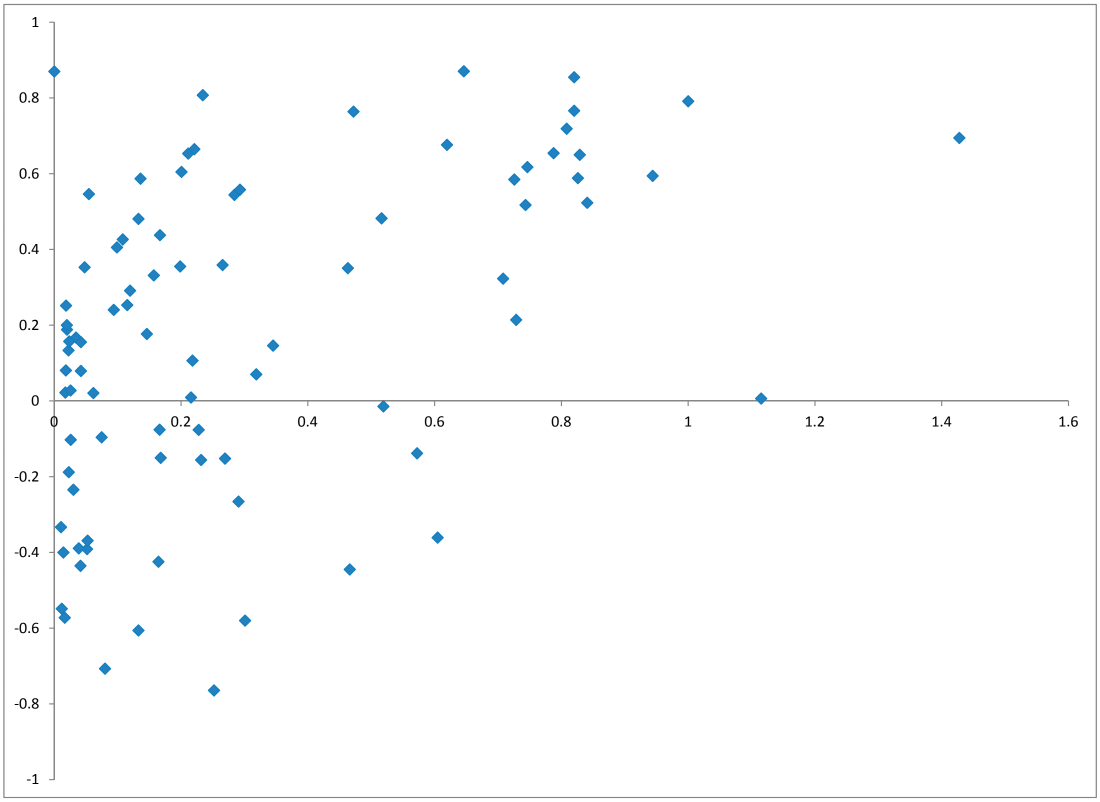

Figure 4: Inflation and Output Correlation Against Income per Capita.

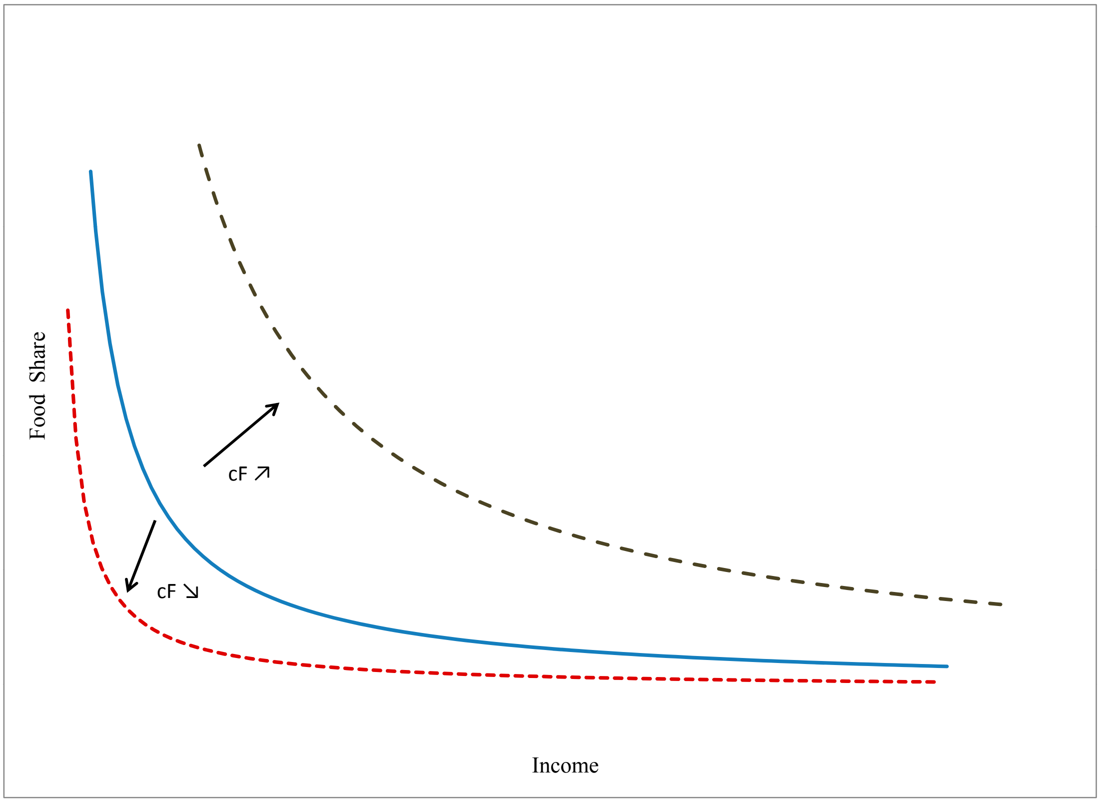

Figure 5: Food Share Against Income.

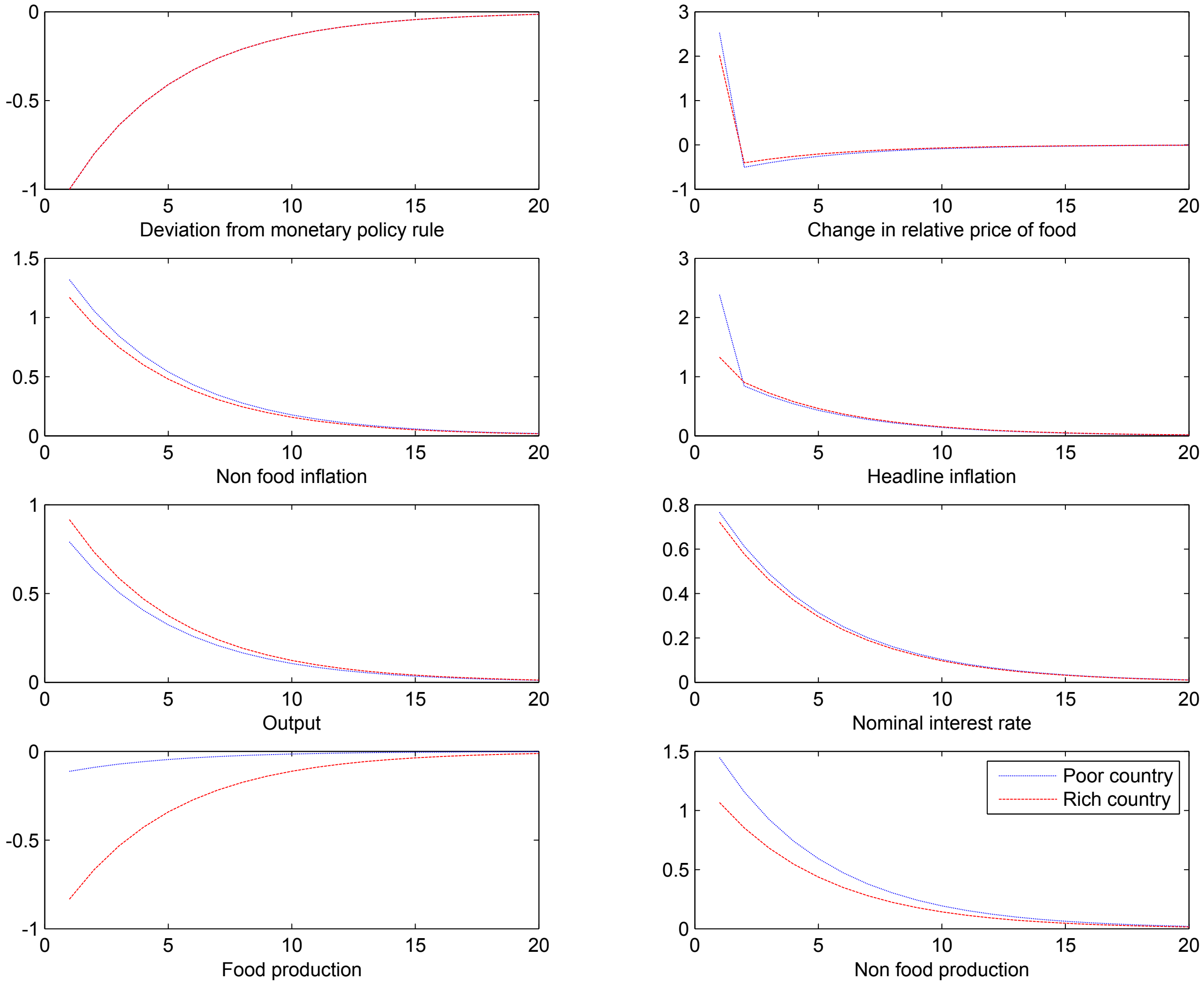

Figure 6: A monetary policy shock, $e_{MP} < 0$

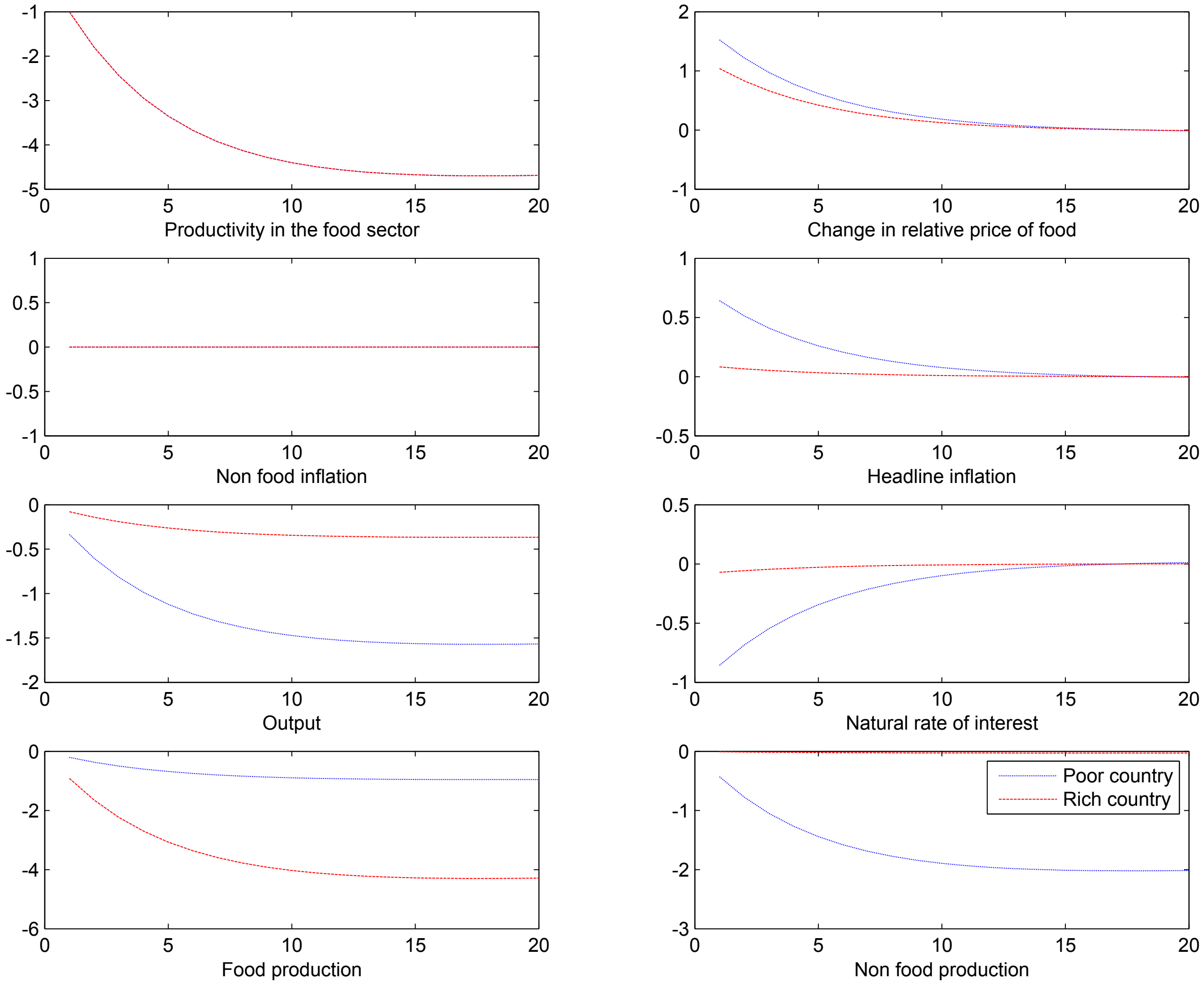

Figure 7: A shock to Food Sector Productivity, $e_{A_F} < 0$

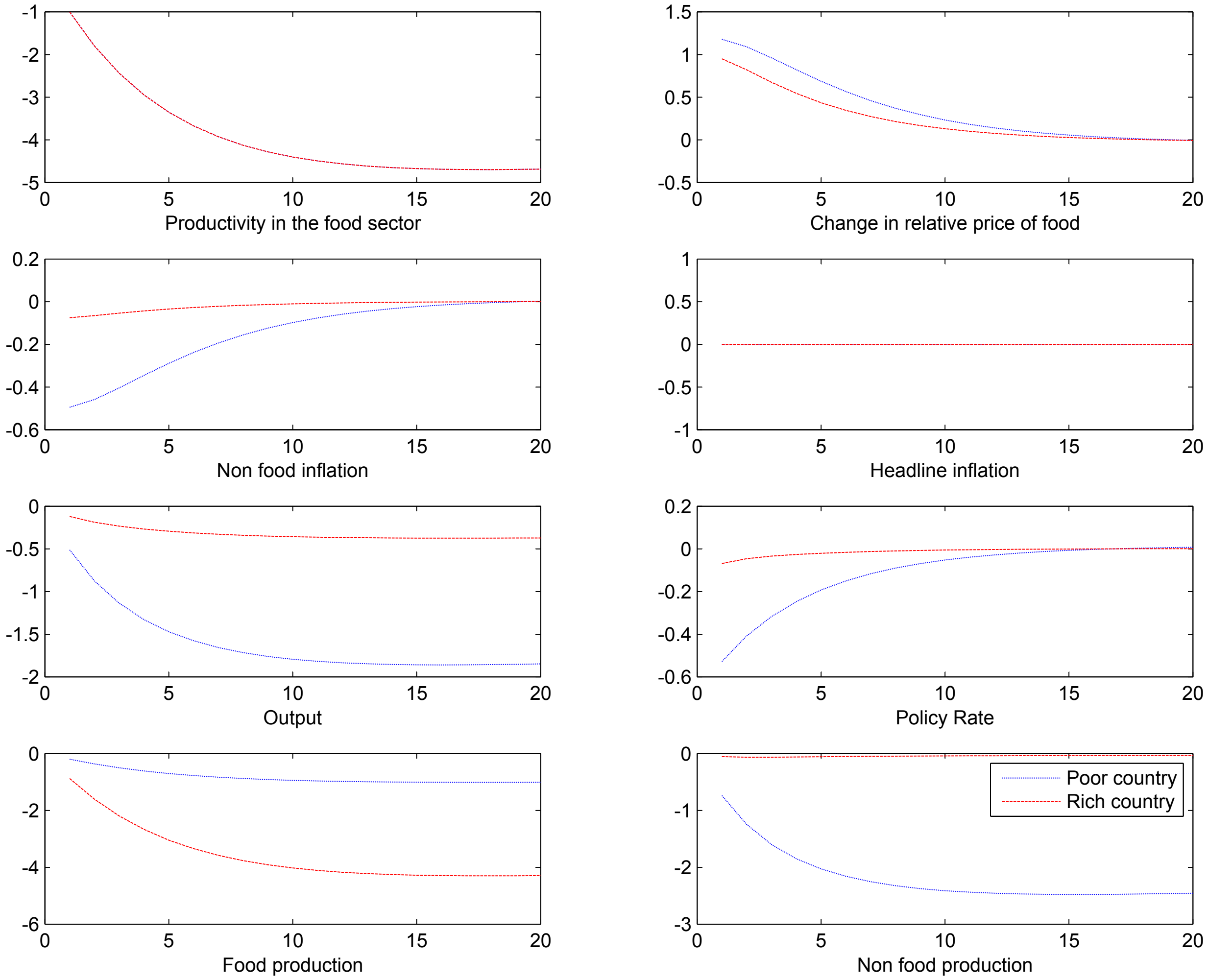

Figure 8: A shock to Food Sector Productivity, $e_{A_F} < 0$, Under Headline Inflation Targeting ($\hat{\pi}_t = 0$).

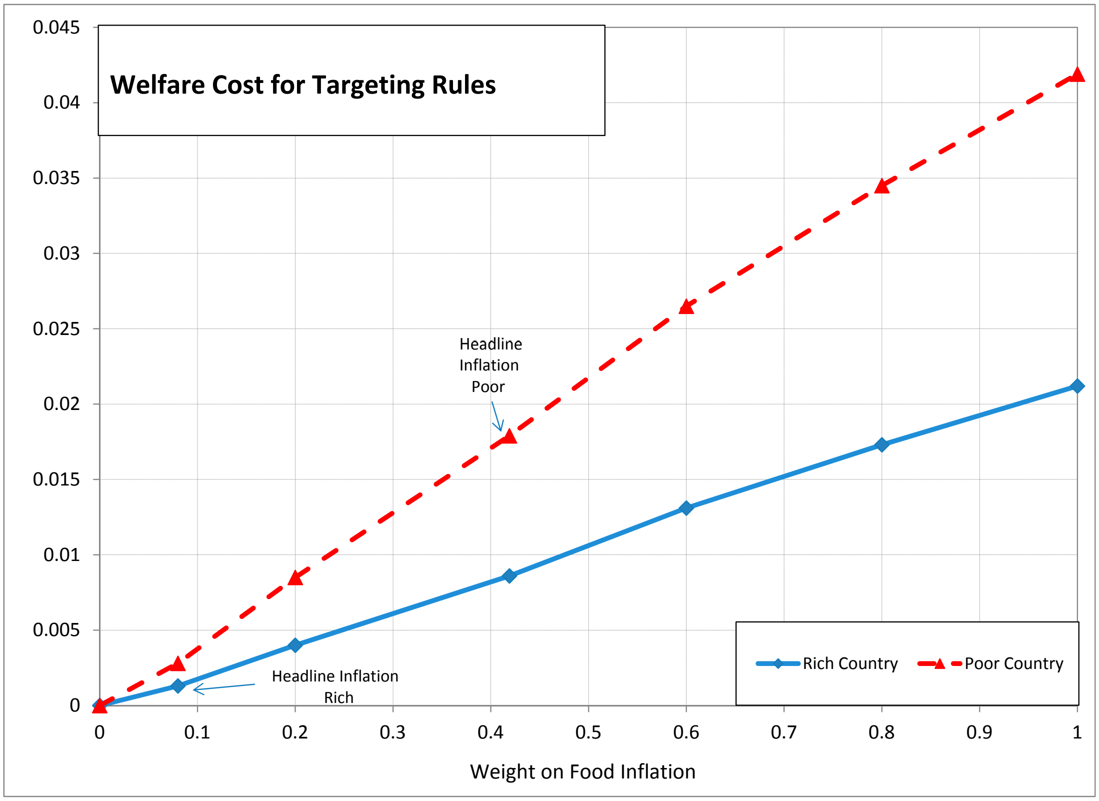

Figure 9: Welfare Comparisons: Targeting Rules.

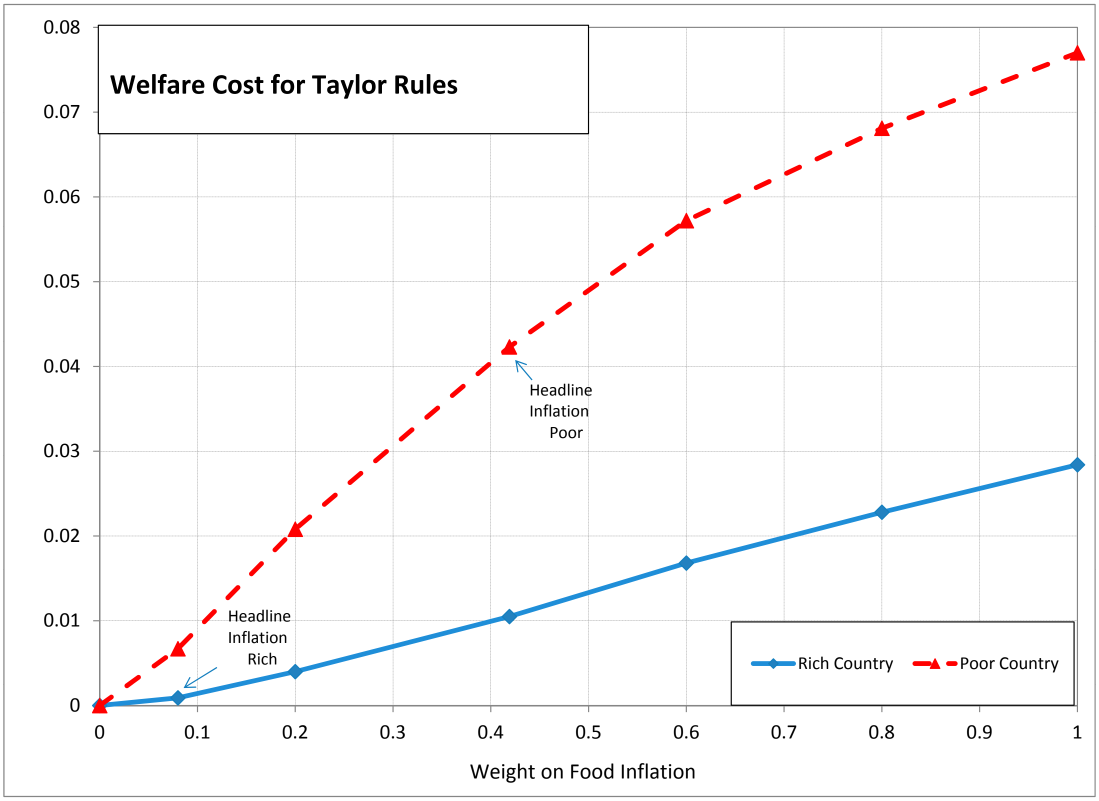

Figure 10: Welfare Comparisons: Instrument Rules.