Commodity Price Booms: Macroeconomic and Distributional Implications*

Marina Mendes-Tavares
ITAM and IMF

Adrian Peralta-Alva
IMF

Irina A. Telyukova
UCSD and IMF

April 28, 2014

Abstract

Global real food prices increased by about fifty percent between 2003 and 2013. This increase occurred after a two-decade period of food price stability. It is of concern because food prices may affect disproportionately those who are economically vulnerable. Indeed, households in low income countries (LICs) devote half of their budget to food while households in developed nations devote less than 15 percent. It is also true, however, that a larger fraction of households are food producers in LICs and most of the exports of these countries relate to commodities. As a result, the impact of increases in food prices on LICs is not obvious. In this paper, we derive the quantitative implications of observed changes in food prices on macroeconomic aggregates and the distribution of income, and study the implications of some of the policies currently being debated to mitigate the impact of this shock. Our tool of analysis is a multi-sector dynamic general equilibrium model that includes key features of LICs economies and heterogenous agents subject to idiosyncratic and aggregates shocks. We calibrate the model to Ghana, which has unique household panel data. We find this shock can have strong distributional implications that operate through general equilibrium effects by changing the price of domestic food, and thus the purchasing power of farmers vis-a-vis other agents. Non distortionary food subsidies can partially undo the negative effects of this shock.

*The authors are grateful to U.K.'s DFID for the generous financial support. We thank Paolo Falco for his extensive help with the GUHPS data set, as well as the participants of the Oxford CSAE 2014 conference for their generous feedback. The views express herein are those of the authors and do not necessarily reflect the views of the IMF

1 Introduction

After staying roughly constant between 1982 and 2003, the UN's Food and Agriculture Organization's (FAO) global real food price index started increasing, and is expected to be 50% higher than the 2003 level by the end of 2014. Several alternative hypotheses have been proposed for this increase, including a combination of an increase in global demand for food and the increased prevalence around the world of distortionary policies that promote biofuels. This protracted price increase created significant concerns among policymakers, mainly because increasing food prices tend to affect disproportionately those who are economically vulnerable. As a result, many governments adopted a wide range of policies to combat the negative implications of price increases, including reductions in import taxes, increases in food subsidies and price controls.[1] Although many of these policies were successful in the short run in controlling food prices domestically, it is not clear that these policies are desirable in the longer run, because they protect consumers by hurting producers and reducing competitiveness.

Low-income countries (LICs) in particular have been disproportionately affected by the protracted increase in the prices of staple foods. Consumers in low-income countries on average spend 47 percent of their budget on food, while the share is 29 percent in middle-income countries and just 13 percent in high-income countries, according to Regmi et al. (2001). However, a larger share of households in low-income countries produce staple foods as well. In a recent study, Aksoy and Isik-Dikmelik (2008) found, using country survey data from nine low-income countries, that an average of 46 percent of households in these countries are staple food producers. As a result, the final impact of an increase in staple food prices in low-income countries can be potentially positive because of income effects, or negative because of price effects. Which force dominates depends on general equilibrium effects.

In this paper, we study the impact of increases in staple food prices in low-income countries. More precisely, we are interested in understanding the impact of food price shocks on income inequality, and in analyzing the macro and distributional impacts of the policies that arose in response to these shocks. To do this, we build a multi-sector dynamic general equilibrium model that has the key features of low-income countries, as in Adamopoulos and Restuccia (2011) and Caselli (2005). The model has multiple sectors, and includes an industrial sector, exporters of agricultural goods, and small farmers. The labor force in these sectors is comprised both of wage earners who work for firms, and of household enterprises. Since our focus is on inequality, we consider a model with heterogeneous agents and idiosyncratic and aggregate shocks. The income shocks allow for heterogeneity at the individual level, which are standard in the literature on inequality.

To perform our quantitative analysis we use data from Ghana, as it is one of the few low-

[1] A complete discussion of the policies that have been proposed can be found in Adam (2011)

income countries with panel household data. Ghana's GDP per capita is 1,500 dollars, just below the average for LICs, which is 1,900 dollars, according to the World Bank (2012). Also, inequality in Ghana, measured by the Gini coefficient of 0.43, is just below the average of 0.44 for this country group. Ghana's main export commodities are gold and cocoa. The Ghana Urban Household Panel Survey is a unique panel dataset for low-income countries. The survey follows workers and their households in urban areas annually from 2004 to 2013, which allow us to estimate idiosyncratic shocks to households living in a low-income country, which is a contribution in its own right.

We study the impact of an increase to the price of imported food comparable to what is observed in the data. This is a negative terms of trade shock. What happens depends crucially on whether domestic and imported food are substitutes or complements. If they are complements the demand for both imported and domestic food falls. Further, since farmers demand less food themselves the net supply goes up and the domestic price of food goes down. This has a negative impact on the purchasing power of farmers. If these goods are substitutes then the price of domestic food goes up and the redistribution works in favor of farmers.

Since a key general equilibrium force causing redistribution is changes in the price of domestic food, we evaluate the implications of a domestic food price subsidy. As benchmark, we assume the cost of the subsidy can be financed with non distortionary taxation on the business sector. Under these conditions food price subsidies can partially undo the distributional effects of the shock, and may also result a smaller decline in consumption and GDP.

The paper is organized as follows. In section 2, we present a frictionless version of our economy, whose allocations are Pareto-optimal, for comparison to our full quantitative frictional model. In section 3, we present the full general theoretical model that we will use in computation, and discuss some implications of the general model. Section 4 presents a simplified model which allows us some analytical insights. Section 5 presents the description of the household-level data and some stylized facts that we later use in calibration. Section 6 presents our calibration strategy and demonstrates quantitatively an example of an import price shock, as well as a possible subsidy policy to ameliorate the impact of the shock on the domestic economy. Section 7 concludes.

2 A Frictionless Economy

Low income countries are subject to various economic frictions that interact in important ways with commodity price shocks, and affect the impact of these shocks on macroeconomic performance and the distribution of income. The frictions also impact the role and implications of macroeconomic policy. To better understand the role of such frictions, we introduce them progressively. We start with a frictionless economy where financial markets allow full insurance and redistribution can be done in a lump sum fashion. The allocations of such an economy are Pareto-optimal. Hence, they can be derived from a "social planner" that maximizes welfare of the agents subject to technological constraints.

Next, we consider an economy with sectoral and occupational mobility frictions, and household heterogeneity within sectors. In particular, we will assume that only a subset of agents can run firms, and that different agents can work in different subsets of sectors in the economy. Regarding financial markets, we will assume that some agents can borrow abroad, while others can only access a market for domestic state-uncontingent bonds, in zero net supply. That is, financial markets are incomplete in this departure from the first-best world.

The model economies we consider are populated by a continuum of heterogeneous households who live forever in discrete time, $t = 0, 1, ...$ The households have the same preferences over stochastic streams of non-food items, c^o and food, c^f. All utility functions are assumed to satisfy standard conditions. Food is a composite of imported food, c^*, and domestically produced agricultural goods, c^a. This food composite is summarized by a general function $A(c^a, c^*)$, so that domestic and imported goods can be complements or substitutes. The food composite may also be subject to subsistence requirements so that preferences may be non-homothetic.

Agricultural goods are produced through a continuum of technologies akin to small farming. Each of these production units is subject to idiosyncratic shocks, s^A, and also to a sector-wide shock, z^a. The total supply of land for agriculture is normalized to 1, and each production unit is exogenously assigned l units of it. Idiosyncratic shocks are assumed to follow a Markov process, and drawn from their ergodic set. The role of these shocks is to generate within sector inequality. Notice, however, that if there are no aggregate shocks then the law of large numbers guarantees that the aggregate feasible set for agricultural goods is constant.

Non-food items are produced using two different technologies, both subject to a sector level productivity shock z^o. The first technology, F^o, requires capital and labor and displays constant returns to scale. The second employs a continuum of decreasing returns to scale technologies, using labor as the only input. Each one of these technologies is affected every period by a Markovian shock, s^E, which affects the effectiveness of time employed in each technology.

Non-food items can be used indistinctly for investment, x, or consumption. The stock of capital follows a standard law of motion

$$K_{+1} = x + (1 - \delta)K.$$

Investment is irreversible (namely, capital stock K^o cannot be used as consumption goods) and capital depreciates at a constant rate δ^o.

The last type of good produced in the economy is "natural resources." These are not consumed domestically, but are valued abroad and thus exported. Their relative price is p^r (in terms of the numeraire), and it is determined in international markets. This good is produced employing labor and the agricultural good as an intermediate. The latter captures a common fact of low income countries: agricultural products are mostly produced by small farmers and are often later purchased, processed and exported by larger firms (e.g. tobacco in Malawi, or cocoa in Ghana). The associated production technology is F^r and there is a sector wide shock to productivity, denoted by z^r.

The planner's problem in this type of environment is

$$\max_{\{c^a, c^*, c^o, K, H^o, H^r, h(\cdot)\}} E_0 \sum_{t=0}^{\infty} \beta^t u(A(c^a, c^*), c_t^o) \tag{1}$$

$$
\begin{aligned}
& s.t. \\
& c^a + M = z^a E\left[s^A l^\xi\right] \\
& p^* c^* + c^o + x = z^o F^o(K, H^o) + p^r z^r F^r(H^r, M) + z^o E\left[f(s^E h)\right] \\
& H^o + H^r + E(h) = 1 \\
& K_{+1} = x + (1-\delta)K \\
& x^j \geq 0, 0 < \delta^j \leq 1, \;\; j = o, r.
\end{aligned}
$$

Here E denotes the expectations operator under the invariant distribution of the corresponding Markovian process, while E_0 is the expectations operator conditional on information available at time $t = 0$.

2.1 Characterization and Properties of First-Best Allocations

Consider first the case where productivity and terms of trade (here given by the relative price of natural resources p^r, the only export, and the relative price of imported food p^*) are constant. Also, assume household level shocks are drawn from their invariant distribution with a constant mean. The model has a steady state where all agents consume the same constant amount of each type of good, because the planner provides full insurance against the fluctuations of income caused by the household-level shock. This follows as there is no aggregate risk and all agents share the same preferences. The only relevant income is the per capita income of the economy.

Agricultural goods as intermediates or consumption

For simplicity, we will assume preferences are separable between food and non food items. Consider first the optimality conditions for consumption of the domestic agricultural goods, use of intermediates, and imported food. Subindices in functions denote partial derivatives with respect to the corresponding variable.

$$u_{c^f} A_{c^a} = \lambda_1$$
$$\lambda_1 = \lambda_2 p^r z^r F^r_M$$
$$u_{c^f} A_{c^*} = \lambda_2 p^*$$

Here λ_i denote the Lagrange multipliers on the corresponding constraints. These equations taken together imply a condition for the optimal distribution of agricultural goods between consumption and intermediates.

$$u_{c^f} A_{c^a} = \frac{u_{c^f} A_{c^*}}{p^*} p^r z^r F^r_M$$

In an optimum, marginal utility derived from consuming domestically produced agricultural items must be equal to what can be obtained from their alternative use. Namely, intermediates in the production of natural resources, which yield at the margin $p^r z^r F^r_M$ that can be in turn used to purchase imported food items and are valued at $\frac{u_{c^f} A_{c^*}}{p^*}$. The left hand side of this equation is decreasing in c^a. Since intermediates are what is left after consumption of the agricultural good, and assuming decreasing marginal products for intermediates, the value of the marginal product of natural resources is increasing in c^a.

Hence, holding other factors constant, higher natural resource prices p^r tend to shift agricultural resources towards production rather than consumption. Higher import prices p^* have the opposite effect, as they make the utility value of their use as intermediates lower.

Labor allocations

Consider now the conditions determining optimal allocation of available time.

$$p^r z^r F^r_{H^r}(H^r, M) = z^o E\left[f'(s^E h)\right]$$

$$z_o F^o_{H^o} = p^r z^r F^r_{H^r}(H^r, M)$$

In an optimum, marginal returns of time use across activities must be equated. What are the effects of an increase in natural resource prices? The value of the marginal product of labor in this sector goes up, so that it is optimal to increase hours worked there. Of course, this requires lowering hours in “self employment”, or in production of non food items, or both. What actually happens can only be determined quantitatively as it will depend on factor intensities. What are the expected efffects of a change in import prices? This price does not directly appear in the above labor optimality conditions. However, we found before that higher import prices will tend to reduce the amount of intermediates employed in natural resources. This will in turn lower the marginal product of labor in the sector. In consequence, higher import prices will tend to take labor away from natural resources into self employment or production of the numeraire, or both.

3 The Quantitative Model

3.1 Economic Environment

Agents will now be segmented in different groups, each of which has access to different activities and technologies. Hence, households have permanent types (type will be the first super index in all allocations). The first type, a continuum with measure 1, are firm managers. We will refer to them as "firms", denoted with superscript F. Firms produce non food items and also natural resources. The problem of the representative firm is

$$\max_{\{c^a,c^*,c^o,M,H^o,H^r,B^*,K\}} E_0 \sum_{t=0}^{\infty} \beta^t u(c_t^{F,f}, c_t^{F,o})$$

$$\begin{aligned}
&s.t.\\
&c^{F,f} = A(c^{F,a}, c^{F,*})\\
&p^a(c^{F,a} + M) + p^* c^{F,*} + c^{F,o} + x + (1 + r^*)B_t^* = \pi^o + \pi^r + B_{t+1}^* - T^F(\pi^o, \pi^r)\\
&\pi^o = z^o F^o(K^o, H_d^o) - wH_d^o,\\
&\pi^r = p^r z^r F^r(H_d^r, M) - wH_d^r\\
&K_{+1} = x + (1 - \delta)K\\
&B_{t+1}^* \geq \bar{B}^*\\
&x \geq 0, 0 < \delta \leq 1, \;\; j = o, r.
\end{aligned}$$

Here E_0 is the expectations operator, conditional on information available at period 0. Firm managers' income is the residual of output after the wage bill, investments, and income taxes T^F. We assume firms have access to international asset markets and can borrow, B_{t+1}^*, at an internationally given rate r^*, subject to an exogenous limit.

All other types of households are subject to idiosyncratic and aggregate shocks. All of them can borrow and save using a state-uncontingent domestic bond, in zero net supply, subject to exogenously given constraints. First we have a continuum of households, with total measure μ^H, with an endowment of time H that can be either supplied to the market (be the employees of firms) at hourly wage w, or to run the family enterprise. From now on, we will refer to this type of agents simply as "households". Households are characterized by a random vector (s^E, s^W), which determines their entrepreneurial ability (in the family enterprise) and the effective labor hours they can provide to the market, respectively. This vector of shocks is assumed to follow a Markov process with transition probability distribution given by ψ. Working n hours in the family enterprise results in $zF(s^E n)$ units of the non-food item. It will be assumed that at each period agents learn the value of shocks (s^E, s^W) before making their time allocation decisions

In this market economy we may sometimes introduce a government, whose only role is to exogenously set a demand for hours worked, H^g, and a w^g. We will only consider equilibria where public wages are higher than the private sector. Hence, households that find it optimal to supply available time to the market will first supply as much time as possible as government employees. If they have market time left it will be supplied to the firm. We denote by h the amount of time supplied to the market, by h^g the time supplied to the government, while the rest is supplied to the household enterprise. The problem of the household of type (s^E, s^W) is

$$\max_{\{c^a, c^*, c^o, b, h^g, h\}} \mathbb{E}_0 \sum_t \beta^t u(c^{H,f}, c^{H,o}) \tag{2}$$

subject to

$$c^{H,f} = A(c^{H,a}, c^{H,*}) \tag{3}$$

$$p^a c^{H,a} + p^* c^{H,*} + c^{H,o} + (1+R) b^H = \tag{4}$$

$$b^H_{+1} + s^W (w^g h^g + wh) + Y^H - T^H(wh, Y^H)$$

$$h \in [0, H - h^g] \tag{5}$$

$$Y^H = z^o F\left(s^E (H - h - h^g)\right) \tag{6}$$

$$b^H_{+1} \leq B^H. \tag{7}$$

Income is taxed according to function T^H.

Finally, there is a measure μ^A of households producing the agricultural good. Accordingly, we will use super index A to distinguish their allocations. We will refer to them as "farmers" in what follows. Farmers productivity is subject to idiosyncratic shocks, s^A, and also to sector-wide shocks, z^a. Land for agriculture is normalized to 1, and its distribution is predetermined exogenously. The problem of farmers is

$$\max_{\{c^a, c^*, c^o, b\}} \mathbb{E}_0 \sum_t \beta^t u(c^{A,f}, c^{A,o}) \tag{8}$$

subject to

$$c^{A,f} = A(c^{A,a}, c^{A,*}) \tag{9}$$

$$p^a c^{A,a} + p^* c^{A,*} + c^{A,o} + (1+R) b^A = b^A_{+1} + p^a Y^A - T^A(Y^A) \tag{10}$$

$$Y^A = s^A z^a l^\xi \tag{11}$$

$$b^A_{+1} \leq B^A \tag{12}$$

and their income is also subject to taxes as determined by function T^A.

3.2 Market Clearing

First total effective labor demand (by firms and the government) must equal supply

$$\mu^H \int h I_w(s^E, s^W) \psi(ds^E, ds^W) = (H^r_d + H^o_d)$$
$$\mu^H \int h^g I_w(s^E, s^W) \psi(ds^E, ds^W) = H^g_d.$$

Indicator functions I_w are equal to one for shock values such that households find optimal to work for a wage, and are equal to zero otherwise.

The total demand for domestically produced food, all produced by farmers, must equal production

$$\left(c^{F,a} + M\right) + \mu^H \int (c^{H,a}) \psi(ds^E, ds^W) + \mu^A \int c^{A,a} \nu(ds^A) = \mu^A z^a \int s^A l^\xi \nu(ds^A).$$

Also, domestic bonds are in zero net supply:

$$\mu^A \int b^A \nu(ds^A) + \mu^H \int b^H \psi(ds^E, ds^W) = 0.$$

Because of Walras' law, the market for non-food must also clear.

3.3 Equilibrium

An equilibrium for this economy, given international interest rates, prices for natural resources and imported food $\{r^*, p^r, p^*\}$, public sector employment and wages $\{w^g, H^g\}$, sequences of sectoral productivity, idiosyncratic shocks, and predetermined tax/transfers functions T^F, T^H, T^A, is constituted by stochastic sequences of agricultural prices, wages and bond interest rates $\{p^a, w, R\}$, together with allocations of consumption, investment, time use and bond holdings for each type of households that solve their respective constrained optimization problem and clear markets.

3.4 Frictionless Economy versus the Quantitative Model

To better understand the possible role of economic policies in the context of our quantitative model it is useful to contrast the properties of its equilibria with the allocations from the frictionless economy, which are Pareto optimal.

Let us consider the frictions present in the quantitative model vis-a-vis the constraints of the welfare maximization problem (1). The first one is occupational segmentation. Namely, only some agents can hold capital, while the remaining agents are the only ones that have labor. Our analysis does not provide microeconomic foundations for which of the many well-known financial market and structural limitations may prevent agents from having access to capital. Our quantitative analysis should then be seen as reduced form for such issues. A second, related, friction in the quantitative model relative to the planner is sectoral segmentation. Namely, there is a set of agents that has access to the farming technology, but not to the other technologies; a different set of agents has access to the production of non food items and natural resources; finally, there is another set of agents that has access to production of non-food goods, but through a different technology subject to decreasing returns to scale. Again, this should be considered reduced form for monopoly rights or barriers to entry that may limit sectoral movements. Finally, the quantitative model features incomplete markets, limiting agents' ability to smooth consumption across periods, while the planner is able to provide full insurance against idiosyncratic and aggregate shocks.

Occupational segmentation

Optimality conditions for the planner imply that all agents will equate their intertemporal utilities to the rate of interest, which in turn must equal the marginal product of capital. In fact, in a steady state we have that all agents save enough to cover the per capita depreciation of capital and sustain steady state. In the quantitative model this condition is not satisfied. Indeed, the net savings of agents that have only access to the non contingent bond is zero, at steady state or out. This implies, in turn, lower capital and output (from technologies that require capital) in the quantitative model than what could be achieved without such frictions.

Interestingly, relative allocations of labor are efficient in the quantitative model, as optimal labor allocations in the quantitative model require equalization of marginal products to wages and to productivity at the household level. Of course, in a first-best equilibrium, government employment would equal zero, as it is assumed labor employed there produces no benefits to other economic agents.

Sectoral segmentation

Sectoral segmentation has important implications for the interaction of terms of trade shocks, the distribution of income, and macroeconomic performance. Consider first a positive shock to the price of exports, p^r. In the quantitative model this shock has a direct benefit only to a subset of the population: the agents that can run the export technology. Indirect effects are also present, since such technology requires agricultural goods and labor, and thus the farmers and the owners of labor will receive some benefits from this shock. These indirect effects are different from the planner problem, however, where all agents benefit evenly from the shock.

A similar situation takes place when the price of imported food changes. For the planner this is a negative income shock. However, in the quantitative model this shock, while also being negative, has additional and mixed distributional consequences. In particular, as general equilibrium forces impact the domestic price of food in the quantitative model, if the import price goes up, and pushes the domestic price up, then farmers are relatively better off, while the rest of the agents are worse off. Thus, there is scope for macroeconomic policy, for example redistributive subsidies and taxes, that does not exist in the first-best world.

Incomplete markets

The welfare maximization problem of the planner confronts (absent aggregate shock such as terms of trade, or sector-level productivities) a constant production possibilities set. As a result, consumption of all agents in a first-best allocation will be constant through time. The quantitative model does not have complete markets, resulting in significant household-level consumption volatility. In this model, there is scope for macroeconomic policy that aims to complete the markets.

3.5 Income Distribution

The model has rich heterogeneity that allows us to look at the distribution of agents in multiple ways. First, there is the occupational heterogeneity that results from the employment structure of the model: we have firm owners who are employers, wage earners who can work for the firms or the government, and household enterprises. As we will show below in detail, in the data on urban households in Ghana, who constitute less than one-half of the population, only about 25% of the households are in wage employment, while the other 75% work in household enterprises without employees or as employees in household enterprises (typically, as household members of the enterprise). The share of household enterprises is even higher in the rural population.

Second, sectoral heterogeneity results from households and firms being involved in the agriculture, resource and non-agricultural sectors, the latter of which can be interpreted as services or manufacturing, among others. For example, across Ghana, the share of the population involved in agriculture, forestry and fishing is 51% for 2012. Among the urban workers in 2012, 53% were in services, and a further 15% were in retail. 12% of urban workers worked in manufacturing and about 7% were in public employment.

Finally, the model produces a rich income distribution that can be mapped to data. Wage employees earn wages from both the private sector and the public sector. Wages across industries (resource and non-agricultural) are equated as there are no mobility restrictions between them, but the public wage is higher by assumption. Household enterprises' profits in the services and agricultural sector are determined by production in each period, and thus can vary in average levels from wage earnings. In addition, all household enterprises and wage earners are subject to idiosyncratic productivity shocks, the current level and history of which will produce an income distribution within and across sectors. We can quantify the idiosyncratic productivity shocks for both non-agricultural household enterprises and wage earners from our panel data. We calibrate the shocks for agricultural household enterprises from repeated cross-section data.

4 Building Intuiton through a Simple Model

To gain a better understanding of some of the economic transmission mechanisms present in our quantitative analysis, we use the above model but abstract from capital and bonds. This allows for deriving some analytical results that will prove useful when considering the simulations from the quantitative model.

Assume separable log preferences on consumption of non-food and food, and assume a CES food aggregator function. The problem of firms is:

$$
\begin{aligned}
&\max E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log((\lambda (c^{F,a})^{\rho} + (1-\lambda)(c^{F,*})^{\rho})^{\frac{1}{\rho}}) + \mu \log(c^{F,o}) \right\} \\
&s.t. \\
&p^a c^{F,a} + p^* c^{F,*} + c^{F,o} = \pi^o + \pi^r \\
&\pi^o = z^o (H_d^o)^{\alpha} - w H_d^o, \\
&\pi^r = p^r z^r (H_d^r)^{\eta} - w H_d^r.
\end{aligned}
$$

Note that when the CES parameter $\rho > 0$, imported food and domestically produced agricultural goods are substitutes, whereas when $\rho < 0$, they are complements.

For households, we only assume one type of shock: entrepreneurial ability. The problem of the household of type s^E is

$$\max \mathbb{E}_0 \sum_t \beta^t \left\{ \log((\lambda(c^{H,a})^\rho + (1-\lambda)(c^{H,*})^\rho)^{\frac{1}{\rho}}) + \mu \log(c^{H,o}) \right\}$$

s.t.

$$p^a c^{H,a} + p^* c^{H,*} + c^{H,o} = [w^g h^g + wh] + Y^H$$

$$Y^H = z^E \left(s^E (H - h^g - h) \right)^\nu$$

$$h^g \leq H^g$$

$$H \leq h + h^g$$

We close the model by considering the problem of farmers. Famers are only subject to idiosyncratic shocks, s^A. The conditional probability distribution of idiosyncratic shocks is ν. Their production technology is assumed linear. We abstract from land distribution issues.

$$\max \mathbb{E}_0 \sum_t \beta^t \left\{ \log((\lambda(c^{A,a})^\rho + (1-\lambda)(c^{a,*})^\rho)^{\frac{1}{\rho}}) + \mu \log(c^{A,o}) \right\} \tag{13}$$

$$\text{s.t. } p^a c^{A,a} + p^* c^{A,*} + c^{A,o} = p^a s^A z^a. \tag{14}$$

Aggregate constraints and equilibrium can be easily defined following the setup of the general model.

4.1 Comparative Statics

Simple derivations in the appendix illustrate the supply of domestically produced agricultural goods is negatively sloped whenever $\rho < 0$. The intuition is straightforward. Higher price of domestic food p^a has a positive income effect on farmers. This makes them want to consume more of all goods, including their own, so they supply less to the market, producing the negative relationship between market supply and prices. Instead, when $\rho > 0$, domestic and imported foods are substitutes. In this case, although higher price of agriculture also has a positive effect, there is a substitution effect. If the domestic food price rises, farmers will substitute towards more imported food, and will consume less domestic food, thus providing more to the market. This is the standard positively-sloped supply curve.

The import price p^* also has different effects on the supply of domestic food, depending on the values of ρ. When domestic food and imports are complements, a higher import price shifts the supply of domestic food up, as this is a negative income shock for farmers, and they consume less of all goods. Instead, when domestic food and imports are substitutes, a higher import price p^* results in higher demand for domestic food, and thus farmers supply less of it to the market.

The *demand* for domestically produced agricultural goods, which consists of demand by firms and households, is negatively sloped. However, derivations in the appendix show that even when the supply of domestic food is negatively sloped, demand has a stronger negative slope at each point. Hence, a unique equilibrium price always exists. The reaction of demand to an import price increase depends on the value of ρ. When domestic and imported food are complements, this negative terms of trade shock lowers consumption of both goods, so that demand for domestic food shifts down. When these goods are substitutes, however, the higher price of imported food makes agents substitute towards domestic food, and demand shifts up.

Similar analysis can be done for other macroeconomic shocks, such as an increase in agents' income or an increase in agricultural productivity. We can ascertain analytically some of the resulting impacts on domestic food prices. We summarize some of these insights in the following proposition.

Proposition. *If domestic and imported food are complements, then higher imported food prices have an ambiguous effect on domestic food prices. If domestic and imported food are substitutes, then higher imported food prices increase domestic food prices.*

5 Data

In this section, we briefly introduce the macroeconomic and household data that we use for stylized facts connected to the model, including the characterization of recent fluctuations in food prices and of household inequality in low-income countries. As our application, we choose the case of Ghana, due to availability of relatively good household-level data.

5.1 Data Sources

There are two key data sources from which we draw our information. The Ghana Urban Household Panel Survey (GUHPS) is an annual panel that only covers urban workers and households, which constitute less than one-half, and likely closer to one-third, of the population. The Ghana Living Standards Survey (GLSS) is a repeated cross-section that covered, in the last 2012-2013 wave, 18,000 households in a nationally representative sample of the total population of 25 million. This survey covers both urban and rural areas.

According to the GLSS, in 2013, 52% of Ghana's population was engaged in agricultural, forestry and fishing activities, which fall predominantly in rural areas. Thus, the main source of economic activity in the country is not well covered by the GUHPS panel, where only 2.6% of the population report being engaged in these activities. Although panel data are more suitable for our goal of understanding different aspects of the income distributions as well as individual transitions within it over time, we also need to characterize the rural sector at the household level, and hence will utilize both surveys. We begin by describing results from the GUHPS.

5.2 The Data - Ghana Urban Household Panel Survey

The Ghana Urban Household Panel Survey, collected by the Centre for the Study of African Economies at Oxford University in collaboration with the Ghana Statistical Office, is an annual panel that covers the period 2004-2012. The survey covers urban workers in four largest urban areas – Accra, Kumasi, Takoradi and Cape Coast. The sample started with 1,156 workers aged 15-65, and grew to about 2,100 workers by 2011, which amounts to between 400-600 households in most years, thought the main unit of observation for most variables of interest is a worker.

In terms of demographics, the median age in each wave of the survey is between 28 and 30 years old. This reflects the focus of the survey on the labor force, which thus excludes the economically inactive older population, and the fact that the labor force in general is young in Ghana (Fox et al xxx). According to the Ghana Living Standards Survey, about 75% of the population of age 15 and above are economically active.

5.3 Labor Force Facts

Table 1 presents the breakdown of our sample of the urban labor force by employment type. On average across the years, about 22% of workers worked for household enterprises with no employees, and another 40-50% of workers reported to be unpaid, which typically implies being household members of these enterprises. In addition, about 8-10% of workers run household enterprises with employees. In other words, a vast majority of the urban labor force are the self-employed, typically in household enterprises. The remaining fraction, on average about 22% across the years of the survey, are engaged as wage employees, with about 8-10% working for firms with more than 20 employees. As we will see below, just over one-quarter of the wage employees are employed in the public sector, either as civil servants or as employees of public enterprises.

Next, table 2 presents industrial distribution of wage employment in our sample, for years in which this information is available. Since this is the urban population, the largest sectors of employment is services, at about 55% average across the years, followed by manufacturing at 21%, and retail and trade, at about 12%. There was a visible monotonic decline in manufacturing employment, and an increase in the retail sector over the period. Note that "manufacturing" is a broad term here, capturing any kind of processing of inputs, and at the household level often refers to very small-scale production, even for wage employment. Public sector employment is relatively steady at about 6-7%, depending on the year. Agriculture, fishing and mining, summarized under "agriculture" in the table, are negligible sectors for the urban pop-

Table 1: Distribution by Employment Type, Percent

Year	Self-Empl. no employees	Self-Empl. w/ employees	Unpaid	Wage-Empl. firm <= 5	Wage-Empl. firm 5-20	Wage-Empl. firm > 20
2004	37.8	4.1	35.5	7.8	7.0	7.8
2005	36	6	36	8	6	8
2006	28	5	38	7	12	10
2007	19	9	50	5	6	11
2008	20	9	47	5	7	12
2009	24	10	43	6	6	10
2012	13	4	64	6	4	9

Table 2: Distribution of Wage Employees by Industry, Percent

Year	Manufacturing	Agriculture	Services	Retail	Tourism	Public
2006	28.5	1.6	57.8	6.1	0.2	5.9
2007	24.6	6.6	53.1	7.8	2.0	5.9
2008	26.8	5.1	51.9	8.3	2.2	5.7
2009	18.9	2.0	55.3	14.6	1.3	8.0
2010	15.2	2.2	54.3	18.3	0.8	9.2
2012	13.2	3.2	57.5	16.9	1.2	8.0

ulation, although country-wide they account for more than 50% of the labor force, as per the GLSS survey.

Based on these tables, we will be able to calibrate population shares of private wage employees, household enterprises in agricultural and non-agricultural sectors, and public employees, as described below.

5.4 Income and Consumption Inequality

As we discussed above, the model will produce rich income inequality based both on the source of income (public and private wages and self-employment) and the differences in earnings stemming from differential individual and aggregate productivity of workers. In order to assess the inequality implied by the model, as well as to calibrate idiosyncratic shocks, in this section we characterize the distribution of both earnings and consumption, since these are the two measures typically used to proxy income in low-income countries in the presence of significant measurement error in household income data.

In the GUHPS, the earnings variable for the wage-earners simply records their self-reported wage – while these can have their own measurement error issues, these data are fairly reliable because wage workers know their wage. For the self-employed, earnings are self-reported profits net of routine operating expenses, such as the cost of raw materials, capital servicing or labor. These self-reports have measurement problems because accurate measurement of expenditures, and sometimes profits, is often difficult given the small scale of the enterprise. Nevertheless, we will use these data at face value, with the caveat that measurement error is likely an issue. To make the analysis as revealing as possible, we will also look at consumption data separately.

In our sample, the earnings data are collected at an individual worker level. In the context of urban Ghana, however, household earnings are more informative to study, since households tend to be large and are known to share risk, and household enterprises employ multiple family members some of whom are not formally paid. For our model of a unitary household, household data also translate better than individual data. Thus, we construct measures of household monthly earnings, pooling individual earnings of all the members. These numbers – real monthly earnings of households, expressed in 2002 dollars – are presented in table 3. First, in 2010, the median household earnings were at about $110 per month in our urban sample, with the mean at $259. Second, it appears that real earnings have grown significantly over time in the mean and the median, though the growth is not even, particularly in the mean. The five-fold growth of mean earnings in the 2004-2010 period has been driven particularly by the growth of earnings in the top decile, while the median grew less than three times over the period, and the bottom 10 percent only just doubled. It is hard to know whether any of this increase is the result of a change in the sample, given that the number of households in a typical year is only about 500. In particular, the year 2012 looks like an outlier, with a significant increase in earnings that does not seem to be explained simply by the 2-year gap between the waves. The increase is robust to various ways of controlling the sample, but the data should be treated with caution. When we calibrate income paths of households below, we will exclude the 2012 data.

Table 3: Distribution of Real Monthly Household Earnings, Dollars, 2002=100

Year	p10	Median	Mean	p90	N
2004	8.7	34.7	51.3	111.2	514
2005	14.2	50.0	71.3	147.8	528
2006	15.7	63.5	93.2	194.9	583
2007	16.6	85.4	155.3	363.0	355
2008	12.1	80.3	152.4	343.9	418
2009	16.8	80.6	145.6	335.8	432
2010	18.4	110.5	259.2	563.0	602
2012	41.9	178.5	314.0	614.0	719

In the survey, consumption is measured at the household level only, and not in all of the survey years. Moreover, consumption is clearly measured with more error, as households are asked to give the average amount they consume in a month; this kind of recall is notoriously difficult for households even in developed economies. (See, e.g. Attanasio, Battistin, and Ichimura (2004) and Attanasio, Battistin, and Padula (2010) for a related discussion on the Consumer Expenditure Survey in the U.S.) Nevertheless, the distribution of a consumption measure comparable to the above earnings measure, in dollars, is presented in table 4, for the available years 2006, 2008 and 2009. According to tables 3 and 4, household earnings grew about 27% in the median and 56% in the mean from 2006 to 2009, while both median and mean consumption increased by over 70% in that period. Consumption growth also outpaced earnings growth in the tenth percentile.

Table 4: Distribution of Real Monthly Household Consumption, Dollars, 2002=100

Year	p10	Median	Mean	p90	N
2006	34.4	74.0	97.0	168.9	633
2008	44.3	108.5	163.5	310.11	432
2009	44.4	129.9	166.4	317.29	455

In order to compare consumption and earnings at the household level, we construct for each household a measure of the consumption-earnings ratio . Then, grouping households in each year into earnings quintiles, we measure the median consumption-earnings ratio for each quintile, by year. These results are in table 5. Given potential measurement error in both the numerator and the denominator, it is unclear how much one should read into the large increase in the consumption-earnings ratio in the bottom 20% of the earnings distribution, which nearly doubled between 2006 and 2008. It does seem clear, however, that these households are consuming significantly more than their reported earnings on a monthly basis. This is true also for the second and third quintiles to a diminishing extent, where the median consumption-earnings ratio is just at or above 1. Above the median, households appear to consume less than they earn – for example consuming only one-half of their earnings in the top quintile. This distribution suggests the presence of a formal or informal borrowing mechanism for the lower tail of the earnings distribution, or sources of income not reported in the earnings variable. We will investigate these financial arrangements more below.

Table 5: Household Real Consumption-Earnings Ratios by Earnings Quintile

Quintile	2006	2008	2009
1	3.6	7.4	7.7
2	1.4	2.0	2.9
3	1.1	1.3	1.5
4	0.7	0.7	1.0
5	0.6	0.4	0.5

6 Quantitative Analysis

6.1 Quantitative Model and Omitted Channels

We begin by analyzing steady states of a version of the model where all households have permanent types, so that wage earners cannot simultaneously be self-employed. This is achieved by a combination of idiosyncratic shocks (s^E, s^W) described below. That is, in addition to firms and farmers, our households will be of two types: wage earners (in the private and public sectors) and non-agricultural household enterprises. This version of the model severs some interesting channels of interaction that will ultimately be important, but it allows to isolate other interactions more cleanly. Below we calibrate the model and compute its steady state, then examine the impacts of a few macroeconomic shocks and policies by comparing steady states. After this, we will move on to transition path analysis of the policies.

Several assumptions of our general model, as well as features of the nested model we consider in this section, lead to the omission of several channels that would be important in the transmission of shocks that we study here. First, notice that by separating households into permanent wage-employment and self-employment types, we do not allow flow in and out of household enterprise sector, and there is no flow in and out of the agricultural sector, which is represented solely by self-employed farmers. The lack of agriculture transition would be an issue in the study of any long-run horizons, but in the short run, it is reasonable to assume, and shown empirically, that mobility out of agriculture is slow to occur. However, the transition between non-agricultural self-employment and wage employment is more common, as is shown also in our data. Many wage-employed workers also work part time in household enterprises. The general version of our model will address this.

Second, we have assumed to date that the good produced by public employees does not play any productive role and does not transform into a public good enjoyed by consumers. This will clearly impact results having to do with public employment; we will relax this assumption going forward.

Third, the segmentation of financial markets implies a limited interaction between the borrowing and saving of households and the productive sector represented by firms. This means that fluctuations in the interest rate that may result from increases in idiosyncratic uncertainty, say, do not translate to movements in firm production and the like. This can be relaxed in the future, for example, by allowing household enterprises invest in the productive asset such as capital.

6.2 Calibration

In this section we discuss the calibration strategy, using macro-level and household-level data from Ghana. We start by discussing estimation of the income process, which is a challenge because of many data restrictions. Then we go over the more standard parts of calibration.

6.2.1 Idiosyncratic Shocks to Productivity

In the model, households and farmers are subject to idiosyncratic productivity shocks. For farmers, these shocks s determine the size of their output in a given period. For households, the shocks $s = (s^E, s^W)$ determine whether the household has wage-earning workers (shock s^E), and how productive the workers are, regardless of whether they are self-employed or wage-earning. In particular, if a household is a wage earner, it receives earnings $s^W w$ in a given period, while if it is self-employed, its output is equal to $s^E z^o F(h^o, s^W)$. What we observe in the data is the entire amount of earnings (per month), either $s^W w$ or $s^E z^o F(h^o, s^W)$, depending on employment type.[2] Given a wage (constant in steady state) and aggregate state of productivity, these earnings imply an underlying distribution of idiosyncratic shocks s.

As we mentioned, below we study the version of the model where household enterprises and wage earners are separate households. That is, the shock s^E is allocated randomly and *permanently* such that some households have $s^E = 0$, while others draw s^E from a nontrivial distribution. If $s^E = 0$, then s^W is drawn from a nontrivial distribution such as the one described above. If $s^E \neq 0$, then s^W is 0. That is, household enterprise owners never become wage earners, and vice versa. Moreover, we establish the distribution of productivity shocks as an arbitrary one, with states $s = (0.9, 1, 1.1)$ and a transition matrix imposed as in table 6. We do this because our data do not yet allow us to calibrate the shocks for a large portion of the population covering the rural/agricultural sector. However, the transition matrix is similar to what we observe in the data for urban households, shown below.

Table 6: **Current Calibration – Productivity Shock Transitions**

	1	2	3
1	0.5	0.25	0.25
2	0.3	0.4	0.3
3	0.25	0.25	0.5

From the urban panel survey, we can demonstrate how we can use longitudinal data on

[2]The household enterprises in the model do not incur production costs, since inputs other than their own labor are not in the production function, so there is no notion of profit net of cost in the model. In the data, we measure earnings net of costs for the self-employed. Because there is no meaningful way to add back production costs, and because for the wage-employed, the earnings are gross (say, of taxes), we map the model and empirical measures of earnings as they are.

household earnings to characterize variation in earnings, which implies a distribution of productivity shocks which are not directly observed. Relative to standard macroeconomic techniques for estimating idiosyncratic income risk in developed countries, we face severe data limitations which will limit the accuracy of the estimation. In our panel dataset of urban households, we are able to look at the transition between earnings quintiles from year to year. Typically this is not considered sufficient - many of the changes in earnings over time that we observe may be perfectly predictable to households, and thus, it is not accurate to assume that they come from unpredictable shocks. To remove predictable factors in income fluctuation, one typically controls annual income for all the observable characteristics of the households first, as well as possible relevant macroeconomic factors. However, our small sample sizes are likely to produce spurious results from such an exercise. As a first pass, we will take all income transitions as the result of shocks with the acknowledgement of the limitations of such an assumption.

For the shocks that farmers experience, we will need to examine agricultural workers, which are concentrated in rural areas and are not part of our urban survey. However, for the household sector in the model, which are in the non-resource and non-agriculture good production sector by assumption, we can take the entire sample of the urban households, which, as we showed above, are predominantly involved in activities outside agriculture and mining.

Specifically, the exercise is as follows: for the sample in the survey, we pool the households in one of five earnings quintiles in each survey year. Then, for any households that are present in two consecutive survey waves, we calculate the probabilities of staying in the same income quintile versus transitioning to any other income bin. These probabilities are then year-specific. In addition, we have also averaged these probabilities under the assumption of stationarity, and computed the average transition matrix across all the years. Since two years pass between the last two survey waves, we exclude the 2010-2012 transition, as those are two-year probabilities and so are not comparable with the annual transitions of other years.

Notice that in order to be able to compute such transitions, a household has to be present in two consecutive waves of the survey. Since attrition is an issue, this implies that we can only use a subset of the survey households for computation in each year. This is another reason why pooling the households across years yields a more stable measurement. In table 7 we present the 5 income quintiles averaged across years, measured as the median within each quintile, and the transition matrix from the pooled data. The ratio of the top earnings quintile to the first one is 20, and the top quintile is about 4 times the median. The transition matrix represents significant earnings volatility, which is not unexpected given that self-employment is so prevalent. The top and bottom earnings quintiles are the most persistent, while there is significant mobility in the middle three quintiles. The matrix does exhibit monotonicity with respect to the tails, so that the probability of moving to the adjacent income quintiles is higher than the probability of moving into higher ones.

Table 7: **Household Real Earnings Quintiles and Transition Probabilities**

Quintile	Value	Transition Probabilities					Cell size
	(US $)	1	2	3	4	5	
1	15.3	0.43	0.22	0.16	0.11	0.08	481
2	40.7	0.17	0.31	0.24	0.16	0.11	461
3	73.3	0.13	0.23	0.26	0.21	0.16	465
4	103.8	0.10	0.13	0.23	0.31	0.23	494
5	296.3	0.08	0.07	0.14	0.22	0.49	483

6.3 Standard Calibration

The period is one year and the model is calibrated to 2005 in order to isolate the effect of the increase in food prices, and the recession in 2008. In the cases where 2005 data do not exist, we choose the available year closest to 2005. Some parameters are calibrated jointly in the model, while the rest are calibrated separately.

Preferences - Households have preferences over food (f) and other, non-food, goods (o). As we discussed in the theory section, we assume that households consume both domestically produced agricultural goods (c^a), and imported agricultural goods (c^*). We select the following functional form for the household utility:

$$u(c^a, c^*, c^o) = \log((\lambda(c^a)^\rho + (1-\lambda)(c^*)^\rho)^{\frac{1}{\rho}}) + \mu \log(c^o).$$

The main reason for selecting this functional form is the work of Herrendorf, Rogerson, and Valentinyi (2013) that demonstrates that this functional form is able to match many stylized facts on structural transformation in the United States. We calibrate the share of non-food consumption μ to match household expenditure on food in Ghana, which was 52.4% of household income in 2005, according to Ghana Living Standard Survey (GLSS). We calibrate the share of domestically produced food λ and the elasticity of substitution between imported and domestic food ρ jointly with other parameters in the model. Although we cannot pin down a direct moment to match this parameter, it is related to two targets: one is the share of imported food over total export, which was 26% in 2006 according to Rakotoarisoa, Iafrate, and Paschali (2011), and the other target is the household expenditure of imported food as a share of total food consumption, which was equal to 22% in 2005, according to GLSS. The discount factor β is set to 0.96, which is the standard annual value in literature.

Agricultural Sector - We assume that the only inputs used to produce agricultural goods are land (L) and inelastically-supplied labor of small farmer households, and we match some stylized facts about land distribution in Ghana. We calibrate agricultural productivity z_a to match the average ratio of urban to rural household income, which is 1.69 according to GLSS, and we calibrate the variance of the land distribution to match the Gini coefficient in rural Ghana, which is equal to 0.40, according to Bank (2007).

Household Enterprise - We assume that another subset of households work on the household enterprises outside of agriculture, and they produce the "other" non-food good. In this sector, the only input is labor, and household enterprises have a decreasing returns to scale technology:

$$F^{H,o}(H) = s^E z^{o'} H^{\chi}.$$

We assume that household enterprises are less efficient than firms in producing non-food, and their productivity is calibrated to 90% of the firm productivity in non-food production.

External Sector - We assume that the production function of export goods, $F^{r,e}$, has decreasing returns to scale and that the external sector uses labor (H) to produce the final export good:

$$F^r(H) = p^r z^r H^{1-\alpha^1}.$$

Exported goods prices p^r and export good productivity z^r can not be identified separately. As a result, we calibrate the product $p^r z^r$ to match the share of total exports in GDP, which is 29.7% in 2006, according to AfDB and UNDP (2013). We choose the labor share $1 - \alpha_1$ to be equal 0.66, which is the standard value of the United States . We assume that capital depreciates at 6.5% per year, which is a standard value in the United States.

Numeraire Sector - We assume that the production function of the non-food sector $F^{o,e}$ is Cobb-Douglas and the inputs are capital (K) and labor (H):

$$F^o(K, H) = z^o K^{\alpha^o} H^{1-\alpha^o}.$$

We normalize TFP in this sector to one, and we set the capital share α_o to 0.33, which is the standard value in the literature. We assume that the depreciation rate of capital in this sector is again equal to 6% per year.

Prices and Wages - The price of imported food p^* is calibrated endogenously in the model to match the ratio of imported food price to domestic food price in Ghana in 2005. We calculate this relative price using data on wholesale prices and consumption provided by the Ministry of Food and Agriculture. We construct a representative basket of imported and domestically produced food, and we calculate the relative prices of these two baskets.

Private wages are endogenous in the model, but we calibrate the public wage premium according to the data. For wage employees, we have information on wages by sector. Taking the average wages of public employees divided by the weighted average wages of private employees in all sectors, we get ratios between 1.5 and 2.3, depending on the year of the survey. Because of small sample sizes and the resulting noise, we take 1.5 as the conservative estimate of the public wage premium.

Sectoral and Labor Force Shares - The demand for public labor is the share of time that a wage-earner household spends in the public sector, H^g. In GUHPS data, we find that on average 25% of urban workers report being primarily wage employees, and of these, about 7% on average are public employees. Since urban workers constitute less than one-half of the total labor force in the country, we calibrate the share of wage-earners, μ^h to be 25% of one-half, or 12%, and these workers devote $H^g = 0.07$, or 7% of their time, to public employment.

The remainder of the labor force is assumed to be self-employed. Based on GLSS, we know that 48% of the labor force are in agriculture, hence $\mu^a = 0.48$. The remaining 34% are non-agricultural household enterprises. Table 8 reports the shares labor shares that we impose in the model.

Table 8: **Population Share**

Parameter	Value
Pop. share wage earners μ^h	0.12
Pop. share agriculture μ^a	0.48
Pop. share non-ag hh. enterprises $\mu^{o,h}$	0.34
Pop. share firms μ^e	0.05

Financial Markets - We assume that agents have access to a risk-free bond, which is in zero net supply. Thus, interest rates are determined in equilibrium to clear the bond market. Agents also face borrowing constraints equal to one year of their income.

Table 9 reports the calibration values, and Table 10 reports the value of the moments and targets used to calibrate the five parameters $\{\rho, \lambda, p_r z_r, z_a.p^*\}$ with the income process.

Table 9: **Calibration**

Parameter	Value	Target
Preferences		
Discount factor β	0.96	Period = 1 year
Elast. of substitution, domestic and imported ρ	-0.2	Share imported food over total export
Weight of numeraire in utility μ	0.91	Food Expenditure
Share of imported food in utility λ	0.16	Imported food expenditure
Technology		
Agricultural productivity z^a	0.5	Share of urban to rural income
Household enterprise productivity $z^{o'}$	0.9	Share of firm's productivity
Household enterprise prod. fn. χ	0.67	Standard range (U.S)
External sector productivity $p^r z^r$	1.7	Share of total exports in GDP
External sector production fn. labor share α_1	0.62	Standard range (U.S.)
Numeraire productivity z^o	1	Normalization
Numeraire production labor share η	0.59	Standard range (U.S.)
Depreciation in the Numeraire and External sector δ	0.06	Standard range (U.S)
Relative prices and wages		
Import price p^*	11	Exchange rate $p^*/p^a = 2.71$
Public wage premium w^g/w	1.5	Earnings data

Table 10: **Calibration Targets**

Target	Data	Model
Relative price of imported and domestic produced food	2.71	2.36
Household Expenditure on imported food	0.23	0.22
Total export over GDP	0.30	0.05
Ratio of urban over rural household income	1.69	1.30
Expenditure of domestic food over expenditure of non-food goods	0.85	0.85

From Table 10 we can observe that overall the benchmark economy is able to reach the targets, with the exception of the total share of exports over the GDP, which is work in progress. The model currently clearly misses this target, as a result the export sector in the model is much smaller than the export sector in the data. In the next section, we discuss the results of our main experiment which is the increase in the price of imported food.

6.4 Results

We perform two important exercises. First, we quantify the impact of a 50% increase in real agricultural import prices on consumption of wage workers, agricultural workers, and household enterprises, and we quantify the impact of this shock on macroeconomics aggregates. Second, we propose a policy that aims to mitigate the impact of an increase in imported food price on food consumption. The policy is a subsidy of 5% on the domestic food price, designed to limit the pass-through of the import price shock to domestic prices. The way the subsidy is financed is clearly important for results; we assume that it is financed by taxing firms lump-sum.

After we perform the main policy experiment, we depart from a key estimated value of the parameter ρ in the model, which implies complementarity in the consumption of domestic and imported foods, and assume instead that they are substitutes. Under this alternative parameterization, we perform the same exercises –a 50% increase in the price of imported food, and then a domestic food price subsidy of 5%. The comparison of the results follows.

6.5 Commodity Price Shock

We first consider the impact of a 50% increase in real agricultural good prices. This is the actual change between 2003 and 2013 reported by the FAO. We take the perspective of a net importer of agricultural goods and increase the price of imported food p^*. We first quantify the impact of this increase in the price of imported food on the consumption of the three types of household in the economy, and then we quantify the impact of this price increase on the aggregates. Table 11 presents the main results with respect to consumption. The table is divided into consumption of the three goods, domestic food C^a, imported food C^*, and other good C^o. For each consumption good, we also present the consumption by each household type, where $C^{H,\cdot}$ indicates the consumption of wage workers, $C^{A,\cdot}$ indicates the consumption of farmers and $C^{S,\cdot}$ indicates the consumption of household enterprise. The first column report the level of consumption in the benchmark economy, while the second and third columns report results in percent change relative to the benchmark economy.

The main result from Table 11 is that an increase in the price of imported food p^* causes a reduction in relative price of food produced domestically, p^a decrease by 2.0%. The main force behind this result is that in our benchmark model domestic food and imported food are complements. Consequently, an increase in the price of imported food reduces demand for domestically produced food, while farmers supply more food to the market, since they consume less of it themselves. This reduces the price of domestic food. The final effect of this domestic price decrease is that the consumption of imported food decreases drastically for all consumers, while the consumption of domestic produced food increases slightly for all consumers except

Table 11: Consumption Results from an 50 % Increase in p^* and a 5 % Subsidy in p^a

Variable	Benchmark	50% increase in p^*	50% increase in p^* 5 % subsidy to p^a
$C^{H,a}$	4.6	0.4	-4.6
$C^{A,a}$	1.4	-1.1	7.1
$C^{S,a}$	0.7	0.4	-4.6
C^a	1.5	-0.3	0.7
$C^{H,*}$	0.6	-29.6	-29.8
$C^{A,*}$	0.2	-30.6	-21.3
$C^{S,*}$	0.1	-29.6	-29.9
C^*	0.2	-30.0	-25.9
$C^{H,o}$	25.2	0.0	0.4
$C^{A,o}$	7.9	-1.4	12.7
$C^{S,o}$	3.8	0.0	0.4
C^o	8.5	-0.7	6.0
p^a	4.8	-2.0	9.2
R	0.0	0.0	0.1

Note: columns 2 and 3 are % change relative to column 1.

for farmers.

With respect to changes in inequality, one important result of Table 11 is that farmers are worse off, after the increase in the price of imported food. The main reason for this result is that farms produce domestic food, and as the price of domestic food goes down, the value of their income goes down as well. So, overall farmers' consumption decreases in all three goods, while consumption of domestic produced food and other goods by wage earners and households that work in the household enterprise do not change much. Overall the total consumption of all household types decreases, while the consumption of entrepreneurs, which are small fraction of the population, increases.

In table 12 we report the impact of the increase in the price of imported food on macroeconomic aggregates. A 50% increase in the price of imported food reduces consumption of imported food by 30%. As a result, aggregate consumption decreases, but just by 3.7%. The main reason for for this difference in magnitude is that imported food accounts for only 20% of household consumption, and some of the reduction in the consumption of imported food is compensated by an increase in the consumption of domestic food, driven by falling domestic produced food prices. Output goes down by 3.3%.

Table 12: Aggregate Results from an Increase in 50 % of p^*

Variable	Benchmark	50% increase in p^*	50% increase in p^* 5 % subsidy to p^a
C	19.8	-3.7	-0.6
I	2.9	0.0	0.0
G	0.8	0.0	0.0
X	1.1	0.0	0.0
M	2.3	-30.4	-26.6
Y	22.7	-3.3	-0.5
p^a	4.7	-2.0	9.2
R	0.0	0.0	0.0

6.6 Policy Experiment: Domestic Food Consumption Subsidy

One important, and intuitive, result from an increase in the price of imported food is that overall the consumption of food goes down by 3.2%. One policy that can mitigate this effect is to subsidize the consumption of domestically produced food. This subsidy can reduce the impact of the increase in the price of imported food on the more fragile households. We assume that the government subsidizes directlydomestic food price for all consumers, and finances this subsidy by lump-sun taxation on firms, which is in line with the data that few workers in the economy pay taxes.

In the last column of table 11, we report the effect of this subsidy on the price of domestic food. Overall, even after the subsidy, the consumption of food is still below the benchmark consumption, but it is 0.30% higher than without the subsidy. The households that benefit most from this policy are farmers, because the demand for domestic food increases after the subsidy, while farmers supply less to the market because they consume more themselves. The final effect is an increase of 9% of the price of domestic food relative to the benchmark, which increases farmers' income. Farmers' total consumption increases by 13% relative to the economy without the subsidy but with the import price shock, while the total consumption of all other households, including entrepreneurs who finance the subsidy, goes down.

In the last column of Table 12, we report the results on the aggregates. Total consumption still drops a bit, but by much less than in the no-subsidy import price shock case. Clearly, in aggregate, the subsidy is a beneficial policy. Because taxation in our model is lump-sum, the large tax bill on firms does not distort any decisions on their part, so the negative impact of this increase in tax is limited. With respect to income inequality, since the subsidy is funded using resources from firms, the inequality on the top decreases: the ratio of the top to bottom deciles, $p90/p10$, drops by 0.2%. In our model, the top decile includes firms and wage earners, while the bottom decile consists of workers in non-food households enterprises. At the same time, the ratio of the median income to 10th percentile, $p50/p10$, increases by 14%. Thus, the "middle class", i.e. the median households, who in our model are farmers, is the group that benefits the most from the subsidy; however, the poorest also benefit, as their income increases by 0.5%

6.7 Sensitivity Analysis

In this section we quantify the importance of the calibration result that domestic and imported food are complements. In an additional numerical experiment, we relax this hypothesis by assuming that they are now substitutes; more precisely, we set ρ equal to 0.2, and we perform the same exercise as in the previous section. It is important to notice that by applying this change, our new "benchmark" no longer matches some moments from the Ghanaian economy, so the quantitative results from this experiment are purely theoretical in nature. The two main differences between this benchmark and the previous one are the relative price of imported food to domestic food, which is now 1.74 and previously was 3.6, and the expenditure on imported food, which is now 0.10 % of total consumption, while previously it was 20%. Overall in this new economy household spend less on imported food.

Table 13: Consumption Results from an 50 $\%$ Increase in p^* and a 5 $\%$ Subsidy in p^a when $\rho > 0$

Variable	Benchmark	50% increase in p^*	50% increase in p^* 5 % subsidy to p^a
$C^{H,a}$	4.0	0.2	-1.4
$C^{A,a}$	1.6	0.2	5.5
$C^{S,a}$	0.6	0.2	-0.5
C^a	1.5	0.2	2.4
$C^{H,*}$	0.2	-39.1	-39.2
$C^{A,*}$	0.1	-39.0	-34.9
$C^{S,*}$	0.1	-39.0	-38.6
C^*	0.2	-39.0	-36.8
$C^{H,o}$	25.5	0.0	-0.5
$C^{A,o}$	10.2	0.0	6.5
$C^{S,o}$	3.9	0.0	0.5
C^o	9.9	0.0	3.3
p^a	6.3	0.8	7.2
R	0.0	0.0	0.0

Note: columns 2 and 3 are % change relative to column 1.

Table 13 reports the distribution of consumption across households types and across goods, as in Table 11. The first important result is that the price of domestically produced food *increases* after the shock on the price of imported food. In this economy, domestically produced food and imported food are substitutes. Consequently, when the price of imported food increases, consumers switch from consuming imported food to consume more domestic food, and the consumption of the other good does not change. Table 14 reports the macroeconomics aggregates values

Table 14: Aggregate Results from an Increase in 50 % of p^* when $\rho > 0$

Variable	Benchmark	50% increase in p^*	50% increase in p^* 5 % subsidy to p^a
C	22.8	-2.0	0.1
I	2.9	0.0	0.0
G	0.8	0.0	0.0
X	1.1	0.0	0.0
M	0.8	-38.2	-36.6
Y	25.2	-1.8	0.1
p^a	6.4	0.8	7.2
R	0.0	0.0	0.0

From Table 14 we observe that total consumption decreases after the shock. Although consumption of domestic produced food now increases, it is not enough to compensate for the decrease in the consumption of imported food. As a result, output also decreases by 1.8%. However, note that this is about one-half of the decrease when imported food and domestic food are substitutes.

We perform the same 5% subsidy on the price of domestically produced food in the economy. This subsidy is again financed by lump-sum taxation paid exclusively by firms. We observe the effect of this subsidy on consumption in the last column of table 13. The first important result is that the price of domestically produced food increases even more: as before, the subsidy increases demand for domestic food from households; in addition, because domestic and imported food are substitutes, farmers want to consume more of their own product as well, thus supplying less to the market. Both forces work to increase the price of agricultural good; the increase is large enough so that wage workers and domestic enterprise workers end up consuming less domestic food, and only farmers consume more of it. However, overall, the consumption of food increases relative to the economy without subsidies. Total consumption increases by 0.1%, and output by 0.1%. Although overall output and consumption increases, there is more inequality after the subsidy: both measures of income inequality $p90/p10$ and $p50/p10$ increase. The $p90/p10$ increases by 0.02%, while the $p50/p10$ by 7.5%.

7 Conclusion

In this paper, we develop a rich general-equilibrium stochastic dynamic macroeconomic framework for studying long-term distributional effects of macroeconomic shocks on low-income countries, as well as the effects of possible policies to address these shocks. As an application, we have focused on recent commodity price shocks, to which low-income countries are particularly vulnerable. Our model economy is predominantly agricultural, with agriculture being the low-productivity sector, has a large share of household enterprises in agriculture as well as in non-food production, and a small share of wage employment. The economy features frictions to sectoral movement of labor, and a rich degree of heterogeneity of agents, which allows us to study a realistic income distribution and changes to it as a result of macroeconomic shocks and macroeconomic policies.

We calibrate the model using unique household-level data from Ghana, as well as macroeconomic data where appropriate. Under the current calibration, we perform experiments to quantify the macroeconomic and distributional effects of a 50% import price increase, in line with the recent increase in the FAO index. Under the current calibration that domestic and imported foods are weak complements; in this scenario, a 50% import price shock drives the price of domestic food slightly down, thus especially hurting incomes of the median household – the farmers . We show in sensitivity analysis that this is entirely the product of complementarity of domestic and imported food. In either scenario, the import price shock drives aggregate consumption, and output, down.

In response to the import price shock, we evaluate one policy that has been viewed as having the potential to mitigate these shocks: a 5% subsidy on domestic food consumption, financed by a nondistortionary lump-sum tax on firms, which is in line with the data that few households pay taxes. Under this taxation scenario, we find the subsidy to be beneficial; it mitigates the negative effect of import price shocks on consumption and output, and decreases inequality, both by driving the incomes of the top households down, and by lifting the incomes of median, as well as poorest, households. We leave the evaluation of alternative tax regimes that may be more distortionary, as well as of other policies, to ongoing and future work.

References

Adam, Christopher. 2011. "On the Macroeconomic Management of Food Price Shocks in Low-income Countries." *Journal of African Economies* 20 (suppl 1): i63–i99.

Adamopoulos, Tasso, and Diego Restuccia. 2011. "The size distribution of farms and international productivity differences." *Manuscript, University of Toronto*.

AfDB, OECD, and UNECA UNDP. 2013. "African Economic Outlook 2012." *Country Note Ghana*.

Aksoy, M Ataman, and Aylin Isik-Dikmelik. 2008. "Are low food prices pro-poor? Net food buyers and sellers in low-income countries." *Journal of Rural Mental Health* 32 (2): 46–79.

Attanasio, Orazio, Erich Battistin, and Hidehiko Ichimura. 2004. "What really happened to consumption inequality in the US?" Technical Report, National Bureau of Economic Research.

Attanasio, Orazio P, Erich Battistin, and Mario Padula. 2010. *Inequality in living standards since 1980: income tells only a small part of the story*. Government Institutes.

Bank, World. 2007. *World development report 2008: Agriculture for development*. World Bank.

Caselli, Francesco. 2005. "Accounting for cross-country income differences." *Handbook of economic growth* 1:679–741.

Herrendorf, Berthold, Richard Rogerson, and ?kos Valentinyi. 2013. "Two Perspectives on Preferences and Structural Transformation." *American Economic Review* 103 (7): 2752–89.

Rakotoarisoa, Manitra, Massimo Iafrate, and Marianna Paschali. 2011. *Why has Africa become a net food importer*. FAO.

Regmi, Anita, MS Deepak, James L Seale Jr, and Jason Bernstein. 2001. "Cross-country analysis of food consumption patterns." *Changing structure of global food consumption and trade*, pp. 14–22.