Differential Effects of Food Security Policies on Subsistence Farmers and the Urban Poor

Mario J. Miranda
Don F. Larson
Francis M. Mulangu
Katie Farrin*

April 4, 2020

Abstract

The Global Food Price Crisis of 2007-2011 had mixed effects on the poor in developing nations. By some estimates, the Crisis lifted nearly 24 million poor farmers out of poverty; however, it also cast 68 million net food buyers into poverty. In this paper, we analyze the distributional impacts of the Crisis and the merits of different food security policies proposed to address it, focusing on policies that employ buffer stock reserves, direct cash transfers, emergency export bans, and transportation infrastructure enhancements. Of special interest are how the impacts of these policies differ among the rural and urban poor and between importing and exporting countries. Our analysis is based on a stylized stochastic dynamic heterogeneous agent model of a developing country exposed to aggregate food production and world food price risk that is populated by rural and urban poor who suffer from "malnutrition" whenever their resources are insufficient to meet basic nutritional needs.

*The authors are, respectively: Professor, Department of Agricultural, Environmental and Development Economics, The Ohio State University; Senior Economist, Development Research Group, The World Bank; Agricultural Economist, African Center for Economic Transformation; and Agricultural Economist, Food Security and Development Branch, Market and Trade Economics Division, US Department of Agriculture Economic Research Service.

1 Introduction

Real world cereal prices began to rise dramatically in November 2006, and over the subsequent twenty months doubled relative to the stable levels they had maintained during the preceding ten years (Table 1). Cereal prices moderated over the subsequent 24 months, but in mid-2010 took another upward turn, this time rising to levels about 75% above what they had been between 1997-2006 (World Bank 2012a). The dramatic rise in the level and volatility of general food prices after 2006, known as the "Global Food Price Crisis", had impacts that varied across developing nations and between rural and urban poor. World Bank studies suggest that the higher food prices lifted nearly 24 million poor farmers out of poverty, but also cast 68 million net food buyers into poverty (Ivanic, Martin, and Zaman 2011). Worst hit were the poor whose diets rely heavily on staple grains and cereals, and who reside in net importing countries.

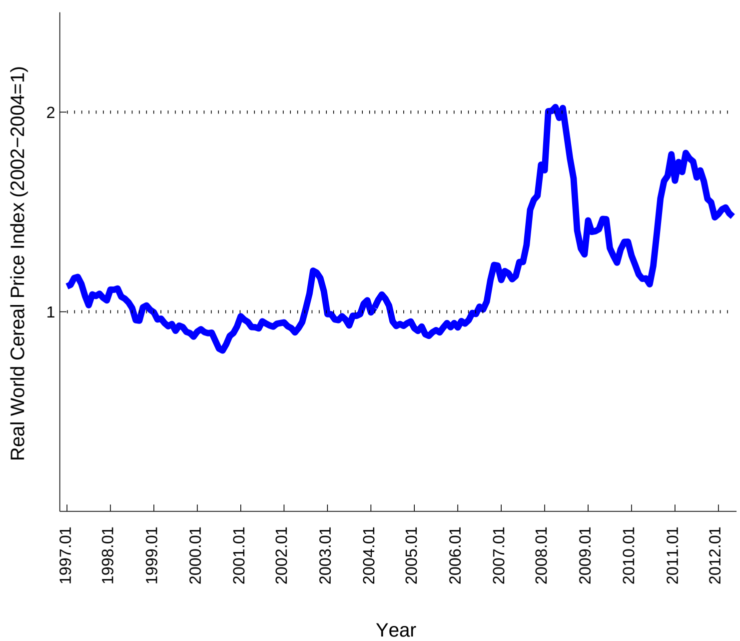

Figure 1: Real World Cereal Price, January 1997 - June 2012.

Source: World Bank Food Price Watch 2012

Numerous reasons have been offered for the dramatic increases in world food prices (Mittal 2008; von Braun and Torero 2008, 2009; Food and Agriculture Organization of the United Nations 2011c; Cororaton and Timilsina 2012). These reasons include: i) tightening of world grain balances due to sustained growth in food demand from emerging markets, coupled with stagnant agricultural productivity growth; ii) declines in global grain stocks, resulting from liberalization of agricultural markets and reduced reliance on buffer stocks to support prices in the United States and European Union; iii) diversion of land to biofuel production, particularly in the United States (corn-based ethanol), Europe (rapeseed for biodiesel), and Argentina (soybeans for biodiesel); iv) higher production costs, primarily due to increases in energy prices, which have especially impacted landlocked countries; v) hoarding, hysteria, and excessive speculation in commodity futures markets; and vi) imposition of grain export bans designed to insulate domestic markets from world price volatility, particularly in Asia.

In response to the Crisis, the development community took steps to mitigate the impact of high and volatile prices. For example, in 2008, the World Bank launched the Global Food Crisis Response Program to reduce the impact of high food prices on the poor and to help governments design sustainable mitigation policies. As of February, 2011 the Program had financed operations amounting to $1.5 billion, reaching 40 million people in 44 countries.

The Crisis also spawned a number of proposals for governmental or multi-governmental interventions in markets to promote food security. These proposals include: i) establishment of strategic reserves of food in disaster-prone areas (Hall 2010; Zoellick 2011; Wright and Cafiero 2011); ii) the use of "virtual" food inventories based on purely financial futures markets operations (von Braun and Torero 2009); ii) the use of tax and trade policies; iv) direct cash transfer program and targeted food supplements; v) increases in food production through seed and fertilizer subsidies, small-scale irrigation, and better access to finance and risk management tools; and vi) improving infrastructure, including roads, irrigation, storage, port, and distribution systems.

In the end, food crises typically arise in a developing country primarily in one of three ways: a rise in the price of traded grains, a shortfall in domestic production, or a physical disruption of trade. The relative importance of each type of risk and the probability of its occurrence depends greatly on the particular circumstance of the country or region. For example, in the Middle East and North Africa, risks associated with high prices and physical disruptions are key, while harvest failures are of primary concern in East Africa. The importance of these risks also varies across different groups of poor, depending on their sources of income an access to food. For example, poor farmers who grow most of their own food are vulnerable to catastrophic production losses from droughts and floods, but are relatively impervious to changes in food prices; urban poor who must purchase all of their food, however, are especially vulnerable to food price increases, as well as declines in wages and aggregate employment.

In this paper, we examine policies that employ buffer stock reserves, direct cash transfers, emergency export restrictions, and transportation infrastructure enhancements to promote food-security among the poor. Of special interest are how the effects of these policies differ between the rural and urban poor and between importing and exporting countries. Among the questions addressed are: i) how large should direct food safety net budgets be; ii) how large should public inventories be; iii) how should public food aid and buffer stock policies be coordinated with trade policies; and iv) how does investment in storage, transportation, and trade infrastructure affect food security?[1]

Our analysis of the costs and benefits of different food security policies is based on a stylized stochastic dynamic heterogeneous agent model of a developing country exposed to aggregate food production and world food price risk. The country is populated by significant numbers of poor rural farmers and urban laborers who subsist on a generic staple food commodity called "grain" and who suffer from "malnutrition" whenever their household production, income, and savings are insufficient to meet basic nutritional needs. To render our analysis concrete, we parameterize our model so as to reflect the stylized facts for a coastal Western African country such as Senegal or Ghana, both of which are net importers of grain and which contain major populations of urban and rural poor, making them susceptible to both domestic supply disruptions and international food price increases.

In the following section, Section 2, we summarize national policy responses to the World Food Price Crisis between 2007-2011. In Section 3, we provide a survey of historical experience and research findings on food security over the past twenty-five years. In Section 4, we briefly review the stylized facts regarding food security in Senegal. In Section 5, we present

[1]For discussions about trade and infrastructure, see Blonigen and Wilson 2008; Bougheas, Demetriades, and Morgenroth 1999.

the basic one-country stochastic dynamic market simulation model that we use in our analysis, in the absence of government policy interventions. In Section 6, we examine the impacts of different food security policies on rural and urban poor under the base-case parameterization.

2 Responses to World Food Crisis

The boom in cereal prices in 2007 and 2008, and again in 2010 and 2011, severely deteriorated terms of trade for net importing countries and sparked a global food security crisis. In addition, the poor population - even in net exporting countries - suffered from the drop in purchasing power caused by the price spikes of goods that make up a significant portion of their consumption bundle. This was especially the case in urban areas where agriculture is not a main source of income, although in rural areas it is often the case that subsistence farmers are also net consumers (Aksoy and Isik-Dikmelik 2008). In response to the upward price spiral, importing and exporting countries alike implemented policies to insulate domestic markets in an attempt to protect consumers from falling into poverty. The depth and breadth of these policy responses varied from country to country, but they can be broadly categorized into four classes of action (Brahambhatt and Christiaensen 2008):

- Trade-based policies such as export restrictions or the lowering of import tariffs for net exporters and importers, respectively.
- Domestic market-based policies such as releasing public stocks, enacting food subsidies or reducing taxes on retail goods.
- Targeted aid packages designed to safeguard the food-insecure poor from the adverse effects of high staple foods prices; and
- Medium- and long-term policies designed to increase production, including farm input subsidies, minimum price guarantees, public infrastructure investment, and agricultural research and development.

Among trade policy response mechanisms, the international community looked favorably upon countries that eschewed import restrictions in order to cushion their own consumers from price shocks. Data collected by the Food and Agriculture Organization on 81 countries suggest that the lowering of tariffs was widely applied, with 43 of the countries surveyed reporting having taken such measures (Demeke, Pangrazio, and Maetz 2009). However, interventions by net importers can be problematic due to the fact that most large cereal importers have already taken on high levels of external debt, with further action adding to fiscal stress in such countries. For this reason, international aid has increased to developing countries who have lowered tariff barriers for grains; an example of such aid is seen in the grants given by the World Bank's Global Food Price Crisis Response Trust Fund, money that has helped countries like Burundi and Sierra Leone finance additional budget allocations for measures to increase food security (Brahambhatt and Christiaensen 2008).

Additionally, for trade policy responses to be effective, tariff levels must be sufficiently high when prices increase; otherwise, reducing already low import tariffs may have little impact on stabilizing food prices. For example, Morocco and Turkey cut tariffs on wheat imports from 130 to 2.5 percent and from 130 percent to 8 percent, respectively; similarly, Nigeria cut rice import duties from 100 to 2.7 percent, while in Guinea import duties on rice were only modestly cut, from 12.75 to 2.75 percent (Demeke, Pangrazio, and Maetz 2009; World Bank 2008). Finally, while trade liberalization policies reap efficiency gains and may have an overall positive effect on domestic prices among importing countries, such policies can also be regressive. For example, the majority of imported rice in Ghana is consumed by non-poor households (Wodon, Tsimpo, and Coulombe 2008); thus, the reduction of import tariffs for rice has an effect that is biased toward wealthier segments of society.

Similarly, while the storage literature suggests that public buffer stock programs aimed at price stabilization are extremely costly and ultimately unsustainable, the combined use of trade to limit the need for government intervention and the maintenance of stocks to prevent large price increases is an often-suggested policy response (Dorosh 2009; Gouel and Jean 2012). The management and release of public stocks spurned price transmission from the international markets in China (rice) and India (wheat and rice) (Demeke, Pangrazio, and Maetz 2009). Other countries entered late in the game and incurred significant costs to build up grain reserves. Bangladesh, for example, had historically relied on private imports to meet domestic demand, but took a hit when it had to purchase half a million tons of rice when prices were on the rise; it then distributed some of the imported rice to the market at subsidized prices, while reserving part of it to build up rice stocks from 0.4 to 0.9 million metric tons between June of 2007 and 2008 (Ahmed 2008).

Export bans, on the other hand, fuelled the food price fire, thinning international markets and further exacerbating both the increase and volatility of world prices. Among 60 low-income countries surveyed by the FAO in 2008, about a quarter had some sort of export restrictions in place on food products; export restrictions were most common in East and South Asia, with 40 percent of countries implementing such measures, closely followed by Europe and Central Asia at 35 percent (Mitra and Josling 2009). Martin and Anderson 2011 cite the collective action problem that arises as a result of export bans as a catalyst for protracted high and unpredictable grain prices.

The estimated contribution of domestic price insulation on global price spikes in 2006-08 for rice and wheat is 45 and 30 percent of price increases, respectively. In addition, the use of these policies by all countries is largely ineffective in stabilizing prices, as it causes a snowball effect by which international prices rise even further than they would with just an exogenous shock to the food market. A glaring example of such an effect occurred when India announced it would ban exports of all non-basmati rice in November 2007. Vietnam, the second-largest rice exporter, followed suit, announcing a three-month ban on rice exports in March 2008, which would be followed thereafter by restricted exports. When the all-out ban was lifted in June 2008, Vietnam continued to limit sales and cut its export target from 4 to 3.5 million tons (compared to 4.5 million tons exported in 2007), and imposed a minimum export price of $800 per ton for new contracts. In a panic buy, the Philippines signed a contract to import 600 thousand tons of Vietnamese rice for $940 per ton, reflecting the continued tightness of the rice market (Blas and Landingin 2008). Whereas international rice prices had been just above $200 and steadily climbing from the beginning of 2004 (they had reached levels just under $400 per ton before India imposed its ban), April 2008 prices soared above $1100 per ton after the export restrictions by India and Vietnam and subsequent stockpiling purchase by the Philippines (Brahambhatt and Christiaensen 2008).

With respect to the latter two policy response classes, several studies indicate that increasing the scale of targeted transfers and agricultural development programs is a more effective way of compensating for consumption losses to reduce the incidence and depth of poverty, in comparison to consumer subsidies and tariff reductions (Coady, Dorosh, and Minten 2009; Arndt, Benfica, Maximiano, Nucifora, and Thurlow 2008; Valero-Gil and Valero 2008) - although such interventions may not address immediate price increases and their effects on the general population.

While agricultural development projects have been a less-frequent policy response, both the use of cash transfers and input assistance to producers was common as food prices increased. In Sub-Saharan Africa alone, 14 new cash transfer programs were implemented between 2007 and 2010 (Garcia and Moore 2012), while several countries scaled up existing operations to account for the negative effects of food price inflation. One example is the *Solidaridad* conditional cash transfer program in the Dominican Republic, which doubled the number of beneficiaries to 800 thousand and increased the value of food vouchers by 27 percent in May 2008 (Food and Agriculture Organization of the United Nations 2011a).

In examining countries' reactions to the food price crisis and the effects of such policies, implications can be drawn for food security and recommendations can be given for future policy response. One such example is found in Cuesta 2011 where classification system systematically compares government interventions by assessing coverage, cost, levels of distortion and reversibility of reactionary policies enacted after the food price crisis. A "desirable" policy package is one that (i) has broad coverage or, in the alternative, is well targeted to the poorest segments of the population; (ii) has a low fiscal cost or possibly a positive fiscal impact; (iii) creates only small distortions or generates positive incentives; and (iv) is easily reversible after completion of its goal. Policies tagged as predominantly desirable include expansion of conditional cash transfer (CCT) programs, tariff reduction and the provision of agricultural support services; policies that generate undesirable impacts include export restrictions, producer subsidies, price controls and public procurement of food stocks. Overall, the recent lessons learned emphasize maintaining open markets, supplementing trade with a modest level of national reserves, targeting vulnerable populations and investing in long-term projects to increase agricultural productivity, especially in developing countries.

3 Historical Experience with Buffer Stocks

Five international commodity price stabilization agreements were launched between 1954 and 1980, including three (for tin, cocoa, and rubber) that relied on managed buffer stocks to smooth international prices. Numerous national governments also launched domestic commodity price stabilization programs based on buffer stocks. For example, the European Union, Japan and the United States all employed government-controlled inventories to help manage commodity prices, and buffer stock schemes were launched in Bangladesh, India, Indonesia, the Republic of Korea, Mexico and the Philippines. In 1969, the International Monetary Fund (IMF) established a Buffer Stock Financing Facility to provide lending support to the stabilization efforts. The Common Fund for Commodities was established to provide liquidity to international stabilization programs under a United Nations initiated Integrated Program for Commodities established to stabilize the prices of ten core commodities in 1975 (Larson, Anderson, and Varangis 2004; Knudsen and Nash 1990.)

The keen interest in managed commodity buffer stocks gave rise to studies that focus on using commodity inventories to smooth prices and producer incomes. A conceptual motivation for stabilization policies is formalized in Massell 1969, 1970 who argued that commodity price stabilization could potentially generate welfare benefits that could be shared among producers and consumers. Other studies focused on the determinants of commodity price risk and the role of competitive storage. A series of theoretical and empirical studies emerged to suggest that average welfare gains from commodity price stabilization were small, relative to changes in average price levels (Gardner 1979; Newbery and Stiglitz 1981). This is partly because public storage can crowd out stabilizing private storage and trade (Wright and Williams 1982; Miranda and Helmberger 1988).

Much of the research literature and practical experience revealed that even well-run buffer stock schemes face major technical problems. Wright and Williams 1982 used a storage model to explain the widely observed failure of commodity stabilization schemes. Empirical studies also suggested that even well-managed stabilization schemes were subject to eventual bankruptcy, even when hedged in financial markets (Deaton and Laroque 1992). These technical problems were exacerbated by political economy problems that often converted stabilization programs into programs to defend high price levels or extract rents from producers (Bardsley 1994). By the 1990s the stabilization component of the international commodity agreements were no longer in force and Gilbert 1996 gave an obituary notice.

As objections grew toward policies aimed at managing prices, a separate literature emerged on the consequences of commodity risks for vulnerable households and governments. This is also a large literature centered on the role of risk-mitigation and adaptation strategies, rural livelihoods and forms of formal and informal insurance (Larson, Anderson, and Varangis 2004; Dercon 2005). Topics related to storage and trade are relevant here, since these are the market mechanisms that work to automatically smooth prices due to supply and demand shocks.

When physical supplies are uninterrupted, reliance on trade and private storage is usually much more efficient than relying on government inventories to buffer demand and supply shocks (Dorosh 2008). World markets have the potential to diversify away volatility by pooling risks across many countries. This can change however when there are risks of physical disruptions from sources such as armed conflicts and lawlessness, sovereign risks from export bans, or simple logistical constraints. It is perhaps most common to think of disruptions occurring at national borders; however, logistical constraints to providing food in response to harvest shortfalls in remote areas present a similar problem. For this reasons, countries and food relief agencies invest heavily in understanding the logistics of domestic food delivery systems (Thomas and Fritz 2006; Van Wassenhove 2006).

Though strategic and precautionary public stores are often used, there are few empirical studies that examine the trade-off between trade, storage and logistical bottlenecks. Instead, most strategic storage papers deal primarily with political and national security issues (Victor and Eskreis-Winkler 2008; Fan and Zhang 2010). This creates a knowledge gap for policy makers, since other forms of investment, including investments that improve trade corridors or expand irrigation, can be viewed as partial substitutes to investments in public storage.

There are a few studies in which trade and storage are jointly modelled, finding both spatial and temporal equilibriums. For example, Makki, Tweeten, and Miranda 1996 and Makki, Tweeten, and Miranda 2001 explore the roles of trade, government policy and competitive storage in smoothing consumption in the face of harvest shocks. Brennan, Williams, and Wright 1997 examine storage in a model of spatially separated supply points linked by a rail transportation network in Western Australia. Using mathematical programming techniques, the authors showed how capacity constraints led to temporary discontinuities in trade with consequences for local storage and prices. Larson 2007 looks at spatial and temporal equilibriums using data on prices and inventories from the London Metals Exchange.

4 Food Security in Senegal

Senegal is a low-lying country on the West African coast with a population of about 13 million people, one quarter of which live on less than $2 per day (World Bank 2012b). About 70 percent of the population relies primarily on agriculture for income (Food and Agriculture Organization of the United Nations 2011b) and about 20 percent of the population lives in Dakar, the nation's capital and its major seaport. The Food and Agriculture Organization (FAO) estimates that about 15.5 percent of the land in Senegal is arable, which works out to less than a third of a hectare per person.

Senegal is a food deficit country. Senegal produced 58 percent of its food needs between 2002-2007, with grains accounting for a significant portion of the calories in an average diet (World Food Programme 2008). Rice accounted for more than 30 percent of the available calories in 2007 and wheat and maize together accounted for another 20 percent (Food and Agriculture Organization of the United Nations 2011b). These staple crops are even more important for the poor, who are less able to afford meat and milk. Most land planted to cereals in Senegal is planted to millet, followed by maize, sorghum, and rice in importance. Agricultural production is subject to abundant risks, primarily from droughts and periodic weather events (heugs) that bring flooding and high winds. Invasions of locusts occurred in 7 regions between 1998 and 2004 (World Food Programme 2008; Cafiero, Larson, and Wright Undated). An isolated but long-running dispute also threatens food production in the Casamance region.

Until recently, most efforts to mitigate food vulnerability have focused on managing the risks posed by low incomes and irregular production. For example, in 2007, the Government of Senegal, in collaboration with the WFP, launched a school feeding programs in four regions of Senegal where malnutrition rates are especially high. The program was meant to benefit nearly 960,000 Senegalese (World Food Programme 2008). However, beginning in 2008 and extending into 2010, Senegal faced a different type of risk as the price of imported food rose dramatically. In response, the WFP modified a second program targeted regionally as part of a package of post-conflict relief actions. As domestic prices rose in concert with the prices of imported rice, wheat, maize and sorghum, a rapid assessment suggested that upwards of 40 percent of the rural poor were at risk of malnutrition. Even so, the program, which was slated for scaling up in July of 2008 did not get underway until

September, due to low stocks of grain.

5 Single-Country Model

Consider a developing country with significant numbers of poor rural "farmers" and poor urban "laborers" who subsist on a staple food commodity called "grain". The country is divided into a rural "interior", in which all domestic grain production takes place, and an urban "port", which is directly connected to both the interior and the world grain market via a capacitated transportation network (see Figure 2).[2]

Poor farmers reside in the rural interior and consume most of the grain grown on their farms, selling their surplus when on-farm production exceeds household needs and using their savings to purchase grain when household needs exceed on-farm production. Poor laborers reside in the urban port, earning non-agricultural income that they use to purchase grain and drawing on their savings whenever income is insufficient to meet household nutritional needs. Poor farmers and laborers whose production, income, and savings are insufficient to acquire the quantity of grain required to meet basic nutritional needs are said to be "malnourished".

5.1 The Rural Interior

The rural interior, in which all domestic production takes place, is inhabited by poor farmers, commercial farmers, and non-poor consumers. Each period begins with a random realization of aggregate grain production Q, a proportion γ of which is produced by N_f poor, food-insecure farmers and the remainder of which is produced by commercial farmers. Rural non-poor consumers are food-secure and demand a quantity of grain $D_r(p_r)$ that strictly decreases as the rural market price p_r increases.

The typical poor farmer must consume a quantity q^* of grain each period to avoid malnutrition. He begins each period with pre-determined levels of new production q_f and cash savings s_f. If on-farm grain production exceeds household needs, $q_f > q^*$, the farmer sells his surplus $q_f - q^*$ and saves the cash proceeds $p_r(q_f - q^*)$. If on-farm grain production falls short of household needs, $q_f < q^*$, the farmer draws on his savings to purchase grain.

[2]Think Senegal or Ghana, for example.

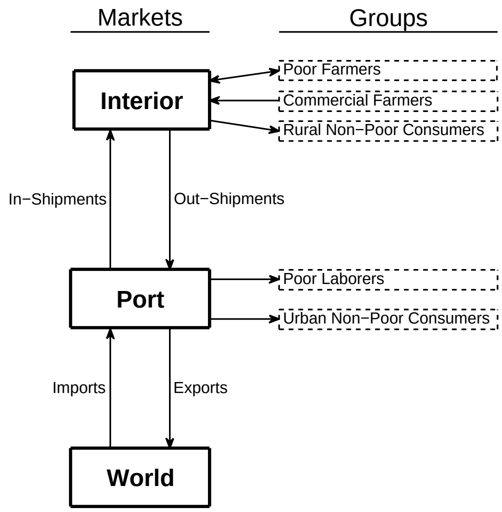

Figure 2: Flow of Grain Between Markets, Producers, and Consumers.

If the farmer possesses sufficient savings to meet his nutritional needs, $p_r(q^* - q_f) \leq s_f$, he consumes the required quantity q^*, spending $p_r(q^* - q_f)$ of his savings; if the farmer lacks sufficient savings to meet his nutritional needs, $p_r(q^* - q_f) > s_f$, he spends his entire savings on grain, consuming a quantity $q_f + s_f/p_r < q^*$ and entering a state of malnutrition. The typical poor farmer's individual demand for grain and the change in his savings resulting from market transactions may be succinctly expressed as

$$d_f = \min\{q^*, q_f + s_f/p_r\}$$

and

$$\Delta s_f = \max\{p_r(q_f - q^*), -s_f\}.$$

The many poor farmers who reside in the interior behave as the typical poor farmer, but are heterogeneous with respect to savings as a result of having experienced distinct, idiosyncratic production shocks over time. In particular, the typical poor farmer's production satisfies

$$q_f = q\epsilon_f$$

where

$$q = \frac{\gamma Q}{N_f}$$

is per-capita grain production among poor farmers and ϵ_f is a positive shock with mean 1 that is specific to the individual farmer. The idiosyncratic production shocks ϵ_f are independently and identically distributed across poor farmers and have a common cumulative distribution function G_f. The number of poor farmers, moreover, is assumed to be sufficiently large that the idiosyncratic shocks are fully diversifiable. As such, if $F_f(s)$ denotes the proportion of poor farmers who begin the period with savings less than or equal to s, one may aggregate individual demands to derive the market-level demand for grain among poor farmers

$$D_f(p_r; q, F_f) = N_f \int \min\{q^*, q\epsilon + s/p_r\} dG_f(\epsilon) dF_f(s).$$

Market-level demand for grain among poor farmers is a non-increasing function of the rural price p_r and depends on predetermined per-capita production q and distribution of savings F_f among poor farmers.

A poor farmer saves only a fraction $\rho_f < 1$ of his disposable income, spending the remainder on non-grain food and non-food goods. Given that idiosyncratic production shocks are independent and fully diversifiable across poor farmers, it follows that the proportion of poor farmers who begin next period with savings less than or equal to s' is given by

$$\begin{aligned} F'_f(s') &= \int \Pr\{\rho_f \left(s + p_r(q\epsilon - q^*)\right) \leq s' \mid s, p_r, q\} dF_f(s) \\ &= \int G_f \left(\frac{s'/\rho_f - s}{q p_r} + \frac{q^*}{q} \right) dF_f(s). \end{aligned}$$

Figure 3 illustrates how per-capita demand for grain among poor farmers varies with production and savings. In a typical year (blue), in which aggregate production is normal and farmers possess modest savings, the quantity of grain demanded is a declining function of the rural market price, but strictly less than the nutritional requirement q^*, indicating that, due to idiosyncratic variations in production and savings across farmers, some proportion of poor farmers cannot meet the minimum nutritional requirement and the proportion grows with the market price. The demand curve in a typical year also is highly inelastic, given that poor farmers fulfill most of their nutritional needs by consuming grain grown on the farm, rather than by purchasing it at the market price. In a year in which farmers have no savings (green), perhaps due to a run of bad harvests, the quantity of grain demanded is less than in a typical year and demand is perfectly inelastic, indicating that poor farmers meet their nutritional needs exclusively by consuming grain grown on farm production, since they lack the cash to buy grain on the market. In a year in which farmers experience low production (red), but possess modest savings, the quantity of grain demanded is less than in a typical year, but demand is more elastic because poor farmers must rely on savings and market purchases to meet nutritional needs.

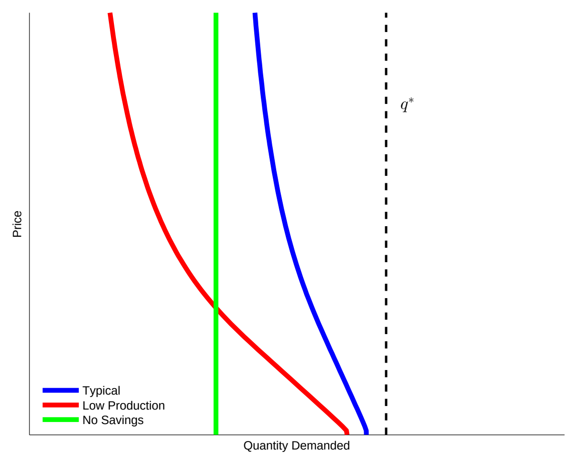

Figure 3: Poor Farmer Per-Capita Demand

5.2 The Urban Port

The urban port is inhabited by poor, food-insecure laborers and non-poor, food-secure consumers. Each period begins with a random realization of aggregate urban income Y, a fraction γ_l of which is earned by N_l laborers and the remainder of which is earned by N_u food-secure non-poor urban consumers who demand a quantity of grain $D_u(p_u)$ that strictly decreases as the urban market price p_u increases.

The urban poor, like the rural poor, subsists on grain and must individually consume a quantity q^* to avoid malnutrition. The typical poor urban laborer begins each period with pre-determined levels of income y_l and cash savings s_l. If the laborer earns sufficient income to meet his nutritional needs, $y_l > p_u q^*$, he consumes the required quantity of grain q^* and saves the excess income $y_l - p_u q^*$. Otherwise, the laborer draws on his savings to purchase grain. If the laborer possesses sufficient savings to meet his nutritional needs, $y_l + s_l \geq p_u q^*$, he purchases and consumes q^*, spending $p_u q^* - y_l$ of his savings; if the laborer lacks sufficient savings to meet his nutritional needs, $y_l + s_l < p_u q^*$, he spends his entire income and savings on grain, consuming a quantity $(y_l + s_l)/p_u < q^*$ and entering a state of malnutrition. The poor laborer's individual demand for grain and the change in his savings resulting from market transactions may be succinctly expressed as

$$d_l = \min\{q^*, \frac{y_l + s_l}{p_u}\}$$

and

$$\Delta s_l = \max\{y_l - p_u q^*, -s_l\}.$$

The many poor laborers who reside in the urban port behave as the typical poor laborer, but are heterogeneous with respect to savings as a result of having experienced distinct, idiosyncratic income shocks over time. In particular, the typical poor laborer's income satisfies

$$y_l = y\epsilon_l$$

where

$$y = \frac{\gamma_l Y}{N_l}$$

is per-capita income among poor laborers and ϵ_l is a positive shock with mean 1 that is specific to the individual laborer. The idiosyncratic income shocks ϵ_l are independently and identically distributed across poor laborers and have a common cumulative distribution function G_l. The number of poor laborers, moreover, is assumed to be sufficiently large that the idiosyncratic shocks are fully diversifiable. As such, if $F_l(s)$ denotes the proportion of poor laborers who begin the period with savings less than or equal to s, one may aggregate individual demands to derive the market-level demand for grain among poor laborers

$$D_l(p_u; y, F_l) = N_l \int \min\{q^*, \frac{y\epsilon + s}{p_u}\} dG_l(\epsilon) dF_l(s).$$

The market-level demand for grain among poor laborers is a non-increasing function of the urban price p_u and depends on pre-determined per-capita income y and distribution of savings F_l among the poor laborers.

A poor laborer saves only a fraction $\rho_l < 1$ of his disposable income, spending the remainder on non-grain foods and non-food goods. Given that idiosyncratic income shocks are independent and fully diversifiable across poor laborers, it follows that the proportion of poor laborers who begin next period with savings less than or equal to s' is given by

$$\begin{aligned} F_l'(s') &= \int \Pr\{\rho_l(s + y\epsilon - p_u q^*) \leq s' \mid s, p_u, y\} dF_l(s) \\ &= \int G_l \left(\frac{s'/\rho_l - s + p_u q^*}{y} \right) dF_l(s). \end{aligned}$$

Figure 4 illustrates how per-capita demand for grain among poor laborers varies with income and savings. In a good year (blue), in which income and savings are relatively high, the quantity of grain demanded is a declining function of the rural market price, but strictly less than the minimum nutritional requirement q^*, indicating that, due to idiosyncratic variations in income and savings, some proportion of poor laborers cannot meet the minimum nutritional requirement and the proportion grows with the market price. In a bad year (red), in which the income and savings are relatively low, the quantity of grain demanded is less than in a good year. The demand for grain among poor urban laborers, in bad and good years, is more elastic than the demand among the rural poor, given that poor laborers fulfill their grain consumption needs strictly through market purchases, whereas poor farmers tend to rely on grain grown on their farms.

5.3 Domestic Market Equilibrium

The rural interior is linked to the urban port via a transportation network that exhibits fixed unit costs and capacities. Whenever there is surplus production in the rural interior, the surplus X_{ru} is out-shipped to the urban

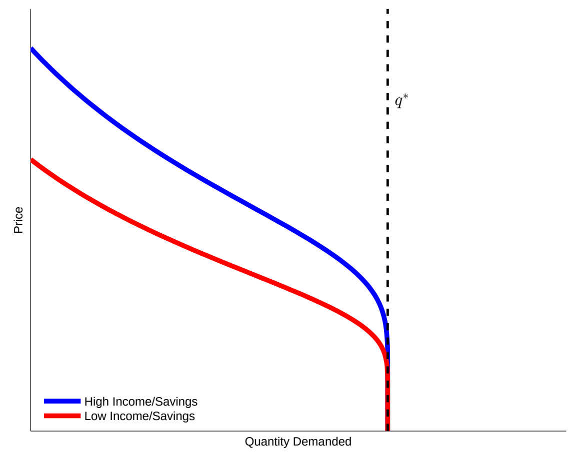

Figure 4: Poor Laborer Per-Capita Demand

port and arbitrage ensures that the rural price p_r equals the urban price p_u less the unit transportation cost τ_{ru}, unless the out-shipment capacity $\bar{X}_{ru}$ is binding. Whenever there is deficit production in the rural interior, the deficit X_{ur} is met by in-shipments from the urban port and arbitrage ensures that the rural price p_r equals the urban price p_u plus the unit transportation cost τ_{ur}, unless the in-shipment capacity $\bar{X}_{ur}$ is binding.

Similarly, the urban port is linked to the world market via a transportation network that exhibits fixed unit costs and capacity limits. Whenever there is surplus domestic production, the surplus X_{uw} is exported to the world market and arbitrage ensures that the urban price p_u equals the world price P less the unit export cost τ_{uw}, unless the export capacity $\bar{X}_{uw}$ is binding. Whenever there is deficit domestic production, the deficit is met by imports X_{wu} from the world market and arbitrage ensures that the urban price p_u equals the world price P plus the unit import cost τ_{wu}, unless the import capacity $\bar{X}_{wu}$ is binding.

In summary, arbitrage between markets gives rise to the following equilibrium complementarity conditions:

$$\begin{aligned}
&0 \le X_{ru} \le \bar{X}_{ru} \quad \perp p_u - p_r - \tau_{ru} \\
&0 \le X_{ur} \le \bar{X}_{ur} \quad \perp p_r - p_u - \tau_{ur} \\
&0 \le X_{uw} \le \bar{X}_{uw} \quad \perp P - p_u - \tau_{uw} \\
&0 \le X_{wu} \le \bar{X}_{wu} \quad \perp p_u - P - \tau_{wu}.
\end{aligned} \tag{1}$$

Here, the notation $0 \le X \le \bar{X} \perp \pi$ indicates that a) X is bounded below by 0 and above by $\bar{X}$, b) $X > 0 \Rightarrow \pi \ge 0$, and c) $X < \bar{X} \Rightarrow \pi \le 0$. Thus, the first complementarity condition precludes opportunities to profit, in equilibrium, from transporting grain from the rural interior to the urban port. Specifically, the marginal profit from transporting one unit of grain from the rural interior to the urban port, $p_u - p_r - \tau_{ru}$, cannot be positive if $X_{ru} < \bar{X}_{ru}$, for then profits could be increased by increasing shipments; similarly, the profit from transporting one unit of grain from the rural interior to the urban port cannot be negative if $X_{ru} > 0$, for then profits could be increased by decreasing shipments. The three other complementarity conditions afford similar interpretations.

Material balance between total grain availability and disappearance must be preserved in both in the rural interior and the urban port. As such, it follows that

$$\begin{aligned}
&Q + X_{ur} = D_r(p_r) + D_f(p_r; q, F_f) + X_{ru} \\
&X_{wu} + X_{ru} = D_u(p_u) + D_l(p_u; y, F_l) + X_{uw} + X_{ur}.
\end{aligned} \tag{2}$$

The four complementarity conditions (1) and the two material balance equations (2) fully characterize the four inter-market flows, X_{ru}, X_{ur}, X_{uw}, and X_{wu}, and two equilibrium prices, p_r and p_u, in any period, given the exogenous realizations of aggregate production Q, aggregate urban income Y, and the world price P, and given the predetermined distributions of savings among poor farmers F_f and laborers F_l. Table 1 summarizes the exogenous stochastic driving variables of the simulation model and Table 2 summarizes the endogenous variables of the simulation model. Both tables also give the mathematical symbols used to represent the variables in his paper and the names assigned to them in the Matlab program used to perform the model simulations (See Appendix **??**).

Table 1: Stochastic Driving Variables

Variable	Matlab Name	Description
Exogenous		
Q	`Q`	Aggregate production
Y	`Y`	Aggregate income
P	`P`	World grain price
Derived		
q	`q`	Per-capita production, poor farmers
y	`y`	Per-capita income, poor laborers

Table 2: Endogenous Variables

Variable	Matlab Name	Description
Pre-Determined		
F_f	`Ff`	Savings distribution, poor farmer, beginning of period
F_l	`Fl`	Savings distribution, poor laborer, beginning of period
Current		
X_{ru}	`Xru`	Shipments, rural to urban
X_{ur}	`Xur`	Shipments, urban to rural
X_{uw}	`Xuw`	Shipments, urban to world
X_{wu}	`Xwu`	Shipments, world to urban
p_r	`pr`	Price, rural interior
p_u	`pu`	Price, urban port
Derived		
m_f	`mf`	Malnutrition rate, poor farmers
m_l	`ml`	Malnutrition rate, poor laborers

5.4 World Market

The developing country is assumed to be sufficiently small that supply and demand conditions in the country do not affect world prices. As such, the world grain price is taken to be purely exogenous to the decisions undertaken by producers and consumers in the developing country. To complete our model, we posit that the world grain price P is generated in commodity market governed by competitive storage undertaken by rational, profit-maximizing storers (Wright and Williams 1982). We calibrate the model so that world grain price P generated by the model exhibits the key features of world food commodity prices: occasional severe up-swings, muted downside variation, high secular correlation when price are low, and low secular correlation when prices are high.

Each period begins with a random realization of RoW grain production Q_w and a pre-determined amount of stocks Z in storage. Denoting demand in the RoW by $D(P)$ and ending stocks by Z', preservation of material balance between total grain availability and total grain disappearance in the RoW implies that:

$$Q_w + Z = D(P) + Z'.$$

Rational, expected-profit maximizing storers enforce the inter-temporal price equilibrium, giving rise to the complementarity condition

$$0 \leq Z' \leq \bar{Z} \perp \delta EP' - P - \kappa.$$

Here, κ denotes the fixed unit cost of storage, δ denotes the per-period discount factor, $\bar{Z}$ denotes world storage capacity, and EP' denotes the current expectation of next period price. The complementarity condition maintains that the expected marginal profit from storing must nonnegative as long as storage capacity is not exhausted, for otherwise storers could increase expected profits by holding more stocks; similarly, the expected marginal profit from storing must be nonpositive as long as stocks are being held, for otherwise storers could increase expected profits by reducing their stockholding.

The rational expectations equilibrium may be characterized by recognizing that the world price P is a function of incoming stocks of grain Z and RoW production Q_w:

$$P = f(Z; Q_w).$$

As such, the expected price next period is simply a function of the

$$EP' = g(Z) = E_{Q_w} f(Z; Q_w).$$

The RoW model will be solved numerically using the orthogonal polynomial collocation techniques described in Miranda and Fackler 2002. However, for the purposes of the current draft of the paper, we simply assume that the world price is i.i.d. and can assume two values (low and high) with specified probabilities.

5.5 Measuring Malnutrition

Given the equilibrium rural price and savings distribution among poor farmers, the malnutrition rate among poor farmers, that is, the proportion of poor farmers whose on-farm production $q\epsilon$ and savings s are insufficient to meet nutritional needs q^* at the rural market price p_r, may be computed as follows:

$$\begin{aligned} m_f(p_r, q, F_f) &= \int \Pr\{q\epsilon + s/p_r < q^* \mid s, p_r, q\} dF_f(s) \\ &= \int G_f\left(\frac{q^* - s/p_r}{q}\right) dF_f(s) \end{aligned}$$

Similarly, given the equilibrium urban price and savings distribution among poor laborers, the malnutrition rate among laborers, that is, the proportion of laborers whose income $y\epsilon$ and savings s are insufficient to meet nutritional needs q^* at the urban market price p_u, may be computed as follows:

$$\begin{aligned} m_l(p_u, y, F_l) &= \int \Pr\{y\epsilon + s < p_u q^* \mid s, p_u, y\} dF_l(s) \\ &= \int G_l\left(\frac{p_u q^* - s}{y}\right) dF_l(s) \end{aligned}$$

Figure 5 illustrates how malnutrition among poor rural farmers varies with the rural price. In a typical year (blue), in which aggregate production is normal and poor farmers possess modest savings, the malnutrition rate is positive and increasing with the rural market price, indicating that, at any time, there is always some proportion of the poor farm population cannot meet the minimum nutritional requirement due to idiosyncratic variations in production and savings; the proportion, moreover, naturally rises with the market price. In a year in which farmers have exhausted their savings (green), perhaps due to a run of bad harvests, the malnutrition rate is higher than in a typical year. The malnutrition rate, moreover, is unresponsive to price, due to the fact that poor farmers are forced to meet their nutritional needs exclusively through on farm production because they lack the cash to buy grain on the market. In a year in which farmers experience low production (red), but possess modest savings, the malnutrition rate is higher than in a typical year, but malnutrition is more responsive to price because poor farmers employ some of their savings to meet nutritional needs via market purchases of grain.

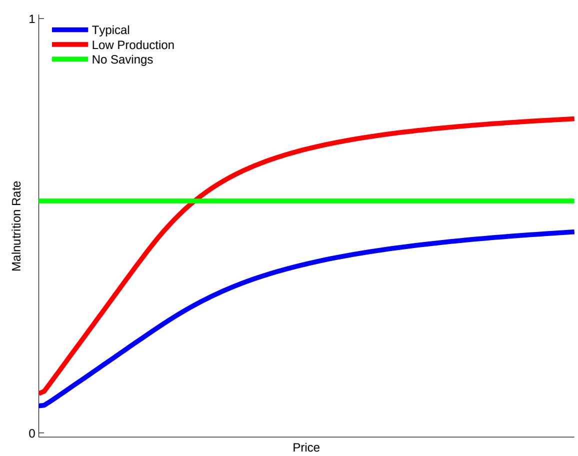

Figure 5: Local Price and Poor Farmer Malnutrition

Figure 6 illustrates how malnutrition among poor urban laborers varies with the urban price. Whether it is a good year (blue), in which income and savings are relatively high, or a bad year (red), in which income and savings are relatively low, malnutrition among urban laborers is an increasing function of the price, reflecting the fact that urban laborers must purchase all of their grain on the market. Malnutrition, quite naturally, is greater at any price in a bad year than in a good year. Regardless of income and savings, malnutrition will disappear at low prices, but will approach 100% of the poor urban labor populations at high prices.

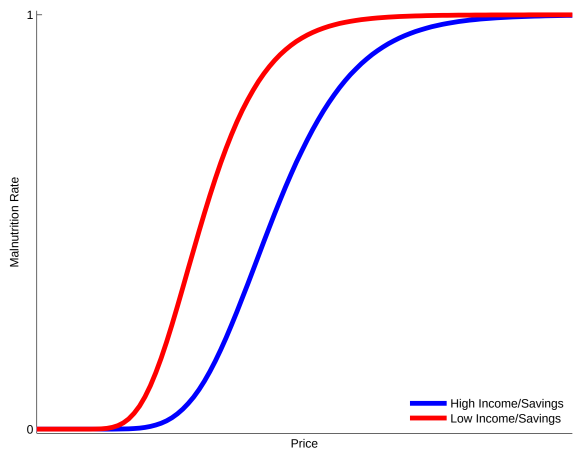

Figure 6: Local Price and Poor Laborer Malnutrition

5.6 Model Parameterization

To perform numerical simulations of the model, we need to: i) specify functional forms for the demand functions of the rural and urban poor, D_r and D_u; ii) specify the distributions of the idiosyncratic farm production and laborer income shocks, ϵ_f and ϵ_l; and iii) specify the values of the remaining model parameters. Ultimately, we wish to posit functions and parameter values that are reflective of the stylized facts of production, consumption, and trade in Senegal, Ghana, or whatever country or countries we choose to simulate in our analysis. However, in this draft of our report, we parameterize the model with artificial values as follows.

5.6.1 Non-Poor Demand

We posit that the demand for grain among rural non-poor consumers is given by

$$D_r(p_r) = N_r q^*(1 + \alpha_r p_r^{\beta_r}).$$

Here, N_r is the number of food-secure, non-poor consumers residing in the rural interior; α_r is the proportion by which per-capita consumption of the typical non-poor rural consumer exceeds the minimum nutritional requirement q^* at a price of 1; and β_r is the elasticity of demand for consumption beyond basic nutritional needs among non-poor rural consumers.

We also posit that the demand for grain among urban non-poor consumers is given by

$$D_u(p_u) = N_u q^*(1 + \alpha_u p_u^{\beta_u}).$$

Here, N_u is the number of food-secure, non-poor consumers residing in the urban port; α_u is the proportion by which per-capita consumption of the typical non-poor urban consumer exceeds the minimum nutritional requirement q^* at a price of 1; and β_u is the elasticity of demand for consumption beyond basic nutritional needs among non-poor urban consumers.

5.6.2 Idiosyncratic Shocks

We posit that the idiosyncratic grain production and urban income shocks, ϵ_f and ϵ_l, both are lognormally distributed with mean of 1, with volatilities σ_q and σ_y, respectively. Under these assumptions, per-capita demand among poor rural farmers possessing a given level of savings s is

$$\begin{aligned} d_f(p,s) &= \int_0^\infty \min\{q^*, q\epsilon + q_s\} dG_f(\epsilon) \\ &= \int_x^\infty q^* dG_f(\epsilon) + \int_0^x q\epsilon dG_f(\epsilon) + \int_0^x q_s dG_f(\epsilon) \\ &= q^* + (q_s - q^*)\, \Phi\left(\log x/\sigma_q + \sigma_q/2\right) + q\Phi\left(\log x/\sigma_q - \sigma_q/2\right) \end{aligned}$$

where

$$x = \frac{q^* - q_s}{q}, \qquad q_s = \frac{s}{p},$$

and Φ is the standard normal cumulative distribution function. Also, per-capita demand among poor urban laborers possessing a given level of savings

s is

$$
\begin{aligned}
d_l(p,s) &= \int_0^\infty \min\{q^*, q\epsilon + q_s\} dG_l(\epsilon) \\
&= \int_x^\infty q^* dG_l(\epsilon) + \int_0^x q\epsilon dG_l(\epsilon) + \int_0^x q_s dG_l(\epsilon) \\
&= q^* + (q_s - q^*)\,\Phi\left(\log x/\sigma_y + \sigma_y/2\right) + q\Phi\left(\log x/\sigma_y - \sigma_y/2\right)
\end{aligned}
$$

where

$$
x = \frac{q^* - q_s}{q}, \qquad q = \frac{y}{p}, \qquad q_s = \frac{s}{p},
$$

and Φ is the standard normal cumulative distribution function.

5.6.3 Parameter Values

To simplify the analysis, we exploit degrees of freedom and choose the units used to measure grain prices and quantities so that the expected world price P equals 1 and the nutritional requirement q^* equals 1. We choose other parameters so as to be reasonable under the polar extreme, but analytically tractable, assumptions that the system is frictionless (no transportation costs), deterministic (all shocks at their mean with probability 1), and the poor have with no savings. Under these assumptions, the equilibrium price is 1 in every market and the quantities consumed by poor farmers, poor urban laborers, and rural and urban non-poor consumers, are, respectively,

$$
\begin{aligned}
D_f &= N_f \min\{q^*, \bar{q}\} \\
D_l &= N_l \min\{q^*, \bar{y}\} \\
D_r &= N_r q^*(1+\alpha_r) \\
D_u &= N_u q^*(1+\alpha_u).
\end{aligned}
$$

So, to calibrate the model, we pick reasonable values for D_f, D_l, D_r, D_u, $\bar{Q}$, $\bar{q}$, and $\bar{y}$ under the extreme scenario, and then back-out N_f, N_l, N_r, and

N_u, making sure that $0 < \gamma = N_f q/Q < 1$. Table 3 summarizes the base-case values of the parameters of the simulation model used in this study. The table also gives the mathematical symbols used to represent the model parameters in this paper, and the names assigned to them in the Matlab program that is used to perform the simulations (See Appendix **??**).

Table 3: Base-Case Parameter Values

Parameter	Matlab Name	Base Value	Description
Normalized Parameters			
q^*	`qstar`	1.0	Per-capita grain consumption requirement
$\bar{P}$	`Pbar`	1.0	Mean world grain price
Farmer Production Distribution			
$\bar{q}$	`qbar`	1.2	Mean per-capita grain production, poor farmer
σ_q	`sigmaq`	0.2	Volatility, idiosyncratic production shock
Laborer Income Distribution			
$\bar{y}$	`ybar`	1.2	Mean per-capita income, poor laborer
σ_y	`sigmay`	0.2	Volatility, idiosyncratic income shock
Aggregate Supply and Demand			
$\bar{Q}$	`Qbar`	200	Mean total grain production
$\bar{C}_f$	`Cfbar`	20	Mean total grain consumption, poor farmers
$\bar{C}_r$	`Crbar`	40	Mean total grain consumption, non-poor rural
$\bar{C}_l$	`Clbar`	40	Mean total grain consumption, poor laborers
$\bar{C}_u$	`Cubar`	20	Mean total grain consumption, non-poor urban
Non-Poor Demand			
α_r	`alphar`	0.5	Rural non-poor excess demand scale factor
α_u	`alphau`	0.5	Urban non-poor excess demand scale factor
β_r	`betar`	-0.4	Rural non-poor demand elasticity
β_u	`betau`	-0.4	Urban non-poor demand elasticity
Savings			
ρ_f	`rhof`	0.5	Marginal propensity to save, poor farmer
ρ_l	`rhol`	0.5	Marginal propensity to save, poor laborer
Transportation and Trade			
$\bar{X}_{ru}$	`Xmaxru`	∞	Maximum shipments, rural to urban
$\bar{X}_{ur}$	`Xmaxur`	∞	Maximum shipments, urban to rural

continued on next page

Table 3 – continued from previous page

Parameter	Matlab Name	Base Value	Description
$\bar{X}_{uw}$	`Xmaxuw`	∞	Maximum shipments, urban to world
$\bar{X}_{wu}$	`Xmaxwu`	∞	Maximum shipments, world to urban
τ_{ru}	`tauru`	0.05	Unit shipment cost, rural to urban
τ_{ur}	`tauur`	0.05	Unit shipment cost, urban to rural
τ_{uw}	`tauuw`	0.05	Unit shipment cost, urban to world
τ_{wu}	`tauwu`	0.05	Unit shipment cost, world to urban

5.7 Effects of Driving Variables on Malnutrition

Figures 7-9 describe the effects of domestic grain production, world grain price, and urban income on rates of malnutrition among poor rural farmers and urban laborers. In each figure, one of the three driving variables is varied, with the other driving variables held at their mean values, which are given in Table 3.

As seen in Figure 7, poor rural farmers are highly vulnerable to systemic domestic grain production short-falls, since they rely heavily on on-farm production to meet their nutritional needs; poor urban laborers, on the other hand, are relatively impervious to levels of domestic production, because their needs can easily be met through imports from the world market at the prevailing world price. This to be expected, given that the base case parameterization assumes no upper bound on the level of imports. If imports were bounded above, either because of limited port capacity or the imposition of import quotas, a domestic production short-fall could easily lead to the exhaustion of import capacity, causing malnutrition to rise dramatically, not just among poor rural farmers, but also among poor rural laborers.

As seen in Figures 8 and 9, poor urban laborers are highly vulnerable to increases in the world grain price or declines in income because they must purchase all the grain they consume; poor rural farmers, on the other hand, are relatively impervious to either because they grow most of the grain they consume on their farms.

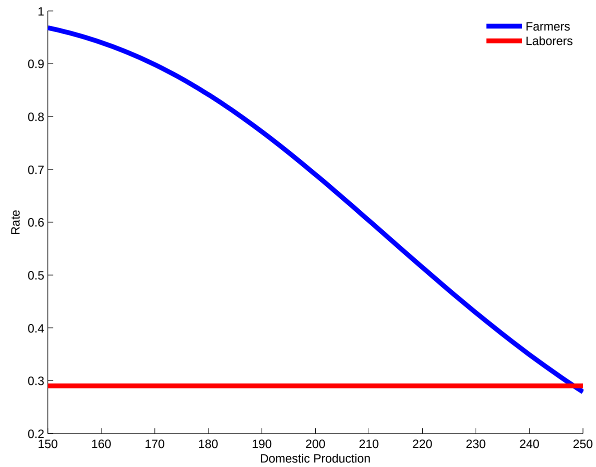

Figure 7: Effects of Aggregate Domestic Grain Production on Malnutrition

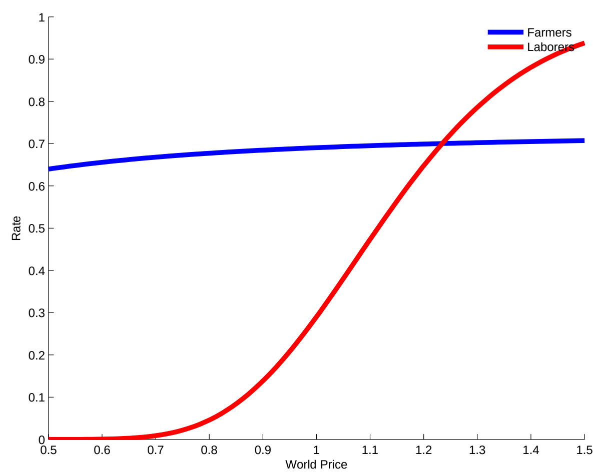

Figure 8: Effects of World Grain Price on Malnutrition

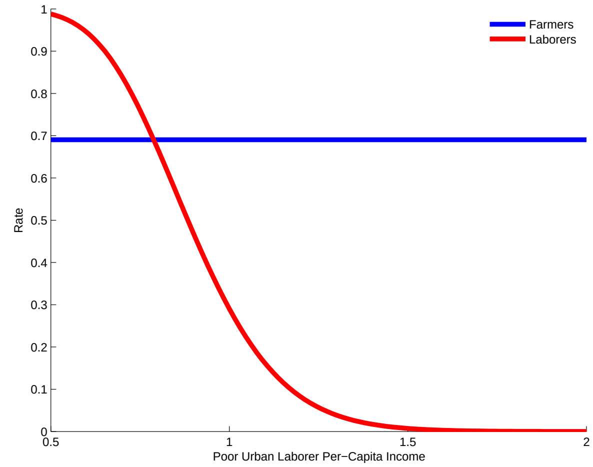

Figure 9: Effects of Per-Capita Urban Laborer Income on Malnutrition

6 Food-Security Policy Interventions

In this section, we begin our analysis of different government policies designed to address food-security problems. We consider four policies. In subsection 6.1, we examine a policy of providing cash transfers to the rural and urban poor whenever their access to grain falls below target levels, either because of production shortfalls or high prices; the total amount of cash transfers permissible in any year is limited by a specified aid budget. In subsection 6.2, we examine a policy of distributing in-kind food aid from publicly maintained grain buffer stocks; stocks are purchased by the buffer stock authority to replenish public stocks whenever prices fall below a specified acquisition price, and the total amount of food aid distributed in any year is limited by the quantities of grain held in reserve in the buffer stock at the beginning of the year. In subsection **??**, we examine a policy of imposing export bans whenever world prices rise above critical levels, threatening access to grain, particularly among the urban poor. In subsection **??** we examine a policy of enhancing transportation and trade capacity, through increases in shipment capacities or lowering of unit transportation costs between the world market and the urban port and between the urban port and the rural interior.

6.1 Cash Aid Policy

In this subsection, we examine a policy of providing direct cash aid to the rural and urban poor whenever their access to grain drops below a specified food security target level. When making cash aid distribution decisions, the government can detect differences in the food needs of the rural and urban poor, taken as classes. However, the government cannot detect differences among individual farmers or among individual laborers, because it cannot directly observe idiosyncratic variations in on-farm production, household income, and savings. As such the government provides the same cash aid a_f to each poor rural farmer and the same cash aid a_l to each poor urban laborer, although the two amounts may differ.

The government distributes cash aid to the rural and urban poor with the objective of achieving a target level of access to grain among the poor, expressed as a fraction θ of the minimum nutritional level per person q^*. Access is defined as the amount of grain that a typical poor person can purchase at prevailing prices, given his individual resources, inclusive of any cash aid grants. More specifically, access for the typical poor rural farmer, inclusive of aid, is computed as

$$g_f = q + \frac{\bar{s}_f + a_f}{p_r}$$

where q is per-capita on-farm production among poor farmers, p_r is the rural price of grain, and

$$\bar{s}_f = \int s \, dF_f(s)$$

is per-capita savings among poor farmers. Also, access for the typical poor rural laborer, inclusive of aid, is computed as

$$g_l = \frac{y + \bar{s}_l + a_l}{p_u}$$

where y is per-capita income among poor laborers, p_u is the rural price of grain, and

$$\bar{s}_l = \int s \, dF_l(s)$$

is per-capita savings among poor laborers.

In any year, if per-capita access to grain in the absence of aid falls below the food security target θq^*, for either poor rural farmers or poor urban laborers, the government initiates cash aid operations. The government distributes cash aid with the goal of achieving the access target for both poor farmers and poor laborers: $g_f = g_l = \theta q^*$. However, the total amount of cash aid that the government can distribute is capped at a fixed amount B. Specifically, the cash aid distributed to poor rural farmers and poor urban laborers must observe the budget constraint

$$N_f a_f + N_l a_l \equiv b \leq B$$

where b is total cash aid and N_f and N_l are the populations of poor rural farmers and urban laborers, respectively. The government, moreover, distributes cash aid in an equitable fashion; that is, if it distributes cash aid to both the rural and urban poor, then the cash aid is distributed so as to ensure that both groups enjoy the same average access to grain.

6.1.1 Market Equilibrium

Government cash aid intervention changes the market equilibrium. Arbitrage between markets gives rise to the following complementarity conditions:

$$\begin{aligned}
&0 \leq X_{ru} \leq \bar{X}_{ru} \quad \perp p_u - p_r - \tau_{ru} \\
&0 \leq X_{ur} \leq \bar{X}_{ur} \quad \perp p_r - p_u - \tau_{ur} \\
&0 \leq X_{uw} \leq \bar{X}_{uw} \quad \perp P - p_u - \tau_{uw} \\
&0 \leq X_{wu} \leq \bar{X}_{wu} \quad \perp p_u - P - \tau_{wu}.
\end{aligned} \tag{3}$$

Preservation of material balance between total grain availability and total grain consumption in both the rural interior and the rural port require that:

$$\begin{aligned}
&Q + X_{ur} = D_r(p_r) + D_f(p_r, a_f; q, F_f) + X_{ru} \\
&X_{ru} + X_{wu} = D_u(p_u) + D_l(p_u, a_l; y, F_l) + X_{ur} + X_{uw}.
\end{aligned} \tag{4}$$

And the rules of the government cash aid intervention imply that:

$$
\begin{aligned}
&0 \le a_f \le \infty \quad \perp g - q - \frac{\bar{s}_f + a_f}{p_r} \\
&0 \le a_l \le \infty \quad \perp g - \frac{y + \bar{s}_l + a_l}{p_u} \\
&0 \le g \le \theta q^* \quad \perp B - N_f a_f - N_l a_l.
\end{aligned}
\tag{5}
$$

Here,

$$D_f(p_r, a_f; q, F_f) = N_f \int \min\{q^*, q\epsilon + \frac{s + a_f}{p_r}\} dG_f(\epsilon) dF_f(s)$$

and

$$D_l(p_u, a_l; y, F_l) = N_l \int \min\{q^*, \frac{y\epsilon + s + a_l}{p_u}\} dG_l(\epsilon) dF_l(s)$$

are the market-level demands for grain among poor rural farmers and poor urban laborers, respectively allowing for the impact of direct financial aid.

The nine conditions 3-5 fully characterize the nine endogenous variables (four inter-market flows, X_{ru}, X_{ur}, X_{uw}, and X_{wu}; two equilibrium prices, p_r and p_u; two food-aid levels a_f and a_l; and achieved access g) given the exogenous realizations of aggregate production Q, aggregate urban income Y, and the world price P, and given the predetermined distributions of savings among poor farmers F_f and laborers F_l. The model parameters and endogenous variables that are new to the basic model upon the introduction of the direct cash aid policy are summarized in Tables 4-5. The tables also give the mathematical symbols used to represent the model parameters and endogenous variables in this paper, and the names assigned to them in the Matlab program used to perform the model simulations.

Given the equilibrium prices and the distributions of savings among poor farmers and laborers, the malnutrition rates among poor farmers and laborers are given by

$$
\begin{aligned}
m_f(a_f, p_r, q, F_f) &= \int G_f\left(\frac{q^* - \frac{s + a_f}{p_r}}{q}\right) dF_f(s) \\
m_l(a_l, p_u, y, F_l) &= \int G_l\left(\frac{p_u q^* - s - a_l}{y}\right) dF_l(s).
\end{aligned}
$$

Table 4: Policy Parameters

Parameter	Matlab Name	Base Value	Description
Food Aid Policy			
B	`B`	30	Food aid budget
θ	`theta`	1.0	Access target factor

Table 5: Policy Variables

Variable	Matlab Name	Description
Current		
a_f	`af`	Per-capita aid, poor farmers
a_l	`al`	Per-capita aid, poor laborers
g	`g`	Per-capita access target
Derived		
$\bar{s}_f$	`sf`	Per-capita savings, poor farmers
$\bar{s}_l$	`sl`	Per-capita savings, poor laborers
g_f	`gf`	Per-capita access, poor farmers
g_l	`gl`	Per-capita access, poor laborers
b	`b`	Total food aid expenditures

6.1.2 Effects of Driving Variables on Malnutrition and Cash Aid

Figures 10-15 describe the effects of domestic grain production, world grain price, and urban income on rates of malnutrition among rural farmers and urban laborers. In each figure, one of the three driving variables is varied, with the other driving variables held at their mean value (see Table 3).

Figures 10 and 11 give the effects of world grain price on per-capita financial aid and malnutrition, respectively. Under the base-case parameterization, food aid targets are met for both the rural and urban poor at a low grain price such as 0.5. At this low price, some malnutrition exists among the rural poor, as a portion of farmers produce less than the required amount; malnutrition, however, is virtually not-existent among the urban poor, because even the poorest laborers have enough income and savings to meet nutritional needs. As the world price rises, malnutrition rises slowly among poor farmers, as the price hikes reduce the modest quantities of grain that they buy on the market to satisfy nutritional needs not met via on-farm production; malnutrition rises more dramatically among poor laborers, however, since they must meet all their consumption needs through market purchases. Nonetheless, although malnutrition begins to rise for both the rural and urban poor, aggregate access levels initially remain above the target level, obviating the need for government intervention.

However, as the world price continues to rise, it ultimately reaches a level where aggregate access among poor laborers falls below the target level, at which point an emergency is declared, prompting the government to begin dispensing aid to the urban poor. Higher world prices are subsequently met through compensating distributions of aid that keep the malnutrition rate among the urban poor relatively constant, until the food aid budget is exhausted, at which point the impacts of higher world prices cannot be addressed by further government aid, causing malnutrition among the urban poor to continue to rise.

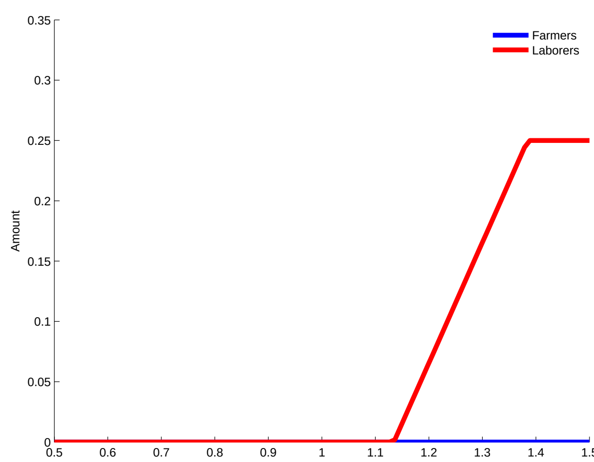

Figure 10: Effects of World Grain Price on Financial Aid

Figures 12 and 13 give the effects of domestic grain production on per-capita financial aid and malnutrition, respectively. Access to grain among the

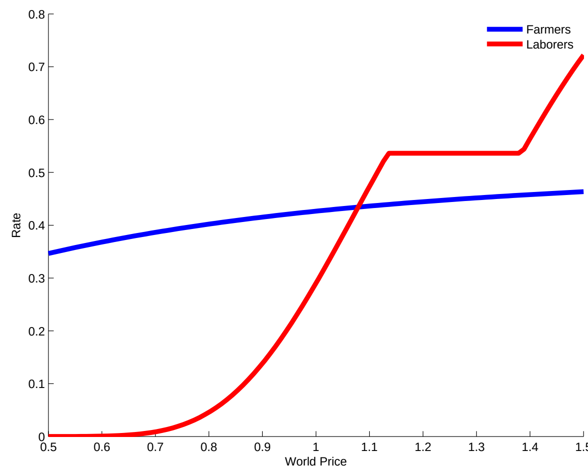

Figure 11: Effects of World Grain Price on Malnutrition

urban poor is impervious to the levels of domestic production, since the urban poor meet their nutritional needs through purchases at prices that are tied to the world price, which does not respond to domestic production. As such, under the base-case parameterization, the malnutrition rate among urban laborers remains constant in the face of variation in domestic production, and never rises to the level that triggers dispensation of government aid to the urban poor.

The situation among poor rural farmers, however, is understandably different. For high levels of production, aggregate grain access targets among poor rural farmers are met and no financial aid is dispensed; over these levels of production, malnutrition among the rural poor nonetheless declines with greater production, as more poor farmers produce sufficient amounts on their farms to meet household needs. For low levels of production, however, aggregate grain access targets can be met only with government aid; over these levels of production, greater shortfalls in production are met with compensating distributions of aid, causing the rate of malnutrition to remain relatively constant in the face of variations in production.

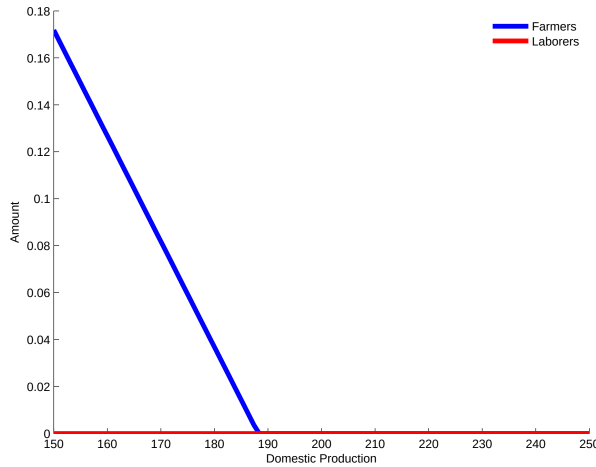

Figure 12: Effects of Domestic Grain Production on Financial Aid

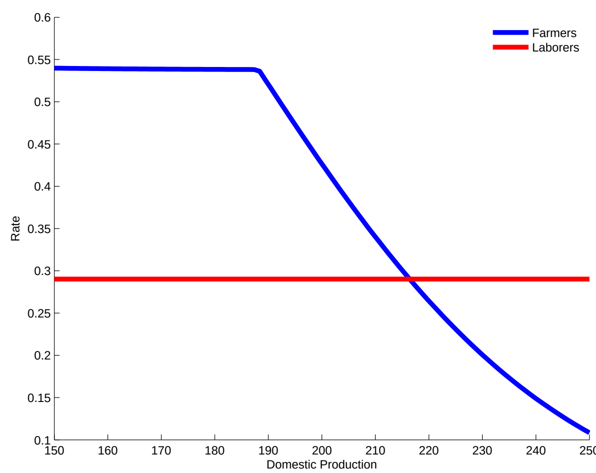

Figure 13: Effects of Domestic Grain Production on Malnutrition

Figures 14 and 15 give the effects of urban laborer income on per-capita financial aid and malnutrition, respectively. Under the base-case parameterization, food aid targets are met for both the rural and urban poor at high urban income levels. Access to grain among the rural poor is impervious to the levels of income among the urban poor, since the rural poor meet their nutritional needs primarily through household production, which is not affected by urban incomes. As such, the malnutrition rate among rural farmers remains constant in the face of variation in urban income, and never rises to the level that triggers dispensation of government aid to the rural poor.

The situation among poor urban laborers, however, is understandably different. For high levels of urban income, grain access targets among poor rural laborers are met and no financial aid is dispensed; over these levels of income, malnutrition among the urban poor nonetheless declines as income declines, as a larger portion of poor farmers are unable to meet their household nutritional needs. For low levels of income, however, aggregate grain access targets among the urban poor can be met only with government aid; over these levels of production, greater shortfalls in income are met with equally greater amounts of aid, causing the rate of malnutrition to remain relatively constant in the face of variations in income. However, at a sufficiently low level of income, the aid budget is exhausted. For income levels below this point, the impact of lower incomes cannot be addressed by further financial aid, causing malnutrition among the urban poor to continue to rise.

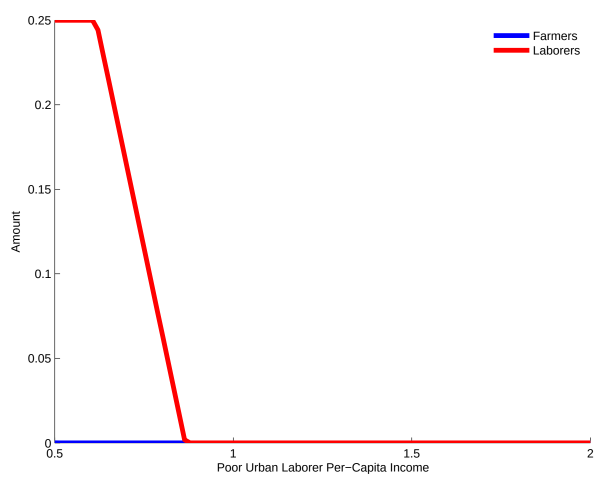

Figure 14: Effects of Urban Laborer Income on Financial Aid

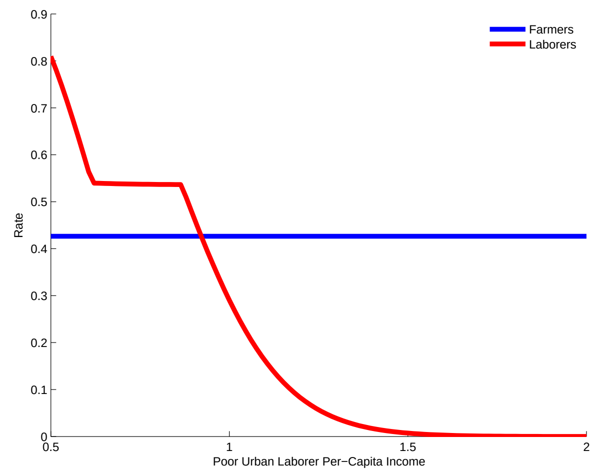

Figure 15: Effects of Urban Laborer Income on Malnutrition

6.2 Buffer Stock Policy

In this subsection, we examine a policy of providing in-kind food aid, distributed from a government buffer stock, to the rural and urban poor, whenever their access to grain drops below a specified target level. When making food aid distribution decisions, the government can detect differences in the food needs of the rural and urban poor, taken as classes. However, the government cannot detect differences among individual farmers or among individual laborers, because it cannot directly observe idiosyncratic variations in on-farm production, household income, and savings. As such the government provides the same amount of food aid z_f to each poor rural farmer and the same amount of food aid z_l to each poor urban laborer, although the two amounts may differ.

The government distributes food aid to the rural and urban poor with the objective of achieving a target level of access to grain among the poor, expressed as a fraction θ of the minimum nutritional level per person q^*. Access is defined as the amount of grain that a typical poor person can purchase at prevailing prices, given his individual resources, inclusive of any food aid provided by the government. More specifically, access for the typical poor rural farmer, inclusive of aid, is computed as

$$g_f = q + \frac{\bar{s}_f}{p_r} + z_f$$

where q is per-capita on-farm production among poor farmers, p_r is the rural price of grain, and

$$\bar{s}_f = \int s \; dF_f(s)$$

is per-capita savings among poor farmers. Also, access for the typical poor rural laborer, inclusive of aid, is computed as

$$g_l = \frac{y + \bar{s}_l}{p_u} + z_l$$

where y is per-capita income among poor laborers, p_u is the rural price of grain, and

$$\bar{s}_l = \int s \; dF_l(s)$$

is per-capita savings among poor laborers.

In any year, if per-capita access to grain in the absence of food aid falls below the food security target θq^* for either poor rural farmers or poor urban laborers, the government initiates grain distributions from its buffer stock. The government distributes grain with the goal of achieving the target for both poor farmers and poor laborers: $g_f = g_l = \theta q^*$. However, the total amount of grain that the government can distribute is limited by the amount Z it contains in its buffer stock at the beginning of the year. Specifically, the amount of grain distributed to poor rural farmers and urban laborers must observe the constraint

$$N_f z_f + N_l z_l \leq Z$$

where N_f and N_l are the populations of poor rural farmers and urban laborers, respectively. The government, moreover, distributes food aid in an equitable fashion; that is, if it distributes food aid to both the rural and urban poor, then the food aid is distributed so as to ensure that both groups enjoy the same average access to grain.

The government replenishes its buffer stock by making market purchases whenever the rural price p_r falls below a specified acquisition price $\bar{p}$, acquiring as much as it can at that price, limited only by the capacity of the buffer stock $\bar{Z}$, less the amount remaining in the buffer stock after aid distributions, $Z - z_f - z_l$. More specifically, the amount that the government purchases Z^+ is subject to the constraint

$$0 \leq Z^+ \leq \bar{Z} - Z + z_f + z_l$$

With these rules of operation, assuming a constant unit cost of storage κ, the amount spent by the government in any year to support food operations is the sum of the cost of purchases and total storage costs:

$$b = (p_r + \kappa) Z^+.$$

6.2.1 Market Equilibrium

The government food aid intervention changes the market equilibrium. Arbitrage between markets gives rise to the following complementarity conditions:

$$\begin{aligned}
&0 \leq X_{ru} \leq \bar{X}_{ru} \quad \perp p_u - p_r - \tau_{ru} \\
&0 \leq X_{ur} \leq \bar{X}_{ur} \quad \perp p_r - p_u - \tau_{ur} \\
&0 \leq X_{uw} \leq \bar{X}_{uw} \quad \perp P - p_u - \tau_{uw} \\
&0 \leq X_{wu} \leq \bar{X}_{wu} \quad \perp p_u - P - \tau_{wu}.
\end{aligned} \tag{6}$$

Preservation of material balance between total grain availability and total grain consumption in both the rural interior and the rural port guarantee that:

$$\begin{aligned}
&Q + X_{ur} + N_f z_f = D_r(p_r) + D_f(p_r, z_f; Q, F_f) + X_{ru} + Z^+ \\
&X_{ru} + X_{wu} + N_l z_l = D_u(p_u) + D_l(p_u, z_l; Y, F_l) + X_{ur} + X_{uw}.
\end{aligned} \tag{7}$$

And the rules of the government food aid intervention guarantee that:

$$
\begin{aligned}
&0 \le z_f \le \infty && \perp g - q - \frac{\bar{s}_f}{p_r} - z_f \\
&0 \le z_l \le \infty && \perp g - \frac{y + \bar{s}_l}{p_u} - z_l \\
&-\infty \le g \le \theta q^* && \perp Z + Z^+ - N_f z_f - N_l z_l \\
&0 \le Z^+ \le \bar{Z} - Z && \perp \bar{p} - p_r
\end{aligned}
\tag{8}
$$

Here,

$$D_f(p_r, z_f; Q, F_f) = N_f \int \min\{q^*, q\epsilon + z_f + \frac{s}{p_r}\} dG_f(\epsilon) dF_f(s),$$

$$D_l(p_u, z_l; Y, F_l) = N_l \int \min\{q^*, \frac{y\epsilon + s}{p_u} + z_l\} dG_l(\epsilon) dF_l(s),$$

are the market-level demands for grain among poor rural farmers and poor urban laborers, respectively allowing for the impact of food aid.

The ten conditions 6-8 fully characterize ten endogenous variables (four inter-market flows, X_{ru}, X_{ur}, X_{uw}, and X_{wu}; two equilibrium prices, p_r and p_u; two food-aid levels z_f and z_l; achieved access g; and government buffer stock acquisitions Z^+) given the exogenous realizations of aggregate production Q, aggregate urban income Y, and the world price P, and given the predetermined distributions of savings among poor farmers F_f and laborers F_l and the pre-determined level of the buffer stock Z. The model parameters and endogenous variables that are new to the model upon the introduction of the food aid policy are summarized in Tables 6-7. The tables also give the mathematical symbols used to represent the model parameters and endogenous variables in this paper, and the names assigned to them in the Matlab program used to perform the model simulations.

Given the equilibrium prices and the distribution of savings among poor farmers and laborers, the malnutrition rates among poor farmers and laborers are given by

$$
\begin{aligned}
m_f(p_r, z_f, q, F_f) &= \int G_f\left(\frac{q^* - z_f - s/p_r}{q}\right) dF_f(s) \\
m_l(p_u, z_l, y, F_l) &= \int G_l\left(\frac{q^* - z_l - s/p_u}{y/p_u}\right) dF_l(s)
\end{aligned}
$$

Table 6: Policy Parameters

Parameter	Matlab Name	Base Value	Description
Food Aid Policy			
$\bar{Z}$	Zbar	20	Buffer stock capacity
$\bar{p}$	pbar	0.7	Buffer stock acquisition price
κ	kappa	0.0	Unit storage cost
θ	theta	1.0	Access target factor

6.2.2 Effects of Driving Variables on Malnutrition and Food Aid

Figures 16-21 describe the effects of the driving stochastic variables on rates of malnutrition and food aid among rural farmers and urban laborers. In each figure, one of the three driving variables is varied, with the other driving variables held at their mean value (see Table 3).

Figures 16 and 17 give the effects of world grain price on per-capita food aid and malnutrition, respectively. Under the base-case parameterization, food security targets are met for both the rural and urban poor at a low grain price such as 0.5. At this low price, some malnutrition exists among the rural poor, as a portion of farmers produce less than the required amount; malnutrition, however, is virtually not-existent among the urban poor, because even the poorest laborers have enough income and savings to meet nutritional needs. As the world price rises, malnutrition rises slowly among poor farmers, as the price hikes reduce the modest quantities of grain that they buy on the market to satisfy nutritional needs not met via on-farm production; malnutrition rises more dramatically among poor laborers, however, since they must meet all their consumption needs through market purchases. Nonetheless, although malnutrition begins to rise for both the rural and urban poor, aggregate access levels remain above the target level.

However, as the world price continues to rise, it ultimately reaches a level where aggregate access among poor laborers falls below the target level, at which point an emergency is declared, prompting the government to begin dispensing food aid from the buffer stock to the urban poor. Higher world prices are subsequently met through greater distributions of aid, causing the malnutrition rate among the urban poor to rise more slowly.

Figures 18 and 19 give the effects of aggregate domestic grain production

Table 7: Policy Variables

Variable	Matlab Name	Description
Pre-Determined		
Z	`Z`	Buffer stock, beginning of period
Current		
z_f	`zf`	Per-capita food aid, poor farmers
z_l	`zl`	Per-capita food aid, poor laborers
g	`g`	Per-capita access target
Z'	`Ze`	Buffer stock, end of period
Derived		
$\bar{s}_f$	`sf`	Per-capita savings, poor farmers
$\bar{s}_l$	`sl`	Per-capita savings, poor laborers
g_f	`gf`	Per-capita access, poor farmers
g_l	`gl`	Per-capita access, poor laborers
b	`b`	Total food aid expenditures

on per-capita food aid and malnutrition, respectively. Access to grain among the urban poor is impervious to the levels of domestic production, since the urban poor meet their nutritional needs through purchases at prices that are tied to the world price, which does not respond to domestic production. As such, under the base-case parameterization, the malnutrition rate among urban laborers remains constant in the face of variation in domestic production, and never rises to the level that triggers dispensation of government food aid to the urban poor.

The situation among poor rural farmers, however, is understandably different. For high levels of production, aggregate grain access targets among poor rural farmers are met and no financial aid is dispensed; over these levels of production, malnutrition among the rural poor nonetheless declines with greater production, as more poor farmers produce enough on their farms to meet household needs. For low levels of production, however, aggregate grain access targets can be met only through the dispensation of government food aid; over these levels of production, greater shortfalls in production are met with compensating distributions of food aid, causing the rate of malnutrition

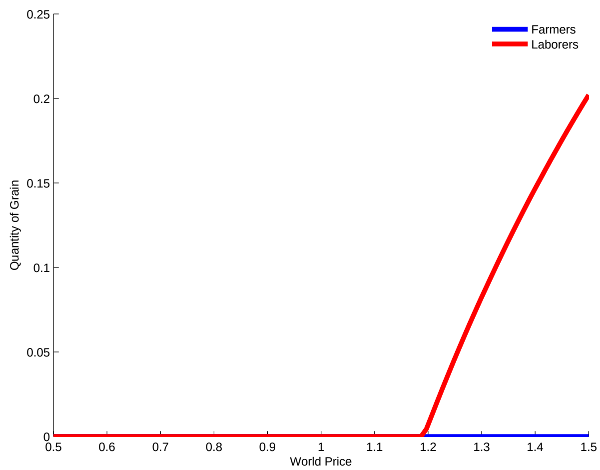

Figure 16: Effects of World Grain Price on Food Aid

among the urban poor to grow more slowly.

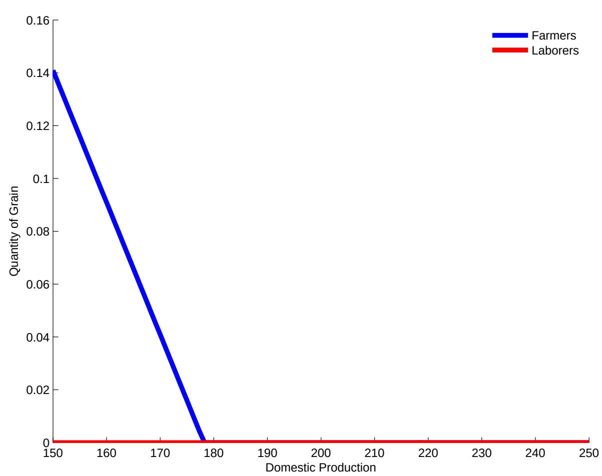

Figure 18: Effects of Domestic Grain Production on Food Aid

Figures 20 and 21 give the effects of aggregate urban laborer income

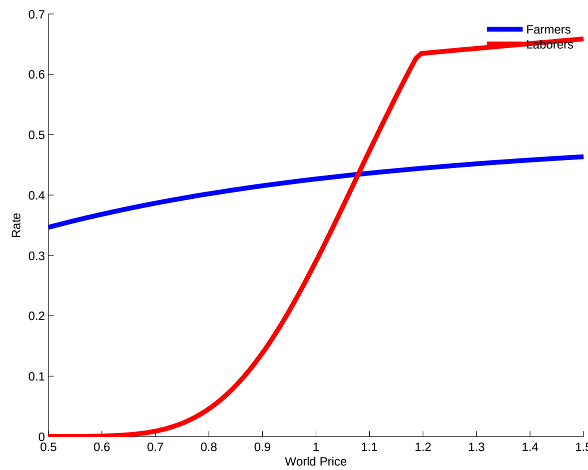

Figure 17: Effects of World Grain Price on Malnutrition

on per-capita food aid and malnutrition, respectively. Under the base-case parameterization, food security targets are met for both the rural and urban poor at high urban income levels. Access to grain among the rural poor is impervious to the levels of income among the urban poor, since the rural poor meet their nutritional needs primarily through household production, which is not affected by urban incomes. As such, the malnutrition rate among rural farmers remains constant in the face of variation in urban income, and never rises to the level that triggers dispensation of government aid to the rural poor.

The situation among poor urban laborers, however, is understandably different. For high levels of urban income, aggregate food security targets among poor rural laborers are met and no food aid is dispensed from the buffer stock; over these levels of income, malnutrition among the urban poor nonetheless declines as income declines, as more poor farmers fail to have the sufficient income to meet their household needs. For low levels of income, however, aggregate grain access targets among the urban poor can be met only through the dispensation of government food aid; over these levels of production, greater shortfalls in income are met with greater amounts of food aid, causing the rate of malnutrition to grow more slowly. However, at a sufficiently low level of income, the aid budget is exhausted. For income

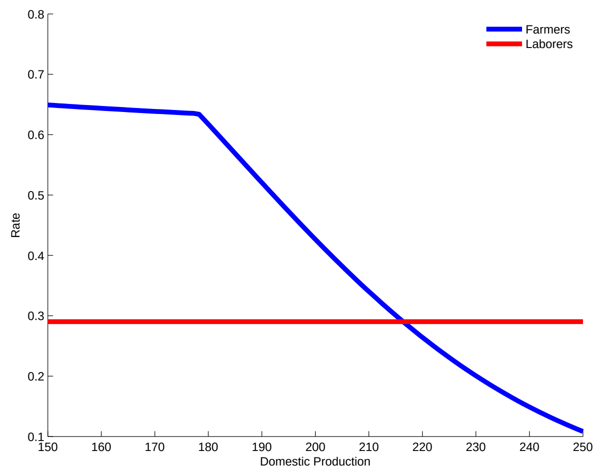

Figure 19: Effects of Domestic Grain Production on Malnutrition

levels below this point, lower incomes lead to higher levels of malnutrition among the urban poor.

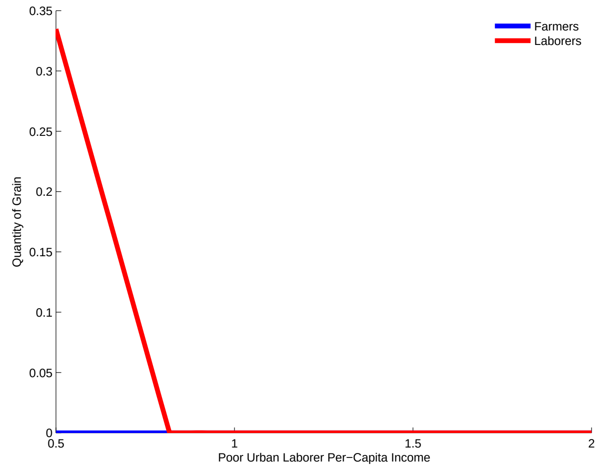

Figure 20: Effects of Urban Laborer Income on Food Aid

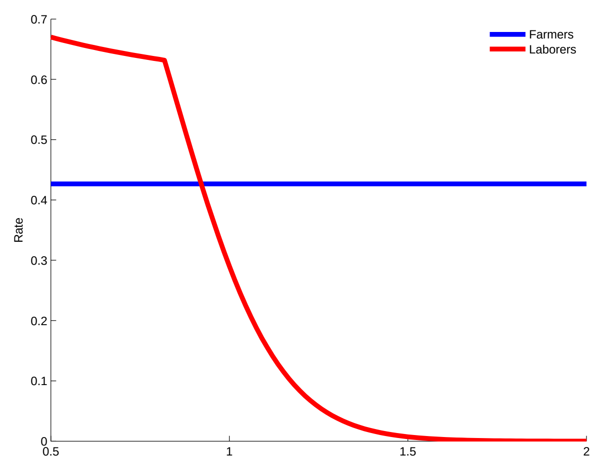

Figure 21: Effects of Urban Laborer Income on Malnutrition

References

Ahmed, Sadiq. 2008. "Global Food Price Inflation: Implications for South Asia, Policy Reactions, and Future Challenges." Policy Research Working Paper 4796, The World Bank, South Asia Regional Programs Unit, Washington, DC.

Aksoy, M. Ataman and Aylin Isik-Dikmelik. 2008. "Are Low Food Prices Pro-Poor? Net Food Buyers and Sellers in Low-Income Countries." Policy Research Working Paper 4642, The World Bank, Development Research Group, Trade Team, Washington, DC.

Arndt, Channing, Rui Benfica, Nelson Maximiano, Antonio M.D. Nucifora, and James T. Thurlow. 2008. "Higher Fuel and Food Prices: Impacts and Responses for Mozambique." *Agricultural Economics* 39(3):497–511.

Bardsley, Peter. 1994. "The Collapse of the Australian Wool Reserve Price Scheme." *The Economic Journal* 104(426):1087–1105.

Blas, Javier and Roel Landingin. 2008. "Vietnam Move Hits Hopes of Cheaper Rice." In *Financial Times*. June 19, 2008.

Blonigen, Bruce A. and Wesley W. Wilson. 2008. "Port Efficiency and Trade Flows." *Review of International Economics* 16(1):21–36.

Bougheas, Spiros, Panicos O. Demetriades, and Edgar L.W. Morgenroth. 1999. "Infrastructure, Transport Costs and Trade." *Journal of International Economics* 47(1):169–189.

Brahambhatt, Milan and Luc Christiaensen. 2008. "Rising Food Prices in East Asia: Challenges and Policy Options." Technical report, The World Bank, Development Research Group, Sustainable Development Department of the East Asia and Pacific Region, Washington, DC.

Brennan, Donna, Jeffrey Williams, and Brian D. Wright. 1997. "Convenience Yield without the Convenience: A Spatial-Temporal Interpretation of Storage under Backwardation." *The Economic Journal* 107(43):1009–1022.

Cafiero, Carlo, Donald F. Larson, and Brian D. Wright. Undated. "Trade Corridors and Storage: Lessons from Senegal." Unpublished manuscript, The World Bank, Development Research Group, Washington, DC.

Coady, David, Paul Dorosh, and Bart Minten. 2009. "Evaluating Alternative Policy Responses to Higher World Food Prices: The Case of Increasing Rice Prices in Madagascar." *American Journal of Agricultural Economics* 91(3):711–722.

Cororaton, Caesar B. and Govinda R. Timilsina. 2012. "Impacts of Large-Scale Expansion of Biofuels on Global Poverty and Income Distribution." Policy Research Working Paper 6078, The World Bank, Development Research Group, Environment and Energy Team, Washington, DC.

Cuesta, José. 2011. "A Qualitative Analysis of Policymaking on the Food Price Crisis in the Andean Region: Preparing for the Next Crisis." *European Journal of Development Research* 23(1):7293.

Deaton, Angus and Guy Laroque. 1992. "On the Behavior of Commodity Prices." *The Review of Economic Studies* 59(1):1–23.

Demeke, Mulat, Guendalina Pangrazio, and Materne Maetz. 2009. "Country Responses to the Food Security Crisis: Nature and Preliminary Implications of the Policies Pursued." Technical report, Food and Agriculture Organization of the United Nations, Initiative on Soaring Food Prices, Rome, Italy.

Dercon, Stefan. 2005. *Insurance Against Poverty.* Oxford, United Kingdom: Oxford University Press.

Dorosh, Paul A. 2008. "Food Price Stabilization and Food Security: International Experience." *Bulletin of Indonesian Economic Studies* 44(1):93–114.

———. 2009. "Price Stabilization, International Trade and National Cereal Stocks: World Price Shocks and Policy Response in South Asia." *Food Security* 1(2):137–149.

Fan, Ying and Xiao-Bing Zhang. 2010. "Modeling the Strategic Petroleum Reserves of China and India by a Stochastic Dynamic Game." *Journal of Policy Modeling* 32(4):505–519.

Food and Agriculture Organization of the United Nations. 2011a. "Country Policy Monitoring." Available on line at www.fao.org/giews/countrybrief/.

———. 2011b. "FAOSTAT Database." Available on line at http://faostat.fao.org.

———. 2011c. "Safeguarding Food Security in Volatile Global Markets." Monograph, Food and Agriculture Organization of the United Nations, Rome, Italy.

Garcia, Marito and Charity M.T. Moore. 2012. *The Cash Dividend: The Rise of Cash Transfer Programs in Sub-Saharan Africa*. Washington, DC: The World Bank.

Gardner, Bruce L. 1979. *Optimal Stockpiling of Grain*. Lexington, MA: Lexington Books.

Gilbert, Christopher L. 1996. "International Commodity Agreements: An Obituary Notice." *World Development* 24(1):1–19.

Gouel, Christophe and Sébastien Jean. 2012. "Optimal Food Price Stabilization in a Small Open Developing Country." Working paper, The World Bank, Development Research Group, Agriculture and Rural Development Team, Washington, DC.

Hall, Ben. 2010. "France's Sarkozy Unveils G20 Leadership Agenda." In *Financial Times*. August 25, 2010.

Ivanic, Maros, Will Martin, and Hassan Zaman. 2011. "Estimating the Short-Run Poverty Impacts of the 201011 Surge in Food Prices." Policy Research Working Paper 5633, The World Bank, Development Research Group, Agriculture and Rural Development Team, Washington, DC.

Knudsen, Odin and John Nash. 1990. "Domestic Price Stabilization Schemes in Developing Countries." *Economic Development and Cultural Change* 38(3):539–58.

Larson, Donald F. 2007. "On Inverse Carrying Charges and Spatial Arbitrage." *The Journal of Futures Markets* 27(4):305–336.

Larson, Donald F., Jock R. Anderson, and Panos Varangis. 2004. "Policies on Managing Risk in Agricultural Markets." *The World Bank Research Observer* 19(2):199–230.

Makki, Shiva S., Luther G. Tweeten, and Mario J. Miranda. 1996. "Wheat Storage and Trade in an Efficient Global Market." *American Journal of Agricultural Economics* 78(4):879–90.

———. 2001. "Storage-Trade Interactions under Uncertainty: Implications for Food Security." *Journal of Policy Modeling* 23(2):127–140.

Martin, Will and Kym Anderson. 2011. "Export Restrictions and Price Insulation during Commodity Price Booms." Policy Research Working Paper 5645, The World Bank, Development Research Group, Agriculture and Rural Development Team, Washington, DC.

Massell, Benton F. 1969. "Price Stabilization and Welfare." *The Quarterly Journal of Economics* 83(2):234–289.

———. 1970. "Some Welfare Implications of International Price Stabilization." *The Journal of Political Economy* 78(2):404–417.

Miranda, Mario J. and Paul L. Fackler. 2002. *Applied Computational Economics and Finance*. Boston, MA: MIT Press.

Miranda, Mario J. and Peter G. Helmberger. 1988. "The Effects of Commodity Price Stabilization Programs." *The American Economic Review* 78(1):46–58.

Mitra, Siddhartha and Tim Josling. 2009. "Agricultural Export Restrictions: Welfare Implications and Trade Disciplines." IPC position paper, International Food and Agricultural Trade Policy Council, Washington, DC.

Mittal, Anuradha. 2008. "Food Price Crisis: Rethinking Food Security Policies." Technical report, G24 Technical Group, Geneva, Switzerland.

Newbery, David M.G. and Joseph E. Stiglitz. 1981. *The Theory of Commodity Price Stabilization*. Oxford, United Kingdom: Clarendon Press.

Thomas, Anisya and Lynn Fritz. 2006. "Disaster Relief, Inc." *Harvard Business Review* 84(11):114–122.

Valero-Gil, Jorge N. and Magali Valero. 2008. "The Effects of Rising Food Prices on Poverty in Mexico." *Agricultural Economics* 39(Supplement S1):485–496.

Van Wassenhove, L.N. 2006. "Humanitarian Aid Logistics: Supply Chain Management in High Gear." *Journal of the Operational Research Society* 57(5):475–489.

Victor, David G. and Sarah Eskreis-Winkler. 2008. "In the Tank: Making the Most of Strategic Oil Reserves." *Foreign Affairs* 87(4):70–83.

von Braun, Joachim and Maximo Torero. 2008. "Physical and Virtual Global Food Reserves to Protect the Poor and Prevent Market Failure." IFPRI Policy Brief 4, International Food Policy Research Institute, Washington, DC.

———. 2009. "Implementing Physical and Virtual Food Reserves to Protect the Poor and Prevent Market Failure." IFPRI Policy Brief 20, International Food Policy Research Institute, Washington, DC.

Wodon, Quentin, Clarence Tsimpo, and Harold Coulombe. 2008. "Assessing the Potential Impact on Poverty of Rising Cereals Prices: The Case of Ghana." Policy Research Working Paper 4740, The World Bank, Human Development Network, Washington, DC.

World Bank. 2008. "Early Impacts from the World Bank's Global Food Response Program." Available on line http://go.worldbank.org/52LKGU2ZA0, posted October 16, 2008.

———. 2012a. "Food Price Watch." Available on line at www.worldbank.org.

———. 2012b. "World Development Indicators."

World Food Programme. 2008. "Logistics Capacity Assessment: Senegal."

Wright, Brian and Carlo Cafiero. 2011. "Grain Reserves and Food Security in the Middle East and North Africa." *Food Security* 3(Supplement 1):61–76.

Wright, Brian D. and Jeffrey C. Williams. 1982. "The Economic Role of Commodity Storage." *The Economic Journal* 92(367):596–614.

Zoellick, Robert. 2011. "Free Markets Can Still Feed the World." In *Financial Times*. January 5, 2011.