PRESAO

Programme de Renforcement et de Recherche sur la Sécurité Alimentaire en Afrique de l'Ouest
West Africa Food Security Capacity Strengthening and Research Program

Working Paper 2016-02 November 2016

SRAI 2 Component

Strengthening Regional Agricultural Integration in West Africa: Phase II

Food Security Implications of Staple Food Substitution in Sahelian West Africa

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The research presented in this paper was made possible by generous funding from The Syngenta Foundation for Sustainable Agriculture, The Syngenta Foundation for Sustainable Agriculture. While gratefully acknowledging this support, the authors take sole responsibility for any errors of fact or interpretation in this paper. Comments are welcome. Corresponding author is Nathalie M. Me-Nsope (mensopen@msu.edu).

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Abstract

Low-income households in Sahelian West Africa face multiple shocks that risk compressing their already-low food consumption levels. This paper develops a multi-market simulation model to evaluate the impact of common production and world-price shocks on food consumption of vulnerable groups in Sahelian West Africa. Empirical analysis confirms that poor households bear the brunt of ensuing consumption risks, particularly in closed markets, where trade barriers restrict imports, and the poor find themselves in a bidding war with richer consumers for limited food supplies. In the absence of trade, a drought that reduces domestic rainfed cereal production by 20% would compress already low calorie consumption of the rural poor by as much as 15%, four times as much as other household groups. Conversely, a 50% spike in world rice prices hits the urban poor hardest, compressing calorie consumption by up to 8%.

Policy responses need to focus on two basic mechanisms that can help to moderate this pressure – consumer substitution among staple foods and trade. Immediately south of the Sahel, coastal West African countries enjoy higher rainfall, dual rainy seasons, more stable staple food production based on root crops (cassava and yams) as well as frequent double cropping of maize.

Our simulation results suggest that regional trade in maize, yams and cassava-based prepared foods like gari and attieké could fill over one-third of the consumption shortfall resulting from a major drought in the Sahel. Increasing substitutability across starchy staples, for example through expansion of maize, cassava and sorghum-based convenience foods, would further moderate consumption pressure by expanding the array of food alternatives and hence supply responses available during periods of stress.

Keywords: Multimarket simulation model; staple food demand; elasticities; food security shocks; urban/rural poor and nonpoor; Sahelian West Africa

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The authors thank the Syngenta Foundation for Sustainable Agriculture for supporting the research leading to the findings reported here, but assume sole responsibility for statements expressed herein.

Food Security Implications of Staple Food Substitution in Sahelian West Africa

1. Introduction

1.1. Motivation

Between 1990/92 and 2014/16, countries of the West African Sahel cut their rates of undernutrition from 23% to 13% (calculated from data in FAO et al., 2015).[3] Despite this notable progress, food insecurity remains a serious problem for low-income families in these countries. The prevalence of stunting (an indicator of long-term malnutrition) among children ranges from 29% in Senegal to 55% in Niger (FAO, 2013).

Low-income households in Sahelian West Africa face multiple shocks that risk compressing their already-low food consumption levels. Two shocks, in particular, impose significant, regular pressure on vulnerable households:

- Reductions in staple-food production due to drought, flooding, insect attacks and plant diseases: Given thin markets for many of the region's basic rain-fed staples (millet, sorghum and maize) and negligible imports of these products into the region, production shocks can lead to strong price spikes, limiting the poor's access to food.
- World price shocks, especially for rice, the main imported staple food in the region: During the 2008 world price spike, the FOB price of the benchmark Thai 5% broken milled rice nearly tripled from US $316/mt in April 2007 to $907/mt in April 2008 (World Bank, 2016), leading to severe pressure on the Sahel region, which relies on rice imports for nearly 60% of its total rice consumption and close to 10% of its total cereal consumption).[4]

Poor households face limited options in dealing with these shocks. They can draw down their meager savings, which may prove effective in the short-run if market supplies increase, for example through imports. However, in situations where trade barriers restrict imports, the poor find themselves in a bidding war with richer consumers for limited food supplies. Alternatively, where diversity of food supply permits, the poor can potentially shift food consumption to alternative food commodities, such as roots and tubers, whose prices are not highly correlated with the poor's habitual staples. A third option, often witnessed in the

[3] The West African Sahel spans the interior middle belt of West Africa, from Senegal and Mauritania in the west to Mali, Burkina Faso, Niger and northern Nigeria in the east. Because many of the nutrition and trade data discussed in this paper are reported only on a national basis, we do not include data from northern Nigeria in the figures cited above, including instead only data from Burkina Faso, Mali, Mauritania, Niger and Senegal. Undernourishment is defined here as "food intake that is insufficient to meet dietary energy requirements for an active and healthy life. Undernourishment, or hunger, is estimated by FAO as the prevalence and number of people whose food intake is insufficient to meet their requirements on a continuous basis; dietary energy supply is used as a proxy for food intake" (FAO et al., 2015, p. 13).

[4] Over the period 2006-09, imports accounted for 59% of the total rice supplies of Burkina Faso, Mali, Mauritania, Niger and Senegal and 9.7% of those countries' total cereal supplies (FAOSTAT, 2016).

coping-strategies literature (e.g. Camara, 2004; Tall, 2013; WFP, 2012; and Hazard, et al., 2008) is simply to cut back on consumption. This reduction in consumption can take many forms – reductions in the consumption of nutrient-dense foods such as animal products, fruits and vegetables in order to "defend" staple-food consumption; lower expenditures on non-food items, such as health and education expenditures; and a decrease in the number of meals eaten per day. Such self-imposed consumption restrictions of high-protein and high-vitamin foods risk eroding the family's human capital and perpetuating long-term, inter-generational poverty.

1.2. Objectives

This paper explores options for moderating compression of food consumption among poor households in Sahelian West Africa following major food supply shocks. The paper begins by quantifying, in the context of a "typical" West African Sahelian country, current consumption patterns across rural and urban household groups, as well as differences in purchasing power and willingness to substitute among staple foods in response to key food-security shocks. These consumption parameters permit quantification of the consumption changes expected among key household groups following two major supply shocks – staple-food production shortfalls and spikes in world rice prices. By highlighting critical factors influencing consumption outcomes, the paper draws implications for food and trade policies, including efforts to develop new technologies and markets for processed products. Ultimately, this analysis aims to identify policy tools that can help to broaden the ability of poor families to deal with these shocks in order to soften the deterioration in food consumption they currently endure following major supply shocks. .

2. Data and methods

2.1. Multi-market simulation model

The paper develops a multi-market simulation model to evaluate the impact of common production and world-price shocks on food consumption of vulnerable groups in the West African Sahel. Following in the tradition of Braverman and Hammer (1986), the model measures staple food consumption responses to price and income shocks of differing household groups using available estimates of key consumption parameters. For useful reviews of multi-market models and their broad range of applications, see Sadoulet and de Janvry (1995) and Croppenstedt et al. (2007).

Structurally, the present model includes four households groups and five commodities. Given differences in consumption patterns, income sources and therefore vulnerability to key shocks, the model distinguishes between two categories of food-insecure households (the rural poor and urban poor) as well as two nonpoor groups, urban and rural. Using 2010 consumption survey data from Mali along with official poverty line estimates, Table 1 summarizes the baseline consumption profile of each of these four household groups.

The five commodity groups include three staple foods, high-value foods and nonfoods. Within the staples, sorghum and millet provide the largest source of calories in most Sahelian countries (Table 1 and Me-Nsope, 2014). Rice, the region's second most important single source of calories, comes roughly 40% from regional production and 60% from imports, largely from Asia (Table 2). Other starchy staples for the Sahelian countries include maize, wheat, sweet potatoes, Irish potatoes, fonio, and small amounts of yams and cassava. Together, these other starchy staples contribute calories per capita roughly comparable to rice. High-value foods include fresh fruits and vegetables, fats and oils, dairy products, poultry, fish, red meat and high-protein legumes such as cowpeas and groundnuts. Nonfood goods and services account for the remainder of household consumption expenditures.

Price formation and supply responses differ across these five commodity groups. Given a single annual cropping season for most agricultural commodities, the model sets the short-run supply elasticity of domestic production at zero for all commodities. Weather-induced shocks to domestic production shift domestic supplies, leading to endogenous price determination for sorghum and millet (SM), other starchy staples (OSS) and high-value foods (HVF). Because imports account for over half of Sahelian West Africa's rice supplies, the model fixes the nominal rice price at import parity. Nonfoods similarly take prices as fixed, with imports balancing supply and demand. Other starchy staples (OSS) include a mix of internationally traded wheat products and regionally traded staple food substitutes, most notably maize, roots and tubers, which traders bring north into the Sahel from coastal production zones. Given two rainy seasons across most of coastal West Africa, maize farmers in particular can respond rapidly to price hikes in regional markets, enabling higher imports during drought years. For this reason, the model includes an upward-sloping supply of OSS imports. In sum, endogenous prices equilibrate sorghum/millet, OSS and high-value food markets, while imports balance supply and demand for the model's two fixed-price commodities, rice and nonfoods. Table 3 summarizes these alternative supply responses and price formations embodied in this stylized model of Sahelian West Africa.

Income for each household group varies in response to production and price shocks, which alter the quantity and value of the group's output. The model takes baseline production shares for each household group as fixed and allocates production shocks proportionally across producing groups.

Consumption likewise varies in response to price changes and shifting nominal income of each household group. For the four food commodities, the model estimates consumption responses using a log-linear demand function with constant elasticities of demand with respect to total expenditure, own price and cross prices. Demand for nonfoods becomes a residual, computed as total expenditure minus expenditure on foods, with changes in total expenditure set equal to changes in nominal income.

Shocks modeled here include a production shock and world-price shock. To model a production shock, the model evaluates the impact of a serious drought that reduces domestic production of sorghum, millet, and other starchy staples by 20%. Given the region's reliance on internationally imported rice, changes in the world rice price likewise introduce significant shocks to the West African Sahel. To illustrate the potential consumption compression implied in moderate crisis years, this model evaluates the impact of a 50% increase in the world rice price.

In order to evaluate the impact of these shocks on vulnerable households' calorie consumption, the empirical runs begin with a baseline model that includes no substitutions in consumption (all cross-price elasticities of demand set to zero) and only the rice supply (via imports) responsive to changes in prices and incomes. A second set of simulations introduces consumption substitution across staple food groups using cross-price elasticities of demand along with varying assumptions about the degree to which regional imports of other starchy staples (maize, roots and tubers) respond to changes in demand. Further sensitivity analysis explores the impact of varying degrees of consumer substitution among staple food products and making income exogenous (as opposed to endogenous). Annex A provides a full set of model equations (programmed in GAMS) used in simulating the impact of these shocks on income, prices and food consumption of vulnerable groups.

2.2. Baseline data

As its baseline, the model constructs an archetype Sahelian food economy using detailed consumption, price, production and trade data from 2010. Food consumption, expenditure and income data by household group come from the 2010 ELIM (Enquête Legère Intégrée auprès des Ménages) study in Mali (République du Mali, 2011). Using the poverty line from 2010 to define poor and nonpoor household groups, Table 1 summarizes the baseline population data as well as per capita food consumption and total expenditure for the four household groups. Rural nonpoor (RN) households produce more food than they consume, making them large net sellers of food. In contrast, the rural poor (RP) and urban households remain net buyers of staple foods (Table 1).

Aggregate food supplies draw on FAO food balance sheets. Because Mali's large irrigated rice infrastructure makes it far more rice self-sufficient than its neighbors, the baseline import shares adopt the Sahel-wide average of 40% domestic production and 60% rice imports (Table 2).

Differences in consumption patterns affect the vulnerability of the urban and rural poor. While poor rural households rely on sorghum and millet for over 40% of total calorie intake, urban households rely more heavily on rice, consuming three times as much rice per capita as the rural poor, 66 kg per capita annually compared to 19 kg (Table 1). As a result, specific shocks will affect these two groups very differently. To capture these differences in consumption patterns, the initial consumption baskets for each household group come from ELIM 2010 (République du Mali, 2011) and Bricas et al. (2013). In aggregate, the baseline food consumption quantities respect the per capita calorie availability of 2,833 kcal/person/day as well as the commodity composition of those calories as outlined in the Mali food balance sheet for 2010.

Detailed consumption data reveal significant differences in the composition of OSS and HVF consumed by different household groups. Within OSS, urban and nonpoor groups consume more wheat products and Irish potatoes than rural and poor groups, while maize and sweet potatoes claim a larger share of OSS consumption among the rural groups. More striking differences emerge in the high-value foods (HVF), where wealthy and urban groups typically consume more beef, dairy, fish, horticultural and processed foods than the rural and nonpoor households. In contrast, the rural households and urban poor consume a greater proportion of oils and legumes (particularly cowpeas and groundnuts). As a result, the calorie density of HVF and OSS differs markedly across household groups. Among HVF, poor households purchase foods with a calorie density more than double that of HVF consumed by nonpoor groups (see Table 1).

2.3. Consumption parameters

The availability of reliable food consumption parameters for the Sahelian countries of West Africa remains an important challenge for the quantification of the effects of food price and production shocks on food consumption and food security. Despite their importance, reliable estimates of food consumption parameters remain scanty and unevenly distributed across the different countries in the Sahelian region of West Africa. While a multitude of studies exist estimating food consumption parameters for Nigeria, few of them cover the Sahelian region of the country. Of the few food demand studies covering the Sahel region, even fewer have attempted to differentiate food demand estimates by location (urban versus rural) or by income groups (poor and nonpoor). Table 4 presents a summary of empirical estimates of demand parameters in the Sahel region used in this analysis, while Annex B presents details on the various empirical estimates available for the region which underlie these baseline parameters.

Most demand studies have focused on estimating consumption responses to changes in income. Far fewer have estimated responses to changes in commodity prices. As a result, empirical estimates of income elasticities of demand for different food commodities are generally more plentiful than consistent estimates of own-price elasticities. Estimates of cross-price elasticities in Sahelian countries are even more limited. This is not surprising given that most demand studies in the region use cross-sectional data, which either do not include price data or contain too little price variation to allow for an accurate estimation of food demand responses to changes in own and related product prices.

Evidence of the effects of seasonality on food demand behavior of different consumer groups is even rarer. In one welcome exception, Camara (2004) examined the effects of seasonality on the cross-price elasticities of different starchy staples in Bamako, Mali. Specifically, Camara's study reports substitution effects among different starchy staples across four different seasons— lean, harvest, post-harvest and planting seasons. Camara's findings reveal that: i) substitution among different starchy staples was strongest during the lean season; and ii) pooling data across seasons dampens the annual average estimated substitution among the different starchy staples. In fact, when data are pooled across seasons, most starchy staples items appear to behave like complements rather than substitutes. Camara's analysis thus injects a strong note of caution about cross-price elasticities estimated using annual averages. (See Table B.11 in Annex B for seasonality in cross-price elasticities as estimated by Camara, 2004). We derive our cross-price elasticities from Camara's uncompensated lean season parameters because the lean season parameters better reflect the behavior of poor households during periods of duress. .

Table 4 summarizes the baseline consumption parameters used in this paper to model the impact of food supply shocks on different household groups. Several patterns emerge. In both rural and urban locations, the poor are more likely than the nonpoor to devote additional income to food (Engel's law). In response to price changes, the poor are also more sensitive than are the nonpoor, in both rural and urban locations. Cross-price elasticities differ as well. The substitution of rice for sorghum/millet increases with income in the rural areas, but decreases with income in the urban areas. This is because rice and maize tend to compete as substitutes for sorghum/millet in the urban areas. The greater availability of maize processing mills in urban areas reduces the preparation time for maize, thereby resulting in competition between maize and rice as easy-to-cook food for time-poor urban consumers (Boughton, et al. 1997). The declining substitution of rice or maize for sorghum/millet as incomes increase in the urban area occurs because urban nonpoor households have higher initial consumption levels of rice and maize, and lower initial consumption levels of sorghum/millet, compared to urban poor households. As a consequence, an increase in the price of sorghum/millet will result in less substitution of sorghum/millet with rice in urban nonpoor households compared to urban poor households. Across rural and urban locations, the substitution of sorghum/millet for rice decreases with income, meaning that richer households are less likely to substitute sorghum/millet for rice in the event of an increase in the price of rice. OSS (mostly maize) are stronger substitutes for rice than are sorghum/millet, especially in the urban areas. In the rural areas, sorghum/millet substitute more for OSS when there is an increase in the price of OSS, while in the urban areas, an increase in the price of OSS increases the demand for rice more than that of sorghum/millet. Note that these consumption parameters rely on empirical estimates of uncompensated, Marshallian demand responses, which incorporate both the price response and the resulting income effect of a given price change.

3. Results

3.1. Impact of a major drought

Table 5 summarizes the impacts of a major drought on the different population groups under different scenarios. These runs define a major drought as a 20% fall in the domestic production of sorghum, millet and other starchy staples. Under all scenarios, the rural poor (RP) face the greatest consumption pressure of all household groups. Under scenarios that allow rice imports but no regional trade in OSS (Simulations a and b), the rural poor face severe compression in caloric intake, as per capita caloric intake falls by 15%, two to four times more than other household groups. The severity of the impact on rural poor households reflects the group's high initial level of sorghum/millet consumption and their sensitivity to changes in the sorghum/millet price (own-price elasticity of demand of -0.8, Table 4). As net buyers of SM and OSS, the rural poor and both urban household groups endure falling real income in the face of sharp spikes in staple food prices of 49% to 67% for SM and 37% to 53% for OSS (Table 5, Simulations a and b).

Regional trade in OSS moderates this consumption pressure significantly. Under moderate trade responsiveness of OSS imports, regionally sourced imports of 164,000 tons from unaffected coastal countries drive calorie improvements among all household groups (Table 5, Simulation c).[5] The increased supplies of OSS moderate the domestic OSS price, which rises only 15% in Simulation c, compared to 53% under the no-trade scenario (Simulation b). The price increases for other foods are lower as well because regional OSS imports facilitate substitution, which moderates pressure on other staple foods. As a consequence, among poor rural households, the calorie shortfall drops sharply, from -15% to –11%. The urban poor also benefit, as their calorie shortfalls dip from -3.6% to -2.0%.

Under higher trade responsiveness (Simulation d), OSS imports increase even more, further moderating the OSS price increase and calorie compression among all household groups. If OSS imports were perfectly elastic at the current price level (similar to rice), Simulation d suggests that OSS imports could increase by as much as 254,000 tons (from -189,000, mt to +65,000 mt) relative to the no-expansion-of-OSS-trade situation (Simulation b), benefitting all household groups. Given likely aggregate supply constraints in coastal countries, we consider the moderate supply response (Simulation c) more realistic.

Substitution among food staples also helps to moderate consumption pressure, though primarily among urban households and the rural nonpoor. Simulations a and b compare the impact of the drought with and without demand substitution among staple foods. The inclusion of non-zero, positive cross-price elasticities in Simulation b leads to increased consumer demand for rice in response to sharply increased SM and OSS prices. As a result, rice imports increase by 100,000 tons (from 13,000 to 113,000), benefitting all rice consumers. Urban nonpoor households benefit most. Given their preference for rice and their strong purchasing power, calorie compression falls from -5.1% in Simulation a (with zero cross-price elasticities) to -1.2% in Simulation b (with positive cross-price elasticities). For the rural poor, substitution in the absence of trade in OSS results in only a marginal improvement in calorie intake, as calorie compression drops from -15.4% to -15.0%. This modest result arises because food substitution in the absence of trade pushes up prices for local foods, and given the rural poor's weak purchasing power, these households get outbid by the nonpoor households (see section 4.1 below).

5 The figure for imports of 164,000 tons under the drought scenario with moderate OSS trade (Simulation c) is calculated as the difference between the change in the OSS supply in Simulation b relative to the non-drought situation (-189,000 mt) and that under Simulation c (-25,000 mt). Equivalently, it is equal to the sum of the net change in imports shown in Table 5 under Simulation c (98,700 mt) plus the original level of imports in normal years (65,300 mt, or 15% of normal supplies).

3.2. Impact of a world rice price hike of 50%

Table 6 illustrates the impacts of a 50% spike in world rice prices. Higher world rice prices hit urban households hardest, particularly the urban poor. Under the most realistic conditions (moderate demand substitution and moderate trade in OSS—Simulation i), per capita calorie consumption would fall by 7.0% among the urban poor and by 3.2% for the urban nonpoor. Rural households face smaller losses given their lower initial levels of rice consumption. The rural nonpoor actually benefit slightly, with calorie consumption increasing by 0.2%. As large net sellers of rice, the rural nonpoor earn higher incomes as rice prices increase, and this income effect overcomes the pressure of rising prices for what is to them a minor consumption item.

Household demand for substitute staple foods increases in response to spiking rice prices. As a result, prices of OSS and SM increase, by 8.8% for SM and 10.4% for OSS, when allowing for price-induced cross-commodity food substitution, but no expansion of OSS regional trade (Table 6, Simulation h).

Regional trade in other starchy staples helps to moderate the consumption pressure originating from the spike in the world rice price. In the absence of regional trade in OSS, a 50% increase in the rice price results in a 20% reduction in rice imports because of falling rice consumption across all consuming groups (Table 6, Simulation h). Under moderate responsiveness of regional OSS imports (scenario i), the total supply of OSS increases by 38,000 tons relative to the pre-price-spike situation, filling about a third of the total supply gap created by the 101,000-ton reduction in rice imports. This growth in the OSS supply softens the impact of the rice price hike; the increase in the OSS price falls from 10.4% with no expansion of OSS trade to an increase of only 4.2% with a moderate increase in OSS trade. The moderation of OSS and SM price increases results in a greater substitution towards these starchy staples and a consequent reduction in the impact of the price hike on per capita calorie consumption for all household groups. The rural poor benefit the most from a moderate increase in trade in OSS, as their calorie loss per capita declines from -2.0% with no expansion of OSS trade to -1.1% with a moderate OSS trade increase.

The effect of consumers' willingness to substitute across staples is seen by comparing Simulation g (no demand substitution and no expansion of regional trade) with Simulation h (substitution across staple foods but still no expansion of regional trade). This comparison reveals substantially higher SM and OSS prices with substitution as well as a slight moderation in rice imports, which fall by 20.2% with food substitution compared to 24.1% without. In the absence of expanded regional trade in OSS, the price increase in SM and OSS intensifies the domestic bidding war to the disadvantage of the rural poor, whose higher price sensitivity leads to a per capita calorie loss that increases from -1.3% under scenario g (no substitution) to -2.0% under scenario h (substitution). In contrast, substitution allows the urban nonpoor to exercise their higher purchasing power to outbid the other groups for limited supplies. As a result, the urban nonpoor see their consumption reduction improve from -5.3% under no substitution (Simulation g) to -3.5% with substitution (Simulation h).

3.3. Sensitivity analysis

Varying cross-price elasticities of demand

Tables 5 and 6 also analyze the impact of variations in the willingness of consumers to substitute among different food staples, as measured by cross-price elasticities of demand. The next-to-last column of each table shows how outcomes would differ if all cross-price elasticities of demand shown in Table 4 were doubled—for example, if expansion in the availability of processed forms of millet, sorghum and other starchy staples made them closer substitutes for each other and for rice. The last column in each table shows the impacts of doubling only the cross-price elasticities in the urban areas —for example, if newly available processed products remain concentrated only in the cities.

In the case of a major drought, higher food substitution among all household groups (Table 5, Simulation e) leads to a major increase in rice imports (compared to the base Simulation c) and to a slight increase in OSS and SM prices, which, in turn, trigger increased OSS imports. In this scenario, the responsiveness of rice imports increases from 58,000 tons in the base scenario (Table 5, Simulation c) to 127,000 tons under higher food substitutability (Table 5, Simulation e). All income groups benefit. However, when higher substitutability occurs only in urban areas, solely the urban households gain. While the urban poor see calorie consumption improve, from a 2% decline with a drought under moderate substitutability (Simulation c) to a 1.2% improvement under urban-only higher substitution (Simulation f), both rural household groups see exacerbated calorie losses.

A similar result occurs in the face of a world rice price spike (Table 6). All households benefit from increased substitutability when cross-price elasticities increase for all household groups (Simulation k). In response to higher substitutability, SM and OSS prices increase, triggering increases in OSS imports. These imports increase from 38,000 tons in the base scenario (Simulation i) to 95,000 tons under high substitution (Simulation k). As a result, all household groups see improved calorie consumption. However, when only urban households have access to higher substitutability foods (Simulation l), urban households improve calorie consumption at the expense of rural households. This outcome suggests that the geographic availability of more substitutable processed foods, which may trigger these changes in substitutability in the first place, will become an important determinant of differential consumption outcomes in rural and urban areas.

Endogenizing farm income.

The simulations presented in Tables 5 and 6 all consider farm income endogenous, by incorporating income gains for surplus food producers (particularly the rural nonpoor), who see their incomes rise as commodity prices rise. Income gains from these net sales help to moderate the consumption shock resulting from increases in staple food prices. Table 7 shows the impact of making farm income exogenous by comparing what we consider our most probable simulations from Tables 5 and 6 (runs c and i, respectively) with equivalent runs in which agricultural income is taken as exogenous and hence unaffected by price increases resulting from the shocks analyzed in the models. In a major drought, without the income gain from net sales, calorie losses accruing to the rural nonpoor nearly double to -7.6% compared to the -4.3% anticipated under endogenized farm income in the base scenario. Similarly, in the event of a 50% hike in world rice price, calorie consumption for the rural nonpoor would fall from roughly neutral (0.2% increase) in the base scenario to -1.1% without the income effect.

4. Discussion

4.1. Bidding wars

Any supply shock, whether it be a shortfall in domestic production or a spike in the world price of rice, will set off a bidding war among different groups in the population for the resulting reduced supply of staples. In these bidding wars, the urban poor and rural poor almost always lose, absorbing a disproportionate share of the reduction in the staple food supply. Even in cases where the shock induces increased imports, either from the world or regional market, the poor (especially the rural poor), because of their low purchasing power, typically obtain a very small proportion of the increased imports.

Table 8 illustrates the bidding war in the aftermath of a major drought. The rural poor absorb a disproportionate share of the total reduction in SM and OSS compared to their share of total consumption of those goods in the baseline (pre-drought) situation. Although the rural poor account for 43% of baseline SM consumption, they absorb 57% of the total reduction in supplies. In contrast, the urban nonpoor account for 17% of total initial SM consumption, but absorb less than 6% of the reduction, as they bid supplies away from the rural poor. The reduction in total OSS supply amounts to only 2.2%, much less than the 20% fall in the SM supply, due to increased regional OSS imports. Nonetheless, the rural poor and all urban households lose the bidding war for OSS supplies to the rural nonpoor, who absorb only 14% of the reduced supply compared to their 31% baseline consumption share. As large net sellers of cereals, the rural nonpoor see their real income increase with rising commodity prices, enabling them to bid away food supplies from all other household groups. Rice supplies, which increase by 7.5% due to imports, also go disproportionately to rural nonpoor households for a similar reason. This group, which accounts for only 18% of the initial share of national rice consumption, absorbs 40% of the increased rice supplies.

Table 9 illustrates the bidding wars following a world rice price hike. These bidding wars revolve around which groups will absorb the reduction in rice supplies and which ones will capture the increase in OSS supplies resulting from the induced increase in regional imports. In the scramble for diminishing rice supplies, the rural nonpoor clearly win. While they account for 18% of initial rice consumption, they absorb only 6% of the total reduction in supplies. In contrast, the urban poor emerge as the clear losers, accounting for only 9% of initial rice consumption but absorbing 17% of the shrinkage. In the bidding for increased OSS supplies, the rural poor lose out. While they account for 25% of initial OSS consumption, they capture only 1% of increased OSS supplies. In contrast, the urban nonpoor capture over 80% of increased OSS supplies.

4.2. Trade

Trade serves as a potentially critical shock absorber in times of food insecurity. In the case of a major drought, regional imports of 164,000 tons of maize, cassava and other starchy staples (OSS) from unaffected coastal countries plus 58,000 tons of rice imports from Asia fill nearly 40% of the gap resulting from a 20% decline in domestic SM and OSS production (Table 5, Simulation c). Similarly, in the case of a world rice price hike, regional imports of OSS (especially maize) would fill over 35% of the gap resulting from price-induced reductions in rice imports (Table 6, Simulation i).

The analysis reported above highlights the importance of rice imports during drought years and of OSS imports from coastal countries during times of drought in the Sahel as well in periods of world price spikes. The results in Tables 5 and 6 clearly show that increases in the supply responsiveness of regional OSS imports can help to moderate consumption pressure in the Sahel.

Together, these findings reinforce the importance of repeated efforts by ECOWAS, WAEMU, CILSS and other regional organization to maintain open borders. These efforts will prove critical in building resilient regional food systems capable of coping with what would otherwise be extreme consumption compression by vulnerable groups during food crises.

4.3. Consumer substitution

In general, substitution among staple foods serves to moderate supply-induced consumption shortfalls. The basic mechanism at work involves bidding up prices of unaffected substitute foods, which in turn helps to elicit a supply response. In Eastern and Southern Africa, for example, multi-year storage of in-ground cassava stocks serves as a regional food buffer stock. In drought years, when maize supplies fall perceptibly, cassava farmers increase the share of in-ground cassava harvested, while regional traders similarly increase volumes of dried cassava traded (Haggblade et al. 2012). In West Africa, maize supplies from the coastal countries, which are generally less affected by drought than their northern Sahelian neighbors and which have two rainy seasons (and hence the possibility of two maize crops per year), play a similar buffering role. In addition, yams and cassava-based convenience foods like gari and attieké also are increasingly traded between the coastal states and the Sahel.

In scenarios without a short-term supply response capacity through expanded regional trade, however, consumer substitution among food staples benefits primarily nonpoor households, who have the purchasing power to outbid vulnerable groups for limited available food supplies.

The results reported here remain sensitive to the values of the demand parameters used in the model, particularly the own-price and cross-price elasticities of demand. Despite the potential importance of commodity substitution among food staples, careful empirical evidence on cross-price elasticities of demand remains surprisingly elusive. The review of the available estimates of these parameters (Annex B) reveals the paucity of empirical estimates for various countries in the region and a great variation in the econometric estimates. In order to design more effective policies and programs, policy makers and analysts therefore need better information on the willingness of different consumer groups to engage in inter-commodity substitution in consumption and across different seasons.

5. Conclusions and Policy Implications

Four major policy implications emerge from the preceding analysis:

• *Policy implication #1: Fluid trade flows benefit vulnerable groups*

Tradability of staple foods, both regionally and internationally, emerges as a vital tool in helping protect both the urban and rural poor populations from shocks resulting from reductions in domestic staple food production and spikes in world prices. In the case of a major drought, policy makers have long recognized the importance of rice imports in helping protect the urban poor and nonpoor populations, which account for much of the rice consumption in the Sahelian countries. Less widely recognized is how regional tradability of other starchy staples, coupled with the willingness of consumers to substitute these other starchy staples for rice to some degree, can mitigate the pain caused by a major drought or a spike in world rice prices. For example, compare a major drought scenario where only rice imports can increase and there is no inter-staple substitution by consumers to a scenario of moderate tradability of OSS and a degree of substitution consistent with our best estimates of cross-price elasticities of demand. In the latter scenario, the reduction in per capita calorie consumption among the urban poor falls by more than two-thirds compared to the former scenario and virtually disappears for the urban nonpoor. Among the rural poor, who absorb the hardest hits during a major drought, compression in per capita calorie consumption falls 27% relative to the no-increase-in-OSS-trade, no-substitution scenario.

Therefore, efforts by ECOWAS and other regional organizations to build a truly regional market for foodstuffs in West Africa will prove vital to the food security of the Sahelian countries. The challenge remains to convince policy makers that more open borders can only function effectively as a two-way street. The Sahelian countries cannot expect to be able to close their own borders to exports in periods of high prices (to protect domestic consumers) and simultaneously expect their neighbors to export to them during periods of stress. Yet, the need to protect low-income domestic consumers during periods of high prices remains a stark political reality. The Sahelian countries therefore need to find instruments other than trade barriers to offer that consumer protection. This leads directly to policy implication #2.

Policy implication #2: The poor require special support

The urban and rural poor typically suffer the most acute calorie compression during food crises, particularly when policy makers place restrictions on regional trade. During rice price crises, the urban poor face the largest consumption pressure, while in drought years the rural poor emerge as most vulnerable. Therefore, in addition to improving trade flows, policy makers need to offer increased purchasing power through temporary, targeted income transfers to vulnerable groups. These could take various forms, from public works employment to direct cash transfers to in-kind distribution of food.

These efforts need to target the rural poor and not just the urban poor. The income impacts of higher food prices help to temper the adverse impacts on the rural nonpoor, but have little positive impact on the rural poor. Because the rural nonpoor are net sellers of starchy staples and high value foods, higher food prices increase their incomes, which helps offset the negative effects of higher prices on their consumption. The differential income effect on the rural nonpoor and the rural poor underlines the need in policy analysis to distinguish between rural net sellers and rural net buyers of staple foods rather than always assuming that all farmers benefit from higher food prices.

Policy implication #3: Increase substitutability through improved processing of traditional staple foods

The sensitivity analysis presented above demonstrates that increasing the degree of substitutability of sorghum/millet and other starchy staples for rice (e.g., through processing) could help reduce the adverse impacts of a world price shock on consumers, particularly when coupled with more open regional trade in these products. For many years, CILSS and other regional organizations have promoted the development of processed maize, millet, sorghum and other local food products to substitute for imported rice (Ilboudou, and Kambou, 2009). Our analysis suggests that these product development efforts can significantly help the poor, but only when coupled with efforts to ensure the regional tradability of locally produced starchy staples. The analysis further suggests that increasing cross-product substitutability only in urban areas — for example, through making such processed products more available only in the cities — can actually make the rural population worse-off by exacerbating the bidding wars between rural and urban groups for available food supplies. This implies that policy makers need to include rural areas in their efforts to improve the availability of processed local staple foods.

Policy implication # 4: Support efforts to get better information on cross-product substitution

Developing improved food policies requires solid information on how consumers will respond to changes in the relative prices of different foods. The results presented above demonstrate the sensitivity of outcomes to the demand parameters used in the model. Despite their importance, available estimates of cross-price elasticities for different staple foods in the Sahel remain scarce. Furthermore, those that exist from econometric studies vary considerably in terms of commodity disaggregation, time periods, location and methods. This suggests the need to support further research on consumer behavior, including use of non-econometric approaches (e.g. contingent valuation studies with consumers) to obtain more reliable and disaggregated estimates of expected consumer responses during periods of stress.

Table 1. Household consumption and expenditure baseline

	Household groups				Total
	Rural		Urban		
	poor	nonpoor	poor	nonpoor	
Population share (%)	37%	25%	8%	30%	100%
Total expenditure ($/capita/year)	207	558	384	1,449	683
Consumption (kg/capita/year)					
sorghum/millet	125	158	55	61	109
rice	19	42	66	117	58
other starchy staples	56	103	45	110	83
high-value foods	39	102	138	278	134
nonfoods*	83	310	133	958	406
Net sales (production minus consumption: kg/capita/year)					
sorghum/millet	-28	133	-55	-61	0
rice	-1	24	-66	-117	-35
other starchy staples	-12	116	-45	-110	-12
high-value foods	89	153	54	-278	-8
Calorie density (kcal/kg)					
sorghum/millet	2,893	2,893	2,893	2,893	2,893
rice	3,618	3,618	3,618	3,618	3,618
other starchy staples	2,725	2,699	2,697	2,560	2,752
high-value foods	6,247	2,482	2,233	1,308	3,224
Caloric intake (kcal/person/day)					
sorghum/millet	990	1,252	436	483	860
rice	189	418	657	1,155	571
other starchy staples	420	764	334	774	510
high-value foods	671	691	843	994	892
total calories	2,270	3,125	2,270	3,406	2,833

*Nonfoods valued in 2010 U.S. dollars.

Sources : République du Mali, (2011), FAOSTAT (2016), Observatoire du Marché Agricole (2015), Bricas et al. (2013).

Table 2. Commodity supplies baseline data

	Commodity				
	sorghum/ millet SM	rice R	other starchy staples OSS	high-value foods HVF	nonfoods NF
Production (kg/capita)*	109	23	71	126	414
Exports (kg/capita)*	0	0	0	5	108
Import share of domestic consumption	0%	60%	15%	10%	25%
Price ($/kg)	0.30	0.56	0.45	1.29	1.00
Value added/value of gross output	0.90	0.75	0.90	0.75	0.80
GDP share	0.06	0.02	0.06	0.22	0.63

*Nonfoods valued in 2010 U.S. dollars.

Sources: République du Mali, (2011),), Observatoire du Marché Agricole (2015), Miller et al. (2011), World Bank (2016).

Table 3. Price determination in the multi-market model

	Supply responsiveness		
Commodity	Domestic production (Q)	Imports (M)	Price determination
1. Sorghum/millet	Fixed	Fixed at zero	Endogenous (S=D)
2. Rice	fixed	Perfectly elastic	Exogenous world price sets domestic price
3. Other starchy staples	Fixed	Imperfectly elastic	Endogenous (S=D)
4. High-value foods	Fixed	Fixed	Endogenous (S=D)
5. Nonfoods	Fixed	Perfectly elastic	Fixed at base level; imports balance supply and demand

Table 4. Demand parameters

Elasticity of demand	sorghum/ millet SM	rice R	other starchy staples OSS	high-value foods HVF
	with respect to commodity i			
Expenditure elasticity of demand				
Rural poor (RP)	0.90	1.40	0.70	1.50
Rural nonpoor (RN)	0.40	0.90	0.50	1.20
Urban poor (UP)	0.80	0.90	0.60	1.00
Urban nonpoor (UN)	-0.20	0.50	0.40	0.80
Price elasticity of demand, Rural Poor				
sorghum/millet (SM)	-0.8	0.1	0.15	
rice '(R)	0.1	-0.4	0.05	
other starchy staples (OSS)	0.2	0.05	-0.9	
high-value foods (HVF)				-0.6
Price elasticity of demand, Rural Nonpoor				
sorghum/millet (SM)	-0.6	0.05	0.15	
rice '(R)	0.2	-0.2	0.1	
other starchy staples (OSS)	0.1	0.05	-0.6	
high-value foods (HVF)				-0.4
Price elasticity of demand, Urban Poor				
sorghum/millet (SM)	-0.4	0.1	0.1	
rice '(R)	0.1	-0.8	0.15	
other starchy staples (OSS)	0.15	0.15	-0.8	
high-value foods (HVF)				-0.9
Price elasticity of demand, Urban Nonpoor				
sorghum/millet (SM)	-0.2	0.05	0.1	
rice '(R)	0.05	-0.4	0.2	
other starchy staples (OSS)	0.1	0.2	-0.5	
high-value foods (HVF)				-0.7

Source: Annex B.

Table 5. Impact of a Major Drought*								
			Simulations					
			a	b	**c****	d	e	f
		Demand substitution	none	moderate	**moderate**	moderate	high	hi-urban
		Import responsiveness						
		rice	infinite	infinite	**infinite**	infinite	infinite	infinite
		other starchy staples	zero	zero	**medium**	infinite	medium	medium
Simulation results								
% Δ	Q	domestic production						
		SM	-20	-20	**-20**	-20	-20	-20
		Rice						
		OSS	-20	-20	**-20**	-20	-20	-20
		HVF						
% Δ	P	price						
		SM	49.4	67.1	**53**	47	60.9	54.5
		Rice						
		OSS	37.1	53.2	**14.7**	0	18.3	15.9
		HVF	3.5	4.9	**2.6**	1.7	3	2.7
% Δ	M	imports						
		SM						
		Rice	2.9	24.5	**12.5**	7.3	27.7	19.7
		OSS			**98.7**	152.7	131.7	108.8
		HVF						
Δ	S	total supply change ('000 tons) =						
Δ	D	change in demand ('000 tons)						
		SM	-289	-289	**-289**	-289	-289	-289
		Rice	13	113	**58**	33	127	91
		OSS	-189	-189	**-25**	65	30	-8
		HVF						
% Δ	Cal/cap/day							
		RP rural poor	-15.4	-15.0	**-11.3**	-9.1	-9.4	-11.5
		RN rural nonpoor	-8.1	-4.4	**-4.3**	-3.8	-0.7	-4.4
		UP urban poor	-6.7	-3.6	**-2.0**	-1	1.4	1.2
		UN urban nonpoor	-5.1	-1.2	**-0.4**	0.2	2.9	2.6

* Shock = 20% reduction in sorghum millet (SM) and other starchy staples (OSS)
Source: model simulations.
** Best-guess baseline scenario.

Table 6. Impact of a 50% Increase in World Rice Price

		Simulations					
		g	h	**i***	j	k	l
	Demand substitution	none	moderate	**moderate**	moderate	high	hi-urban
	Import responsiveness						
	rice	infinite	infinite	**infinite**	infinite	infinite	infinite
	other starchy staples	zero	zero	**medium**	infinite	medium	medium
Simulation results							
% Δ Q	domestic production						
	SM						
	Rice						
	OSS						
	HVF						
% Δ P	price						
	SM	0.6	8.8	**7.0**	5.8	16.6	9.1
	Rice	50	50.0	**50.0**	50.0	50	50
	OSS	0.5	10.4	**4.2**	0	9.5	7.2
	HVF	0.6	1.4	**1.0**	0.8	1.6	1.2
% Δ M	imports						
	SM						
	Rice	-24.1	-20.2	**-22.1**	-23.3	-15.1	-19.2
	OSS			**22.8**	39.4	57.2	41.3
	HVF						
Δ S	total supply change ('000 tons) =						
Δ D	change in demand ('000 tons)						
	SM						
	Rice	-111	-93	**-101**	-107	-70	-88
	OSS			**38**	65	95	69
	HVF						
% Δ Cal/cap/day							
	RP rural poor	-1.3	-2.0	**-1.1**	-0.5	-0.6	-1.9
	RN rural nonpoor	-0.3	0.0	**0.2**	0.4	1.8	-0.1
	UP urban poor	-8.2	-7.5	**-7.0**	-6.6	-4.9	-4.8
	UN urban nonpoor	-5.3	-3.5	**-3.2**	-3	0.1	-0.2

* Best-guess baseline scenario.
Source: model simulations.

Table 7. Impact of Endogenizing Income

Simulation Results		Parameter variations:	Major Drought		50% Increase in World Rice Price	
		Parameter variations:	c		i	
		Agricultural income	endogenous	exogenous	endogenous	exogenous
		Trade response: rice	yes	yes	yes	yes
		other starchy staples	medium	medium	medium	medium
% Δ Q	domestic production					
	SM		-20.0	-20.0		
	Rice					
	OSS		-20.0	-20.0		
	HVF					
% Δ P	price					
	SM		53.0	49.3	7.0	5.9
	Rice				50.0	50.0
	OSS		14.7	13.9	4.2	3.8
	HVF		2.6		1.0	
% Δ M	imports					
	SM					
	Rice		12.5	9.6	-22.1	-23.1
	OSS		98.7	91.9	22.8	20.4
	HVF					
Δ S	total supply change ('000 tons) =					
Δ D	change in demand ('000 tons)					
	SM		-289	-289		
	Rice		58	44	-101	-106
	OSS		-25	-36	38	34
	HVF					
% Δ Cal/cap/day						
	RP	rural poor	-11.3	-11.6	-1.1	-1.2
	RN	rural nonpoor	-4.3	-7.6	0.2	-1.1
	UP	urban poor	-2.0	-1.5	-7.0	-6.8
	UN	urban nonpoor	-0.4	0.1	-3.2	-3.0

Source: model simulations.

Table 8. Bidding wars following a major drought

Household group	SM - supply falls by 20% Initial share of total consumption	Share of reduction absorbed	OSS- Supply falls by 2.2% Initial share of total consumption	Share of reduction absorbed	Rice- Supply increases by 7.5% Initial share of total consumption	Share of increase absorbed
Rural poor	43%	57%	25%	32%	12%	12%
Rural nonpoor	36%	34%	31%	14%	18%	40%
Urban poor	4%	3%	4%	8%	9%	8%
Urban nonpoor	17%	6%	40%	46%	61%	40%
total	100%	100%	100%	100%	100%	100%

Legend: losers (dotted shading); winners (green shading)

Source: Simulation c, Table 5.

Table 9. Bidding wars following a world rice price hike

Household group	SM - supply stable Initial share of total consumption	Share of final consumption	OSS- Supply increase by 3.4% Initial share of total consumption	Share of increase absorbed	Rice- Supply falls by 13.2% Initial share of total consumption	Share of decrease absorbed
Rural poor	43.2%	43.1%	25%	1%	12%	13%
Rural nonpoor	36.1%	35.9%	31%	13%	18%	6%
Urban poor	3.8%	3.9%	4%	5%	9%	17%
Urban nonpoor	16.9%	17.1%	40%	81%	61%	64%
total	100%	100%	100%	100%	100%	100%

Legend: losers (dotted shading); winners (green shading)

Source: Simulation i, Table 6.

Annex A. GAMS Model: Sets, Parameters, Variables and Equations

```
SET    H          households
                  /           RP     h1 rural poor
                              RN    h2 rural nonpoor
                              UP     h3 urban poor
                              UN    h4 urban nonpoor    /  ;

SET     I      commodities
                  /           SORMILLET      c1
                              RICE                c2
                              OTHSTAPLE      c3
                              HIGHVALUE     c4
                              NONFOODS       c5  /  ;

SET F(I)        subset of food commodities
                     /        SORMILLET           c1
                              RICE                       c2
                              OTHSTAPLE           c3
                              HIGHVALUE           c4    /  ;

SET T(I)        subset of tradable commodities with less than perfectly elastic import supply
                     /        OTHSTAPLE             /  ;

PARAMETERS
* supply parameters
     Q0(I)    initial production (thousand tons)
     M0(I)    initial imports (thousand tons)
     X0(I)    initial exports (thousand tons)
     P0(I)    initial price ($ per ton)
     THETA(I) elasticity of import response w.r.t. a 1% change domestic price
     SHOCK(I) supply shifter (% change in harvest due to exogenous shock)

* demand parameters
     ED(H,I,J)  price elasticity of demand by hh H for commodity I wrt J
     EY(H,I)   expenditure elasticity of demand by hh H for commodity I
     CALKG(I) calories per kg from each commodity
     CALKG2(H,I) calories consumed per dollar of other foods, by hh
     CALCAP(H,I) calories consumed by hh H from commodity I (per day)

* income parameters
     PRODSHARE(H,I)  compute production share of each hh group
     NETSALES0(H,I)  net sales of agricultural commodities
     YCAP0(H)        per capita household income
     Y0(H)           total income per hh group
```

```
VARIABLES
        Q(I)            domestic production (thousand tons)
        X(I)            exports (thousand tons)
        M(I)            imports (thousand tons)
        S(I)            supply (thousand tons)
        P(I)            price ($ per ton)
        Y(H)            income per hh group
        D(H,I)          demand by hh H for commodity I (thousand tons)
        DTOT(I)         total demand for commodity I from all hh (thousand tons)
        CONSTANT        constant
;

EQUATIONS
        PRODN(I)                domestic production
        IMPORTS(T)              imports of OSS with imperfect supply elasticity from region
        SUPPLY(I)               total supply
       YENDOG(H)                determines household income as prices and production changes
        HHDEMAND(H,I)         demand from each hh group for commodity i
        TOTALD(I)               total demand from all hh groups
        EQUIL(I)                equilibrium
        OBJ                     objective function
    ;

     PRODN(F) ..                Q(F) =E= Q0(F)*SHOCK(F) ;
     IMPORTS(T) ..              M(T) =E= M0(T) * (P(T)/P0(T))**THETA(T) ;
     SUPPLY(F) ..               S(F) =E= Q(F) + M(F) - X(F) ;
     YENDOG(H) ..               Y(H) =E= Y0(H) + SUM(F, NETSALES0(H,F)*(P(F)-P0(F)) )
;
     HHDEMAND(H,F) ..                   D(H,F) =E= D0(H,F) *
                                    PROD(G, (P(G)/P0(G))**ED(H,F,G) ) *
                                          (Y(H)/Y0(H))**EY(H,F)    ;
     TOTALD(F) ..               DTOT(F) =E= SUM(H, D(H,F) ) ;
     EQUIL(F) ..                S(F)      =E= DTOT(F) ;
     OBJ ..                             CONSTANT =E= 100 ;
;

* SIMULATIONS

* major drought
* SHOCK("SORMILLET") = 0.8   ;
* SHOCK("OTHSTAPLE") = 0.8   ;

* world rice price shock
P.FX("RICE") = P0("RICE")*1.5
```

Annex B. Empirical Estimates of Consumption Elasticities in West African Sahel

Table B.1. Consumption Parameters Used in the Model

	Expenditure Elasticities of Demand by Income Group				
	Sorghum/Millet	Rice	Other Starchy Staples	High Value Foods	Non-foods
Rural poor	0.90	1.40	0.70	1.50	1.05
Rural nonpoor	0.40	0.90	0.50	1.20	1.19
Urban poor	0.80	0.90	0.60	1.00	0.95
Urban nonpoor	-0.20	0.50	0.40	0.80	0.92
	Price Elasticities of Demand by Income Group				
Demand \ Prices	Sorghum/Millet	Rice	Other Starchy Staples	High Value Foods	
	Rural Poor				
Sorghum/Millet	-0.80	0.10	0.15		
Rice	0.10	-0.40	0.05		
Other Starchy Staples	0.20	0.05	-0.90		
High Value Foods				-0.60	
	Rural Nonpoor				
Demand \ Prices	Sorghum/Millet	Rice	Other Starchy Staples	High Value Foods	
Sorghum/Millet	-0.60	0.05	0.15		
Rice	0.20	-0.20	0.10		
Other Starch Staples	0.10	0.05	-0.60		
High Value Foods				-0.40	
	Urban poor				
Demand \ Prices	Sorghum/Millet	Rice	Other Starchy Staples	High Value Foods	
Sorghum/Millet	-0.40	0.10	0.10		
Rice	0.10	-0.80	0.15		
Other Starch Staples	0.15	0.15	-0.80		
High Value Foods				-0.90	
	Urban Nonpoor				
Demand \ Prices	Sorghum/Millet	Rice	Other Starchy Staples	High Value Foods	
Sorghum/Millet	-0.20	0.05	0.10		
Rice	0.05	-0.40	0.20		
Other Starch Staples	0.10	0.20	-0.50		
High Value Foods				-0.70	

Table B.2. Expenditure Elasticity Estimates from the Literature: Rice

		Place of Residence			Income level		
Source	**Coverage**	**All**	**U**	**R**	**L**	**M**	**H**
Olarunfemi (2010)	Ondo, Nigeria	1.42					
Balarabe, et. al. (2006)	Kaduna, Nigeria	0.72					
Edun & Haruna (2013)	Akoko S. West	0.63					
Oyinbo et al, 2013	Kaduna, Nigeria	0.69					
Akinyele & Rahji (2007)	Northern Nigeria				2.56	1.21	0.82
Johnson, et al. (2013)	Nigeria	0.63	0.43	0.77			
Savadogo & Kazianga (1999)	B. Faso-urban	0.80			0.80	0.80	0.60
Chistenson (1999)	Sahel Region	0.93					
Camara (2004)	Mali-Bamako		0.80				
Me-Nsope (2014)	Mali-Urban		0.96		1.25	0.88	1.24
Me-Nsope (2014)	Mali-Rural			0.73	0.65	1.01	1.00
Taondyandé & Yade (2012)	Mali	0.92	0.45	1.24			
Taondyandé & Yade (2012)	Burkina Faso	1.41	0.87	1.41			
Taondyandé & Yade (2012)	Niger	1.35	0,78	1,43			
Taondyandé & Yade (2012)	Senegal	-0.26	0,58	0,91			
Zhou & Staatz (2016)	Nigeria		0.77	0.92			
Zhou & Staatz (2016)	Burkina Faso		0.90	1.40			
Zhou & Staatz (2016)	Mali		0.50	1.20			
Zhou & Staatz (2016)	Senegal		0.60	0.90			
Zhou & Staatz (2016)	Niger		0.80	1.40			
Rogers and Lowdermilk (1991)	Urban Mali		0.56				
Lowdermilk-(1991)	Mali-5 Southern cities		0.62		0.72		0.54

M=Millet; S=Sorghum; U=urban; R=rural; L=Low; M=Middle; H=High

Table B.3. Expenditure Elasticity Estimates from the Literature: Sorghum/Millet

		Place of Residence			Income level			
Source	**Coverage**	**All**	**U**	**R**	**L**	**M**	**H**	**Note**
Balarabe, et. al. (2006)	Kaduna, Nigeria	0.62 0.36						M S
Akinyele & Rahji (2007)	Northern Nigeria				0.21	1.21	0.21	M
Johnson, et al. (2013)	Nigeria	0.07	0.07	0.13				
Savadogo & Kazianga (1999)	B. Faso-Urban	0.4			0.7	0.3	-0.6	
Camara (2004)	Mali-Bamako		0.84					
Me-Nsope (2014)	Mali-Urban		1.04 1.50		0.76 0.67	1.08 1.45	0.42 1.25	M S
Me-Nsope (2014)	Mali-Rural			1.2 1.11	1.25 1.05	0.98 1.07	1.03 0.97	M S
Taondyandé & Yade (2012)	Mali	0.18	0.24	0.51				
Taondyandé & Yade (2012)	Burkina Faso	0.45	-0.22	0.62				
Taondyandé & Yade (2012)	Niger	0.82	0.47	0.87				
Taondyandé & Yade (2012)	Senegal	-0.14	0.48	0.88				
Zhou & Staatz (2016)	Nigeria		0.84	0.44				
Zhou & Staatz (2016)	B. Faso		-0.20	0.60				
Zhou & Staatz (2016)	Mali		0.20	0.50				
Zhou & Staatz (2016)	Senegal		0.50	0.90				
Zhou & Staatz (2016)	Niger		0.50	0.90				
Rogers & Lowdermilk (1991)	Mali-urban		0.52					
Lowdermilk-(1991)	Mali-5 Southern cities		0.38		0.42		0.35	

M=Millet; S=Sorghum; U=urban; R=rural; L=Low; M=Middle; H=High

Table B.4. Expenditure Elasticity Estimates from the Literature: Other Starchy Staples

	YAMS						
		Place of Residence			Income level		
Source	**Coverage**	**All**	**U**	**R**	**L**	**M**	**H**
Akinleye & Rahji (2007)	Northern Nigeria				1.12	1.01	0.56
Tsegai & Kormawa. (2002)	Kaduna, Nigeria	1.30			1.21		1.56
Oyinbo et al (2013)	Kaduna, Nigeria	1.00					
Edun & Haruna (2013)	Akoko S. West	1.79					
Taondyandé & Yade (2012)	Nigeria		0.79	1.22			
Zhou & Staatz (2016)	Nigeria		0.79	1.22			
Johnson, et al. (2013)	Nigeria	0.57	0.47	0.64			
	CASSAVA TUBER						
Tsegai & Kormawa (2002)	Kaduna, Nigeria	0.32			0.73		0.26
Taondyandé & Yade (2012)	Nigeria		0.49	0.85			
Zhou & Staatz (2016)	Nigeria		0.49	0.85			
Johnson, et al. (2013)	Nigeria	0.33	0.21	0.47			
	MAIZE						
Akinleye & Rahji (2007)	Northern Nigeria				0.38	0.49	-0.23
Oyinbo et al, 2013	Kaduna, Nigeria	0.91					
Balarabe, et. al. (2006)	Kaduna, Nigeria	0.57					
Taondyandé & Yade (2012)	Mali	0.35	0.39	0.54			
Taondyandé & Yade (2012)	Burkina Faso	0.70	0.44	0.66			
Taondyandé & Yade (2012)	Niger	1.20	0.79	1.26			
Taondyandé & Yade (2012)	Nigeria		0.68	0.58			
Zhou & Staatz (2016)	Burkina Faso		0.40	0.70			
Zhou & Staatz (2016)	Mali		0.40	0.50			
Zhou & Staatz (2016)	Niger		0.80	1.30			
Me-Nsope (2014)	Mali-Urban		0.67		0.70	1.07	1.03
Me-Nsope (2014)	Mali-Rural			1.10	1.03	0.87	1.01
Savadogo & Kazianga (1999)	B. Faso-Urban	0.90			1.00	0.90	0.90
Johnson, et al. (2013)	Nigeria	0.64	0.64	0.71			

M=Millet; S=Sorghum; U=urban; R=rural; L=Low; M=Middle; H=High

Table B.5. Expenditure Elasticity Estimates from the Literature: Other Starchy Staples - Aggregate

			Place of Residence		
Source/Author	**Coverage**	**Description**	**All**	**U**	**R**
Johnson et al. (2013)	Nigeria	Other grains	0.34	1.35	0.41
Johnson et al. (2013)	Nigeria	Other roots	0.62	0.60	0.74
Lawal et al. 2011	Nigeria (rural)	Roots & tubers			0.73
Obayelu, et al.(2009)	North Central Nigeria	Tubers	0.41		
Lawal et al. (2011)	Oyo, Nigeria	Cereals			0.56
Obayelu, et al.(2009)	North Central Nigeria	Cereals	1.14		
Ashagidigbi et al. (2012)	Nigeria	Staples	0.85		
Camara (2004)	Mali-Bamako	Staples		0.42	
Regmi & Seale (2010)	Mali	Cereals	0.59		
Regmi & Seale (2010)	Nigeria	Cereals	0.54		

M=Millet; S=Sorghum; U=urban; R=rural; L=Low; M=Middle; H=High

Table B.6. Expenditure Elasticity Estimates from the Literature: High-Value Foods

			Place of Residence			Income level		
Author/Source	**Coverage**	**Description**	**All**	**U**	**R**	**L**	**M**	**H**
Savadogo & Kazianga (1999)	B. Faso-urban	Meat & milk	0.90			0.9	0.9	0.9
Lawal et al. (2011)	Nigeria	Animal products			5.78			
Camara (2004)	Mali- Bamako	Meat & Fish		1.78				
Johnson et al. (2013)	Nigeria	Poultry	1.85	2.27	1.92			
Johnson et al. (2013)	Nigeria	Other meat	1.07	0.81	1.26			
Johnson et al. (2013)	Nigeria	Fish	0.62	0.44	0.72			
Ashagidigbi, et al. (2012)	Nigeria	animal protein	0.94					
Taondyandé & Yade (2012)	Mali	Meat	1.28	0.99	1.29			
Taondyandé & Yade (2012)	Mali	Fish & seafood	0.66	0.63	0.87			
Taondyandé & Yade (2012)	B. Faso	meat	1.41	1.36	1.52			
Taondyandé & Yade (2012)	B. Faso	Fish & Seafood	1.17	0.95	1.20			
Taondyandé & Yade (2012)	Niger	Meat	1.30	1.32	1.28			
Taondyandé & Yade (2012)	Niger	Fish & seafood	0.89	0.92	1.01			
Taondyandé & Yade (2012)	Senegal	Fish & seafood	0.93	0.99	0.86			
Taondyandé & Yade (2012)	Nigeria	Meat		1.48	1.62			
Taondyandé & Yade (2012)	Nigeria	Fish & seafood		0.66	1.08			
Obayelu, et al. (2009)	North Central Nigeria	Animal protein	1.40					
Regmi & Seale (2010)	Mali	Meat	0.81					
Regmi & Seale (2010)	Mali	Fish	0.69					
Regmi & Seale (2010)	Nigeria	Meat	0.78					
Regmi & Seale (2010)	Nigeria	Fish	0.67					

U=urban; R=rural; L=Low; M=Middle; H=High

Table B.6. Expenditure Elasticity Estimates from the Literature: High-Value Foods (cont'd.)

			Place of Residence		
Source	**Coverage**	**Description**	**All**	**U**	**R**
Lawal et al. 2011	Nigeria	Fruits /Vegetable			4.34
Camara (2004)	Bamako, Mali	Vegetables		1.01	
Johnson et al. (2013)	Nigeria	Fruits/vegetables	0.52	0.50	0.57
Ashagidigbi et al. (2012)	Nigeria	Fruits			1.12
Ashagidigbi, et al., (2012)	Nigeria	Vegetables			0.89
Taondyandé & Yade (2012)	Mali	Fruits & vegetables	0.52	0.72	0.66
Taondyandé & Yade (2012)	Burkina	Fruits & vegetables	0.98	0.91	0.99
Taondyandé & Yade (2012)	Niger	Fruits & vegetables	1.19	1.02	1.25
Taondyandé & Yade (2012)	Senegal	Fruits & vegetables	0.99	1.01	1.43
Taondyandé & Yade (2012)	Nigeria	Fruits & vegetables		0.78	0.87
Obayelu, et al. (2009)	North Central Nigeria	Fruits & vegetables	1.10		
Regmi & Seale (2010)	Mali	Fruits & vegetables	0.66		
Regmi & Seale (2010)	Nigeria	Fruits & vegetables	0.63		

U=urban; R=rural;

Table B.6. Expenditure Elasticity Estimates from the Literature: High-Value Foods (cont'd.)

			Place of Residence			Income level		
Source	**Coverage**	**Description**	**All**	**U**	**R**	**L**	**M**	**H**
Lawal et al. (2011)	Nigeria	Legumes			9.41			
Johnson et al. (2013)	Nigeria	Pulses	0.48	0.41	0.57			
Akinleye & Rahji (2007)	Northern Nigeria	Beans				0.14	-0.31	-0.12
Oyinbo et al, (2013)	Kaduna, Nigeria	Beans	0.99					
Edun & Haruna (2013)	Nigeria	Beans	1.04					
Taondyandé & Yade (2012)	Mali	Legumes	1.06	0.68	1.06			
Taondyandé & Yade (2012)	Niger	Beans/cowpeas	1.03	0.64	1.12			
Taondyandé & Yade (2012)	Nigeria	Legumes		0.76	0.87			
Obayelu, et al. (2009)	North Central Nigeria	Legumes	1.28					
Johnson et al. (2013)	Nigeria	Milk	1.02	1.04	1.04			
Taondyandé & Yade (2012)	Mali	Milk products	1.12	1.09	1.27			
Taondyandé & Yade (2012)	B. Faso	Milk products	1.21	1.55	1.27			
Taondyandé & Yade (2012)	Niger	Milk products	0.96	1.17	0.95			
Taondyandé & Yade (2012)	Senegal	Milk products	1.32	1.14	2.15			
Taondyandé & Yade (2012)	Nigeria	Milk products		1.41	1.42			
Regmi & Seale (2010)	Mali	Dairy	0.833					
Regmi & Seale (2010)	Nigeria	Dairy	0.81					

M=Millet; S=Sorghum; U=urban; R=rural; L=Low; M=Middle; H=High

Table B.7: Own-price Elasticity Estimates from the Literature: Rice

		Place of Residence			Income level		
Source	**Coverage**	**All**	**U**	**R**	**L**	**M**	**H**
Olarunfemi (2010)	Ondo State	-0.40					
Balarabe, et. al. (2006)	Kaduna	-0.93					
Oyinbo et al. (2013)	Kaduna	-0.89					
Akinyele & Rahji (2007)	Northern Nigeria				0.24	0.25	-0.06
Camara (2004)	Mali		-0.77				
Me-Nsope (2014)	Mali-Urban		-0.96		-1.00	-0.92	-1.07
Me-Nsope (2014)	Mali--Rural			-0.94	-0.78	-0.97	-0.99
Rogers & Lowdermilk (1991)	Mali-Urban		-0.68				
Lowdermilk-(1991)	Mali-5 Southern cities		-0.54		-1.03		-0.11

L=Low; M=Middle; H=High U=urban; R=rural

Table B.8: Own-price Elasticity Estimates from the Literature: Sorghum/Millet

		Place of Residence			Income level			
Source	**Coverage**	**All**	**U**	**R**	**L**	**M**	**H**	**Note 1**
Balarabe, et. al. (2006)	Kaduna, Nigeria						-0.88	M
							-0.40	S
Akinyele & Rahji (2007)	Northern Nigeria				-1.19	-0.85	-0.37	M
Camara (2004)	Mali-Bamako		-0.69					
Me-Nsope (2014)	Mali-Urban		-0.90		-0.24	-1.04	-0.51	M
			-1.16		-1.01	-0.95	-0.66	S
Me-Nsope (2014)	Mali--Rural			-1.14	-1.01	-0.96	-0.99	M
				-0.99	-0.89	-0.95	-0.99	S
Rogers & Lowdermilk (1991)	Urban Mali		-0.53					
Lowdermilk (1991)	Mali-5 Southern cities		-0.03		-0.10		-0.02	

M=Millet; S=Sorghum; U=urban; R=rural; L=Low; M=Middle; H=High

Table B.9: Own-price Elasticity Estimates from the Literature: Other Starchy Staples

		YAMS					
		Place of Residence			**Income level**		
Source	**Coverage**	All	U	R	L	M	H
Akinleye & Rahji 2007	Northern Nigeria				-0.69	-0.34	0.40
Tsegai & Kormawa (2002)	Kaduna, Nigeria	-0.72			-0.21		-0.80
Oyinbo et al, 2013	Kaduna, Nigeria	0.53					
Olarunfemi (2010)	Ondo, Nigeria	-0.48					
		CASSAVA TUBERS					
Akinleye & Rahji 2007	Northern Nigeria						
Tsegai & Kormawa (2002)	Kaduna, Nigeria	-0.46			-0.96		-0.13
Oyinbo et al, 2013	Kaduna, Nigeria						
Olarunfemi (2010)	Ondo, Nigeria						
		MAIZE					
		Place of Residence			**Income level**		
Source	Coverage	All	U	R	L	M	H
Akinleye & Rahji 2007	Northern Nigeria				-0.43	-0.57	-0.33
Tsegai & Kormawa (2002)	Kaduna, Nigeria						
Oyinbo et al, 2013	Kaduna, Nigeria	-0.02					
Me-Nsope (2014)	Mali-urban				-1.00	-1.03	-0.95
Me-Nsope (2014)	Mali-Rural				-1.04	-0.94	-1.00
Olarunfemi (2010)	Ondo, Nigeria						
Camara (2007)	Mali-Bamako		-1.97				

U=urban; R=rural; L=Low; M=Middle; H=High

Table B.10: Own-price Elasticity Estimates from the Literature: Others

STARCHY STAPLES AGGREGATES					
			Place of Residence		
	Coverage	**Description**	**All**	**U**	**R**
Lawal et al. 2011	Oyo, Nigeria	R&T			-0.52
Obayelu, et. al.(2009)	North Central Nigeria	Tubers	0.39		
Lawal et al. 2011	Oyo, Nigeria	cereals			-0.61
Obayelu, et. al.(2009)	North Central Nigeria	Cereals	-0.53		
Camara (2004)	Bamako, Mali	Staples		-0.51	
Regmi & Seale (2010)	Mali	Cereals	-0.43		
Regmi & Seale (2010)	Nigeria	Cereals	-0.40		
HIGH VALUE FOODS					
Lawal et. al. 2011	Oyo, Nigeria	Animal products			-0.64
Camara (2004)	Bamako, Mali	Meat & Fish		-0.91	
Obayelu, et. al.(2009)	North Central Nigeria	Animal Protein	-0.07		
Regmi & Seale (2010)	Mali	Meats	-0.59		
Regmi & Seale (2010)	Nigeria	Meats	-0.57		
Regmi & Seale (2010)	Mali	Fish	-0.51		
Regmi & Seale (2010)	Nigeria	Fish	-0.49		
Lawal et. al. 2011	Oyo, Nigeria	Fruits /Vegetable			-0.48
Camara (2004)	Bamako, Mali	Vegetables		-0.96	
Obayelu, et. al. (2009)	North Central Nigeria	Fruits & Veg	-0.07		
Regmi & Seale (2010)	Mali	Fruits & Veg	-0.49		
Regmi & Seale (2010)	Nigeria	Fruits & Veg	-0.46		
Lawal. et al. 2009	Oyo, Nigeria	Legumes			0.33
Oyinbo et al, 2013	Kaduna, Nigeria	Beans	-0.15		
Edun & Haruna (2013)	Nigeria-Akoko S.W.	Beans	-0.51		
Regmi & Seale (2010)	Mali	Dairy	-0.61		
Regmi & Seale (2010)	Nigeria	Dairy	-0.59		

U=urban; R=rural; L=Low; M=Middle; H=High

Table B.11: Uncompensated Cross-price Elasticities Across Seasons, Urban Mali

Commodities	SEASON				
	Lean	Harvest	Post-harvest	Planting	Pooled
Rice--Demand					
Price of Rice	-1.03	-0.61	-0.64	-0.82	-0.77
Price of MS	0.12	-0.10	-0.46	-0.24	-0.17
Price of M	0.07	0.16	0.04	0.26	0.16
Price of W	0.03	-0.11	0.10	-0.06	-0.01
Price of RT	-0.02	-0.08	0.13	-0.03	-0.02
MS--Demand					
Price of Rice	0.30	-0.36	-1.50	-0.47	-0.44
Price of MS	-1.38	-0.59	-0.66	-0.60	-0.69
Price of M	0.40	-0.03	0.59	-0.12	0.19
Price of W	-0.21	0.14	0.27	0.24	0.11
Price of RT	0.05	-0.11	-0.08	-0.02	-0.04
Maize--Demand					
Price of Rice	-0.01	-0.22	0.21	1.57	0.24
Price of MS	0.41	-0.28	1.14	-0.72	0.16
Price of M	-1.90	-1.84	-1.79	-1.98	-1.97
Price of W	0.36	0.21	-0.20	-0.43	-0.01
Price of RT	-0.12	0.01	-0.16	-0.09	-0.12
Wheat--demand					
Price of Rice	-0.56	-1.58	0.22	-0.60	-0.62
Price of MS	-0.94	0.53	0.93	1.35	0.24
Price of M	0.69	0.87	-0.70	-0.50	-0.04
Price of W	-1.61	-1.45	-2.79	-1.49	-1.76
Price of RT	0.09	0.27	-0.15	0.41	0.34
RT--Demand					
Price of Rice	-0.20	-0.32	1.14	-0.92	-0.42
Price of MS	0.29	-0.16	-0.05	-0.38	-0.26
Price of M	-0.44	0.38	-0.24	-0.18	-0.21
Price of W	0.25	0.27	-0.01	0.52	0.40
Price of RT	-0.68	-0.15	-1.41	-0.78	-0.65

Source: Camara (2004)

MS=Millet/Sorghum; M=maize; RT=roots and tubers; W=wheat

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