Demand elasticities for food staples in Niger and Nigeria: A three-stage approach

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Abstract

We apply a three-stage demand system to nationally representative household survey data to identify household food demand behavior, particularly for food staples, in Niger and Nigeria. Regression methods are used to address the quality bias of the unit values reported by households, and Shonkwiler and Yen's two-step procedure is used to address censoring. We estimate models for rural and urban households separately, and compute demand elasticities for each welfare quintile, in order to capture the differences in food demand behavior between rural and urban areas and among households of different income groups. Results show that rural and poor households allocate a larger share of their food budget share to staple foods; demand for staple foods becomes less responsive to income change as economic status improves. The relationship between own-price elasticity and economic status reveals a more complex pattern. When cross-price elasticities are significant, staple items are substitutes in general. That implies that researchers and policy makers should consider not only the overall effect on the population but also its distribution among households of various economic status.

1 Introduction

The 2008 food price crisis, during which the prices of major food products reached historic highs, reminded the world that food insecurity is still an important issue in developing countries. In 2008, the cereal price index was 2.8 times higher than it was in 2000 and remained high for several years after. Globally, the crisis pushed approximately 130-155 million into poverty and increased the prevalence of undernourishment by 6.8% in 2008 (United Nations, 2011). Food staples, which include cereals and other foods rich in starch, are the main source of calories for poor households in developing countries and play a major role in preventing hunger. Understanding household behavior of food consumption, particularly in the form of food demand elasticities, is essential for evaluating how policies and other impacts influence total demand for food and food security of the population.

Food demand elasticities are also essential for evaluating the impacts of price change and income growth on nutrition intake and security. For instance, Anríquez, et al. (2013) simulated the impact of a 10% increase of food staple price on calorie intake using demand elasticities of eight food groups from a cross-country study by Seale, et al. (2003). They concluded that poor urban/non-farm households with a high food budget share are most vulnerable to food price increase. Elasticities of nutrient demand can be obtained directly by estimateing how demand for various nutrients responds to price and income, or indirectly by transforming food demand elasticities into nutrient demand elasticities. People in developing countries usually lack knowledge about food nutritional values, so it is unlikely that they choose foods based on nutrient contents. It is more reasonable to assume that they make decisions on food consumption, and that energy and nutrient intake is an indirect result.

This makes the indirect approach preferred for studying food demand in developing countries (e.g., Ecker and Qaim, 2011).

In this study, we estimate household food demand systems for Niger and Nigeria in order to identify household food consumption behavior and fill in the knowledge gap on staples demand in these two West African countries. Niger and Nigeria are chosen because both are experiencing rapid urbanization and population growth rate and unstable income growth, making food security an important issue. By the end of 2015, the populations of Niger and Nigeria were 19.9 million and 182.2 million and growing at annual rates of 4.0% and 2.6% respectively, 2.8 and 1.4 percentage points higher than the world average (United Nations, 2015). Both countries are also experiencing rapid urbanization. In 2015, 18.7% and 47.8% of Nigerien and Nigerian populations lived in cities, and urban population was growing at an annual rate of 5.4% and 4.4% in Niger and Nigeria respectively (United Nations, 2015). Population growth and urbanization are major forces driving the demand for food. With urbanization, labor moves from agriculture to the manufacturing and service industries, meaning that agricultural production or food imports must increase in order to avoid an increase in food prices.

In developing countries, income growth not only drives the demand for staple foods but also shifts the diet from staple foods to more expensive items like meat and vegetables. However, income growth has been erratic in both countries. Between 2010 and 2015, the highest per capita GNI growth rate of Niger was 6.2% in 2012 while the lowest was -1.6% in 2011; in Nigeria, the GNI per capita growth rate fluctuated between -5.1% in 2015 and 8.6% in 2010. Facing income uncertainty, households need to consume less and save more as a self-insurance to combat possible income falls. This may hinder the upgrade of dietary structure and make households in poor countries sticking to food staples.

Food staples are key in the diets of households of Niger and Nigeria. The average annual per capita consumption of cereals is 201 kg in Niger (2011) and 138 kg in Nigeria (2013) while per capita consumption of tubers and roots averages 10.5 kg and 253 kg per year in Niger and Nigeria. As a result, 61% and 66% of Nigerien and Nigerian daily energy intake come from cereals, tubers, and roots (Food and Agriculture Organization, n.d.). This high reliance on staples is consistent with the central role staples play in reducing and preventing hunger among the poor. Knowledge about household demand for staples is thus fundamental for evaluating the impacts of price and income fluctuations, demographic transition, and urbanization on household food security.

Previous studies on household food demand in African countries are rather limited, and when available, they have several shortcomings. *Studies based on nationally representative data are scanty and few have been published recently*. After a review of early food demand studies for Sub-Saharan African countries published between mid-1980s and mid-1990s, Teklu (1996) warned against using these estimated elasticities in policy or impact analysis. The reason is that these studies were usually not based on nationally representative data. In another meta-analysis by Melo, et al. (2015) focusing on income elasticities of food demand from 66 studies of African countries, of the 2,028 elasticities from studies published between 1991 and 2015, only 116 are based on data collected between 2006 and 2015. *Another concern is that cross-price elasticities are unfrequently reported*. Food substitution and complementation patterns can have significant implications for policy design. However, Cornelsen, et al. (2015) found that only 78 of the 136 food demand studies published between 1990 and 2012 reported cross-price elasticities, and less than 5% of the 4,162 cross-price elasticities were for studies conducted in Africa. *Elasticities of individual staple food items are also infrequently estimated*. For example, in the meta-analysis conducted by Melo, et al. (2015), only two of the 373 income elasticities reported for cereals are for sorghum. Unlike Asia where rice is the dominant staple food across countries and regions, an important feature of food consumption in Africa is the diversity of staple food. Sorghum and millet are major staple foods in the Sahel, while tubers and roots are more important in the diet of households in the more humid areas of Nigeria, especially in the southern coastal regions. Thus, to fully evaluate the effects of food policy and impacts like price increase on food security, it is preferable to include as many foods as possible while estimating food demand. Finally, yet importantly, we expect that food demand for households of different socio-economic backgrounds to respond differently to income and price changes. This means that average elasticities for the whole population cannot enable us to identify, for example, the impact of food price increase on calorie intakes by population sub-groups, such as the poor, who are most vulnerable to food insecurity. However, the vast majority of studies on food demand did not distinguish between rural and urban households or households of different income groups (Melo, et al., 2015).

Methodological shortcomings, due to the complexity of estimating household food demand, are frequent in this literature. Examples of methodological weakness include ignoring censoring, using unit values instead of prices, and failing to report unconditional elasticities and standard errors for elasticity estimates. Censoring occurs when a household does not consume a food item or food group, resulting in an equation in the food demand system that has zero expenditure. Ignoring censoring can potentially lead to inconsistent and biased estimates (Heien and Wessells, 1990). Empirical studies frequently fail to address this issue; of the elasticities surveyed by Cornelsen, et al. (2015), fewer than 40% addressed censoring. An additional shortcoming of the applied demand literatures is the reliance on unit values, obtained by dividing expenditure by physical quantity, to reflect prices and their variability. Unit values cannot be used directly as substitutes for prices since they are subject to consumers' choice of quality and measurement errors (Deaton, 1988). To apply demand elasticities in policy or impact analysis we need unconditional elasticities, or elasticities conditional on total household expenditure. However, previous studies typically only report elasticities conditional on total food expenditure (e.g., Abdulai and Aubert, 2004; Bilgic and Yen, 2013). Further, many studies fail to report standard errors. Elasticity estimates are random variables since they are calculated using estimated parameters that are random variables themselves. However, only 6% of the income elasticity estimates identified by Melo, et al. (2015) and approximately half of the cross-price elasticity estimates identified by Cornelsen, et al. (2015) are reported with standard errors. As pointed out by Cornelsen, since empirical studies usually do not report all of their details, it is difficult to know the reason standard errors are not reported.

We overcome these shortcomings by estimating a multi-stage censored demand system and adjusting for quality biases of unit values using regression. Our approach follows the one in Boysen (2016), but we make several adjustments. A major difference is that we use a three-stage budgeting system instead of a two-stage system. The third stage allows us to obtain elasticity estimates for individual staple foods. We are aware of only few previous studies (e.g., Ecker and Qaim, 2011;

Edgerton et al., 1996; Jiang and Davis, 2007) that used a three-stage demand system to study household food demand. Our second methodological contribution consists of estimating the three stages simultaneously. This allows us to compute the standard errors of elasticities directly from estimated parameters. The third adjustment is that we incorporate household characteristics into demand system by demographic scaling instead of demographic translation. Demographic scaling allows us to calculate different elasticities for households with same income but different demographic characteristics. As in Boysen (2016), we calculate unconditional elasticities for each welfare quintile[1] separately for rural and urban areas. We follow this approach to assess how the responsiveness of food demand to price and income changes varies by household income groups.

The rest of the article is structured as follows. In Section 2, we introduce the data sets used in this study and the procedures to obtain price and expenditure of each food item and price index and budget share for each food group. In Section 3, we discuss about model specification, estimation, and the calculation of elasticities. Descriptive statistics and elasticity estimates are presented and discussed in Section 4. Finally, we summarize our study and discuss the proposed future work in the last section.

2 Data and data processing

This study makes use of the data collected under the LSMS-ISA project led by the Development Research Group at the World Bank, in collaboration with national statistics institutes. For Niger, *Enquête Nationale sur les Conditions de Vie des Ménages et l'Agriculture* (ECVM/A, National Survey of Household Living Conditions and Agriculture) was conducted in 2011 and included 3,859 households, 2,343 from rural areas and 1,516 from urban areas. The analysis on Nigeria utilizes the second wave data of the General Household Survey-Panel (GHS-Panel) which was conducted in 2012-13 and includes 4,532 households, 3,163 from rural areas and 1,369 from urban areas[2]. Both are nationally representative and representative of urban and rural areas, and include a household survey, a community survey, and an agriculture survey. The food consumption section of the household survey contains detailed information about household food expenditures and forms the basis for this study. In both countries, households were interviewed twice, at post-planting and post-harvest time, in order to capture the seasonality of agriculture and resulting consumption patterns. Households were asked to recall consumption of 125 (Niger) or 105 (Nigeria) food items in the past seven days at each visit, which included food consumed away from home (FAFH) and food consumed at home (FAH) that came from purchases, own-production, and in-kind payments or gifts.

To estimate a food demand system that aggregates food items into groups, we need the price index and the budget share for each group, obtained using prices of all food items in the group and the expenditure on each item by each household. However, the food consumption section of the household questionnaire differs in several respects between countries, which influence the choice of approach used for obtaining prices and expenditures. For food prices, using unit values reported by

[1] We measure the welfare status of a household by its per capita real expenditure. Households belonging to the first welfare quintile is the 20% of all households with lowest per capita real expenditure, and those belonging to the fifth quintile is the 20% with largest per capita real expenditure.

[2] Four households are dropped for Nigeria since they did not report consumption of food at home.

households as substitutes will exaggerate measured responses to prices (Deaton, 1988). For a food item, when prices of high-quality and low-quality products increase simultaneously, households will not only reduce their consumption of the item but also possibly replace high-quality product with low-quality product. Since household may shift from high-priced product to low-priced product, we will observe the increase in unit value is lower than the increase in market price. Therefore, we prefer to obtain food prices from the community survey to get around the issue of price endogeneity. However, in the Nigerian survey, community and household questionnaires include different food items. Since many food items in the household survey did not have community price information, household data are used solely for obtaining food prices for Nigeria. For Niger, we use the community data to obtain food prices, except for a few items that are not covered in the community survey. For these items, we resort to household data.

The differences between surveys of the two countries also require different procedures to obtain the expenditure on each food item. In both countries, households reported physical quantity of each food item consumed for the different sources, while only Nigerien households also reported the monetary value associated with the physical quantity for all food sources. Households of Nigeria reported expenditure for food purchased only[3]. Therefore, for Niger, we use the monetary value reported by households to calculate annualized expenditures and consequently the budget shares. For Nigeria, we need to get the monetary value for physical quantities at first.

In the rest of this section, we firstly introduce the methods of obtaining prices of food items from household data and community data. Then we introduce how we receive the expenditure on each item and food group price indices and budget shares.

Deriving food item prices from household data

Unlike developed countries where food prices are relatively stable across regions, spatial variations in food prices are large in developing countries due to poor transportation infrastructure and market imperfections. This provides an opportunity by which we can observe how household demand responses to price using cross-sectional data. Since households in a community are surveyed in a short period of time, it is reasonable to assume that within a community all households face the same food price, and the observed differences in unit values are due to households' choice of quality which in turns depend on household income and preferences (Deaton, 1997).

Based on this assumption, Deaton ran a regression of the logarithm of unit value on the logarithm of total expenditure and a set of household characteristics to address price endogeneity. Since the right-hand side variables are household specific, Deaton included dummy variables for communities as regressors, and their coefficients are used to compute a proxy for community market price. Boysen (2016) extended Deaton's approach by adding dummy variables for units and crop varieties. Following Deaton and Boysen, for each food item k, we estimate the following regression to obtain an adjusted price that is immune to the quality bias:

[3] This is the expenditure on food purchased during the past seven days. Another question asks households the quantity of food consumed during the past seven days that comes from purchases. They are separate questions because food purchased during the past week may not be completely consumed during the same week.

$$lnp_{ki} = b_{k0} + b_{k1}lnx_i + \sum_l b_{kl}Z_{li} + \sum_u b_{ku}D_u + \sum_r b_{kr}D_r + \sum_s b_{ks}D_s + b_{k2} \cdot visit2 + b_{kur} \cdot urban_i, \quad (1)$$

lnp_{ki} is logarithm of unit value of item k reported by household i. lnx_i is logarithm of household per capita real expenditure. Z_{li} are household socio-demographic variables[4]. D_u are dummy variables for different units[5] used to report quantity consumed, in order to control the influence of using different units on unit values. D_r are dummy variables representing geographic areas[6], referred to as clusters below. D_s are dummy variables for sources of food, included because it is possible for households to evaluate the value of self-produced foods differently from those purchased from markets. They are not needed for Nigeria since households only reported value of purchased food. $visit2$ is a binary-outcome dummy variable that is equal to one for the second visit, added for controlling the change in price between two visits. $urban_{\mathrm{i}}$ is a dummy variable that equals one if household i lives in an urban location, added for controlling the change in price between rural and urban locations.

Similar to Boysen (2016), quality bias and variations in unit values caused by units, source of food, visits and rural-urban differences are adjusted by setting all these variables to their reference level zero. The adjusted log-price of item k in cluster r, $\widehat{lnp}_{kr}$, is:

$$\widehat{lnp}_{kr} = \hat{b}_{k0} + \hat{b}_{kr} \quad (2)$$

where $\hat{b}_{k0}$ is the estimated intercept and $\hat{b}_{kr}$ is the estimated coefficient of the dummy variable for cluster r. This adjusted log-price will used for compose a Stone price index for each food group and subgroup.

For Nigeria, in addition to the adjusted log-price, we need the "ordinary" price (e.g., $/kg) to get the monetary value of physical quantities. By Equation 2,

$$\hat{p}_{kr}/\hat{p}_{k0} = \exp(\hat{b}_{kr}) \quad (3)$$

where $\hat{p}_{k0}$ is the price of item k in the reference cluster, estimated as the median of unit values reported by households living in the reference cluster in the first visit $\bar{p}_{k0}$. We choose median instead of mean to avoid the influence of extreme values. Therefore, the "ordinary" price of item k in cluster r is estimated as:

$$\hat{p}_{kr} = \bar{p}_{k0} \cdot \exp(\hat{b}_{kr}) \quad (4)$$

[4] Household socio-demographic variables include household size; number of household members in each of the age groups 0-5, 6-15, and 16-60; gender of household head; age and education of female household head or head's spouse if the head is male; and a dummy variable that is equal to one if household head is single.

[5] In both surveys, households often reported physical quantity in local units (e.g., a heap of maize). Only the data set of Nigeria includes a unit conversion table that converts local units to kilogram or liter. Most physical quantities can be converted by this table, and those cannot be converted are dropped. Most food items use only one unit (kg or L) after conversion. Therefore, the unit dummy variables are unnecessary for these items.

[6] When only few households in a community reported consumption of a food item, using community dummy variables is unable to give meaningful estimates. In these cases, dummy variables of upper-level administrative areas (e.g., states) are used. The level of geographic areas is selected such that the ratio of number of observations to the number of parameters is greater than five. The cluster with most observations is selected as the reference cluster.

To aggregate the expenditures of two visits, we need to convert an expenditure in the second visit to its equivalent value in the first visit. The ratio of the price in the second visit to that in the first visit, referred to as temporal deflator below, $\hat{d}_k$, is estimated as:

$$\hat{d}_k \equiv \exp(\hat{b}_{k2}) \tag{5}$$

by setting $visit2$ to one, where $\hat{b}_{k2}$ is the estimated coefficient of $visit2$. An expenditure on item k in the second visit can be converted to its equivalent value in the first visit by dividing it by $\hat{d}_k$.

Deriving food item prices from community data

We apply the following procedure to derive prices from community data for the majority of food items only for Niger. Though immune to the quality bias, prices from the community survey still cannot be used directly in estimation. This is because 1) the community survey distinguished varieties for some food items (e.g., white and red sorghum); 2) similar to household survey, physical quantities were usually reported in local units; 3) price differences between rural and urban areas and between two visits also need to be addressed. To address these issues, we apply a similar regression method as the one used to adjust household price data. The price of item k reported in cluster r, in natural logarithm, lnp_{kr}, is estimated as following:

$$lnp_{kr} = a_{k0} + \sum_v a_{kv} D_v + \sum_u a_{ku} D_u + \sum_r a_{kr} D_r + a_{k2} \cdot visit2 + a_{k3} \cdot urban, \tag{6}$$

D_v are dummy variables for varieties of item k. D_u, D_r, $visit2$, and $urban$ are defined similarly as in Equation 1. The adjusted log-price and temporal deflator are derived in the same way as in Equations 2 and 5:

$$\widehat{lnp}_{kr} = \hat{a}_{k0} + \hat{a}_{kr} \tag{7}$$

$$\hat{d}_k = \exp(\hat{a}_{k2}) \tag{8}$$

Deriving food group budget shares and price indices

We decompose annualized household expenditure on FAH into groups and subgroups as described in Section 3. To obtain household expenditures and budget shares for food groups and subgroups, the annualized expenditure on each item by each household is required first. For Niger, for each item and each visit, we first add up the reported values of consumption from the three sources. Then, total consumption value of the second visit is converted to its equivalent value in the first visit by divided by the temporal deflator $\hat{d}_k$ estimated by Equations 5 and 8. The equivalent value is added to the value of the first visit, and the consumption expenditure is annualized[7]. Now we have the annualized expenditure on each item by each household. For Nigeria, before applying the above procedure, monetary values of consumption are obtained by multiplying physical quantities by price $\hat{p}_{kr}$ estimated by Equation 4; the value of the second visit does not need to be adjusted by the temporal inflator, since values of two visits are evaluated at the same price. Household expenditure on FAH is the sum of expenditures on all FAH items, and the expenditure on a group is the sum of expenditures

[7] This is done by multiplying the consumption expenditure by 26 since each visit stands for half a year.

on all items in the group. We can calculate the budget share for a group using FAH expenditure and the expenditure on the group.

To obtain price indices of food groups and subgroups, suppose $w_{k|Gi}$ is the share of item k in group (or subgroup) G for household i. The Stone price index of group G for household i living in cluster r is computed as:

$$lnp_{Gi} = \sum_{k \in G} w_{k|Gi} \ln \frac{\hat{p}_{kr}}{\bar{p}_k} = \sum_{k \in G} w_{k|Gi} \left(\widehat{lnp}_{kr} - \ln \bar{p}_k \right) \tag{9}$$

$\bar{p}_k$ is the median of $\hat{p}_{kr}$ of all clusters. If a household does not consume any food item in group G ($w_{k|Gi} = 0 \;\; \forall \;\; k \in G$), $w_{k|Gi}$ is approximated by the median of $w_{k|G}$ of households living in the same cluster. Similarly, price index of FAH lnp_f is calculated as:

$$lnp_{fi} = \sum w_{k|fi} \ln \frac{\hat{p}_{kr}}{\bar{p}_k} = \sum w_{k|fi} \left(\widehat{lnp}_{kr} - \ln \bar{p}_k \right) \tag{10}$$

where $w_{k|fi}$ is the share of item k in FAH.

3 A three-stage demand system

Since more than one hundred food items were covered in the surveys of both countries, estimating a demand system with one equation for each item is not only computation demanding but also unlikely to give meaningful estimates considering the enormous number of parameters. Therefore, aggregating food items into groups is routine in food demand analysis. In this study, household food expenditure is estimated by a three-stage demand system. A multistage demand system assumes that consumers make consumption decisions in a multi-step process. First, households decide how to allocate their budget among major expenditure groups like food and non-food expenditures, such as housing, clothes, education, etc. Then, households decide how to allocate their food budget among different food categories, e.g., meat, vegetables, and fruits. The multistage demand system is justified either by assuming that households' preferences satisfy separability conditions or by assuming external conditions like collinearity of prices in the Hicks-Leontief composite commodity theorem (Deaton and Muellbauer, 1980). Weak separability assumes the change of price of an item in one group influences the demand for all items in another group in the same way. The assumption of weak separability is strong and hard to test. The Hicks-Leontief composite commodity theorem states that, when prices of a set of commodities move in parallel, we can treat them as a single commodity. The generalized composite commodity theorem by Lewbel (1996) relaxes the perfect collinearity assumption of prices and assumes the ratio of the price of an item to the group price index is independent of group price index and income. However, if commodities are aggregated based on these theorems, it is possible that commodities with little similarities are grouped together. Therefore, in this study we follow the method commonly used in the food demand literature and aggregate food items based on their nutrition similarity. For instance, food staples are rich in starch and the major source of calories; animal source products provide protein, and legumes are a cheaper alternative; vegetables and fruits supply micronutrients.

In our study, the first stage decomposes household total expenditure into two parts: 1) FAH and 2) FAFH and all non-food expenditures. The main motivation for separating FAFH from FAH is the lack of precise price estimates for FAFH. Previous food demand studies rarely discussed about how to treat FAFH. Using Swedish data, Edgerton (1997) decomposed household total expenditure into four parts in the first stage: FAH, FAFH, goods except food, services except restaurants. In the companion full report (Edgerton, et al., 1996), the authors explained that separating FAH and FAFH is based on the assumption that consumers decide firstly eating at home or at restaurants and secondly how to allocate FAH expenditure to major food categories if they choose to eat at home. However, the authors do not explicitly test this separability assumption. Considering the rising importance of FAFH as income grows in developing countries, FAFH should receive more attention in future studies.

In the second stage, household FAH expenditure is allocated to six major food groups: 1) food staples (cereals, cereal-based food, tubers, and roots), 2) animal source products (meat, egg, fish, seafood, and dairy products), 3) vegetables and fruits, 4) legumes, nuts, and seeds, 5) oil, fat, sugar, spices, and other food compliments, and 6) other food (e.g. beverages and snacks). In the third stage, we investigate how households allocate staple food expenditure (Group 1) among six sub-groups: 1) millet, 2) sorghum, 3) rice, 4) corn, 5) other cereals and cereal-based food (e.g., pasta, bread, biscuit), and 6) tubers and roots.

Stage 1: Working-Leser model

In the first stage, the share of FAH in household total expenditure is modeled by following a Working-Leser specification, which assumes the shape of Engel curve is determined by the logarithm of food price and household per capita real expenditure. The original model is extended by adding a quadratic term of household per capita real expenditure and incorporating household heterogeneity by demographic translation (Boysen, 2016):

$$w_f = \alpha_f + \gamma_f lnp_f + \beta_f \ln m + \lambda_f (\ln m)^2 + \sum_{l \in L} \tau_l Z_l, \tag{11}$$

w_f is the share of FAH in household total expenditure; lnp_f is the log-price index of FAH obtained by Equation 10; m is household per capita real expenditure; L is a set of household socio-demographic characteristics and geographic dummy variables. FAH expenditure elasticity η_f, uncompensated (Marshallian) price elasticity ε_f^U, and compensated (Hicksian) price elasticity ε_f^C, evaluated at $\bar{w}_f$ and $\bar{m}$, are derived as:

$$\eta_f = \frac{\beta_f + 2\lambda_f \ln \bar{m}}{\bar{w}_f} + 1 \tag{12}$$

$$\varepsilon_f^U = \frac{\gamma_f}{\bar{w}_f} - 1 \tag{13}$$

$$\varepsilon_f^C = \varepsilon_f^U + \bar{w}_f \eta_f = \frac{\gamma_f}{\bar{w}_f} + \beta_f + \bar{w}_f + 2\lambda_f \ln \bar{m} - 1 \tag{14}$$

Since we estimate rural and urban households separately, m is also normalized at sample median separately for rural and urban areas. Therefore, $\ln \bar{m}$ can be dropped from equations 12 – 14 if the elasticities are evaluated at sample median of m ($\bar{m} = 1$). When calculating the elasticities for each welfare quintile, $\bar{m}$ is substituted by mean of m of the quintile.

Stage 2: Quadratic almost ideal demand system (QUAIDS)

In the second stage, a quadratic almost ideal demand system (Banks, et al., 1997) is applied to explain the demand structure of the six major food categories. Since the majority of surveyed households consumes each of the six groups, censoring is not likely to be a problem and no adjustment is made in the second stage. Household socio-demographic characteristics are incorporated into the QUAIDS model by the demographic scaling method suggested by Ray (1983). Demographic scaling indicates, compared with a reference household (e.g., married couple without children), the additional (or less) expenditure needed for a given household to achieve the same utility. Another common way of incorporating demographics is demographic translating, which replaces the intercept in the share equations with a linear function of demographic variables. Demographic translating is used in the original QUAIDS paper by Banks, et al. (1997). However, the authors asserted that "the impact of demographic and other household characteristics could be allowed to enter all terms" of the share equations. We apply the scaling method in our study because it allows demographic variables to influence budget shares nonlinearly, meaning that elasticities can vary with not only income and price but also household characteristics. QUAIDS that incorporates household demographics by demographic scaling is specified as:

$$w_{i|f} = \alpha_i + \sum_j \gamma_{ij}\, lnp_j + (\beta_i + \boldsymbol{\eta}_i'\boldsymbol{z}) \ln\left(\frac{x}{a(\boldsymbol{p})\overline{m}_0}\right) + \frac{\lambda_i}{b(\boldsymbol{p})}\left[\ln\left(\frac{x}{a(\boldsymbol{p})\overline{m}_0}\right)\right]^2 \quad (15)$$

where

$$\ln a(\boldsymbol{p}) = \alpha_0 + \sum_i \alpha_i lnp_i + \sum_i \sum_j \gamma_{ij}\, lnp_i lnp_j \quad (16)$$

$$\overline{m}_0(\boldsymbol{z}) = 1 + \boldsymbol{\rho}'\boldsymbol{z} \quad (17)$$

$$b(\boldsymbol{p}) = \prod_j p_j^{(\beta_j + \boldsymbol{\eta}_j'\boldsymbol{z})} \quad (18)$$

$w_{i|f}$ is share of group i in FAH expenditure. lnp_i is the log-price index of group i, estimated by Equation 9. x is the normalized household FAH expenditure. $\boldsymbol{z}$ is the set of household socio-demographic characteristics and geographic dummy variables, similar to that in the first stage. To ensure the adding-up condition:

$$\sum_i w_{i|f} = 1 \quad (19)$$

and homogeneity of degree zero in price and FAH expenditure:

$$w_{i|f}(\lambda\boldsymbol{p}, \lambda x) = w_{i|f}(\boldsymbol{p}, x), \quad (20)$$

the adding-up restriction (21), homogeneity-of-degree-zero restriction (22), and Slutsky symmetry restriction (23) are posed on parameters:

$$\sum_i \alpha_i = 1, \sum_i \beta_i = 0, \sum_i \lambda_i = 0, \sum_k \gamma_{ik} = 0 \;\; \forall \;\; k, \sum_i \eta_{ir} = 0 \;\; \forall \;\; r \quad (21)$$

$$\sum_i \gamma_{ik} = 0 \;\; \forall \;\; i \quad (22)$$

$$\gamma_{ik} = \gamma_{ki} \tag{23}$$

QUAIDS is an extension of the almost ideal demand system (AIDS) developed by Deaton and Muellbauer (1980). To test whether QUAIDS is a better specification than AIDS, we can jointly test the λ parameters by Wald test. If the null hypothesis that all λ parameters are equal to zero is rejected, we can reject the AIDS specification and adopt QUAIDS instead.

Expenditure elasticity of group i conditional on FAH expenditure, $\eta_{i|f}$, is computed as:

$$\eta_{i|f} = 1 + \frac{1}{w_{i|f}}\left[\beta_i + \boldsymbol{\eta}_i'\boldsymbol{z} + \frac{2\lambda_i}{b(\boldsymbol{p})}\ln\left(\frac{x}{a(\boldsymbol{p})\overline{m}_0}\right)\right] \tag{24}$$

Uncompensated (Marshallian) price elasticity of group i with respect to the price of group j conditional on FAH expenditure, $\varepsilon^U_{ij|f}$, is estimated as:

$$\begin{aligned}\varepsilon^U_{ij|f} = \frac{1}{w_{i|f}}\Bigg\{\gamma_{ij} - \left[\beta_i + \boldsymbol{\eta}_i'\boldsymbol{z} + \frac{2\lambda_i}{b(\boldsymbol{p})}\ln\left(\frac{x}{a(\boldsymbol{p})\overline{m}_0}\right)\right] \times \left(\alpha_j + \sum_l \gamma_{jl}\ln p_l\right) \\ - \frac{(\beta_i + \boldsymbol{\eta}_i'\boldsymbol{z})\lambda_i}{b(\boldsymbol{p})}\left[\ln\left(\frac{x}{a(\boldsymbol{p})\overline{m}_0}\right)\right]^2\Bigg\} - \Delta_{ij}\end{aligned} \tag{25}$$

where Δ_{ij} is equal to 1 if $i = j$ and 0 otherwise. This means that Equation 25 represents own-price elasticity of group i when $i = j$ and the cross-price elasticity between groups i and j when $i \neq j$. If all prices are normalized at sample median and the elasticities are evaluated at sample medians of prices ($\bar{p}_i = 1$ and $ln\bar{p}_i = 0 \ \forall \ i$),

$$\eta_{i|f} = 1 + \frac{1}{w_{i|f}}[\beta_i + \boldsymbol{\eta}_i'\boldsymbol{z} + 2\lambda_i(\ln x - \ln\overline{m}_0)] \tag{26}$$

$$\begin{aligned}\varepsilon^U_{ij|f} = \frac{1}{w_{i|f}}\{\gamma_{ij} - \alpha_j[\beta_i + \boldsymbol{\eta}_i'\boldsymbol{z} + 2\lambda_i(\ln x - \ln\overline{m}_0)] \\ - \lambda_i(\beta_i + \boldsymbol{\eta}_i'\boldsymbol{z})(\ln x - \ln\overline{m}_0)^2\} - \Delta_{ij}\end{aligned} \tag{27}$$

Compensated (Hicksian) price elasticity conditional on FAH expenditure is obtained by Slutsky decomposition:

$$\varepsilon^C_{ij|f} = \varepsilon^U_{ij|f} + w_j\eta_{i|f} \tag{28}$$

Stage 3: Censored QUAIDS

In the third stage, a censored QUAIDS model is estimated to explain the consumption pattern of individual staple food item. Censoring occurs when not all households consume the food item. For instance, in our data only 46.4% and 44.3% of rural households in Niger and Nigeria consume corn during the survey period. Ignoring to address censoring can lead to inconsistent and biased estimates (Heien and Wessells, 1990). To address the censoring problem, Heien and Wessells' (abbreviated as HW) proposed a two-step procedure. In the first step, probit regressions are estimated for each commodity to determine the probability that a household consumes the commodity and inverse Mills ratios are computed for each household in each regression. In the second step, share equations are augmented by the inverse Mills ratios. HW showed that the censored model greatly improves goodness of fit and reduces both expenditure and own-price elasticities bias significantly for items with many zeros. Shonkwiler and Yen's (abbreviated as SY) suggested improvements over the two-step procedure proposed by HW (Shonkwiler and Yen, 1999). SY's method also estimates probit models in the first step, but treats the second step differently. Using Monte Carlo simulation, SY showed that their method produces consistent estimates, while estimates obtained following HW's approach are inconsistent and the inconsistency becomes greater as the number of zeros increases. Our study follows SY's procedure, which assumes that the selection mechanism is determined by a latent variable that can be considered as the net utility gain from consuming item k:

$$d_{ki}^{*} = \mathbf{z}_{ki}'\boldsymbol{\beta}_k + u_{ki} \tag{29}$$

Household i chooses to consume item k if and only if $d_{ki}^{*} > 0$, i.e. the household receives positive utility gain from consuming the item. The observed choice d_{ki}, the observed budget share w_{ki} and the latent budget share w_{ki}^{*} are:

$$d_{ki} = \begin{cases} 1 & \text{if } d_{ki}^{*} > 0 \\ 0 & \text{otherwise} \end{cases} \tag{30}$$

$$w_{ki} = d_{ki} \cdot w_{ki}^{*} \tag{31}$$

$$w_{ki}^{*} = f(\boldsymbol{x}_{ki}, \boldsymbol{\gamma}_k) + \varepsilon_{ki} \tag{32}$$

However, the above system of equations is difficult to estimate by the method of maximum likelihood considering the correlation between error terms of different equations. Therefore, SY suggested using the two-step estimation procedure. In the first step, a probit model is estimated for each staple item k that is influenced by the censoring problem using the observed choice d_{ki} as the dependent variable[8]. Since it is unlikely that a household selects one kind of staple food independent of others, probit models explaining the selection mechanism for all staple foods are estimated simultaneously. After estimation, the estimated cumulative probability ($\widehat{\Phi}_k$) and probability density ($\widehat{\phi}_k$) functions are calculated for each household. In the second step, share equation of item k in the QUAIDS model is augmented by $\widehat{\Phi}_k$ and $\widehat{\phi}_k$ to correct for censoring:

$$w_{k|1} = \widetilde{w}_{k|1} \cdot \widehat{\Phi}_k + \delta_k \widehat{\phi}_k \tag{33}$$

where $w_{k|1}$ is the share of item k in staple food expenditure (Group 1), and $\widetilde{w}_{k|1}$ is the right-hand side of the share equation in the uncensored QUAIDS. To test whether the censored QUAIDS specification is superior to the uncensored one, we can perform a Wald test on the δ parameters. If the null hypothesis that all δ variables are equal to zero is rejected, we can reject the uncensored model, and the censoring issue matters and has to be addressed.

Based on the coefficient estimates of the censored QUAIDS, expenditure and uncompensated price elasticities conditional on staple food expenditure evaluated at sample medians of prices, with prices normalized at sample medians, are computed as:

[8]Besides demographic variables, geographic dummies, and food group price indices in the QUAIDS models, we include the share of food in household total expenditure and a dummy variable that is equal to one if the household is single in the probit regressions. We only estimate probit models for items that are consumed by less than 95% of all households. For items that are consumed by more than 95% of all households, we still need $\widehat{\Phi}_k$ and $\widehat{\phi}_k$ to estimate the censored QUAIDS. For these items, $\widehat{\Phi}_k$ is assumed 0.9999 for each household and $\widehat{\phi}_k$ is assumed the appropriate probability density.

$$\eta_{k|1} = 1 + \frac{\bar{\Phi}_k}{w_{k|1}}[\beta_k + \boldsymbol{\eta}_{\boldsymbol{k}}'\boldsymbol{z} + 2\lambda_k(\ln x_1 - \ln \bar{m}_0)] \tag{34}$$

$$\begin{aligned} \varepsilon_{kl|1}^U = \frac{\bar{\Phi}_k}{w_{k|1}}\{\gamma_{kl} - \alpha_l[\beta_k + \boldsymbol{\eta}_{\boldsymbol{k}}'\boldsymbol{z} + 2\lambda_k(\ln x_1 - \ln \bar{m}_0)] \\ - \lambda_k(\beta_k + \boldsymbol{\eta}_{\boldsymbol{k}}'\boldsymbol{z})(\ln x_1 - \ln \bar{m}_0)^2\} - \Delta_{kl} \end{aligned} \tag{35}$$

where x_1 is household expenditure on staple foods.

Estimation and calculation of unconditional elasticities

In this study, all 12 equations of the three stages (one for the first stage, five for the second stage, and six for the third stage) are estimated simultaneously by the nonlinear seemingly unrelated regression (NLSUR) method. We estimate the subsamples of rural and urban households separately based on the notion that urbanization induces changes in food preferences. Another motivation is that, while rural households can produce part or all the food they consume, urban households have to rely on market supply. This makes the urban households more vulnerable to price fluctuations. Verpoorten, et al. (2013) showed that, during the 2008 food price crisis, while self-reported food security improved in rural areas, urban households reported worse situation in 2008 than in 2005 in 18 Sub-Saharan African countries.

After estimation, elasticities as well as their standard errors are calculated from the estimated parameters using the delta method. Elasticities from the three stages are combined to produce the unconditional elasticities of major food categories and food staple items. The unconditional expenditure (eq. 36), uncompensated (eq. 37) and compensated price elasticities (eq. 38) for major food categories are computed following Carpentier and Guyomard (2001):

$$\eta_i = \eta_{i|f}\eta_f \tag{36}$$

$$\varepsilon_{ij}^U = \varepsilon_{ij|f}^U + w_{j|f}\left(\frac{1}{\eta_{j|f}} + \varepsilon_f^U\right)\eta_{i|f}\eta_{j|f} + w_f w_{j|f}\eta_f\eta_{i|f}(\eta_{j|f} - 1) \tag{37}$$

$$\varepsilon_{ij}^C = \varepsilon_{ij|f}^C + w_{j|f}\varepsilon_f^C\eta_{i|f}\eta_{j|f} \tag{38}$$

Similarly, the unconditional elasticities of the food staple items are:

$$\eta_k = \eta_{k|1}\eta_1 \tag{39}$$

$$\varepsilon_{kl}^U = \varepsilon_{kl|1}^U + w_{l|1}\left(\frac{1}{\eta_{l|1}} + \varepsilon_{11}^U\right)\eta_{k|1}\eta_{l|1} + w_1 w_{l|1}\eta_1\eta_{l|1}(\eta_{l|1} - 1) \tag{40}$$

$$\varepsilon_{kl}^C = \varepsilon_{kl|1}^C + w_{l|1}\varepsilon_1^C\eta_{k|1}\eta_{l|1} \tag{41}$$

Unconditional elasticities of the second and third stages are computed in a recursive way: unconditional elasticities of the second stage are obtained by combing the first-stage elasticities and the second-stage elasticities conditional on FAH expenditure, and unconditional elasticities of the third stage are obtained by combing the second-stage unconditional elasticities and the third-stage elasticities conditional on staple food expenditure. When calculating elasticities, we allow household demographic variables to differ only between rural and urban areas and hold them constant across welfare quintiles. That allows us to observe how household total expenditure alone influences elasticities.

4 Result

Summary of descriptive statistics

We summarize socio-demographic characteristics of Nigerien and Nigerian households in Table 1 and household food consumption structures in Table 2, disaggregated by rural and urban areas and welfare quintiles. We perform t-tests to compare the means of demographic variables and budget shares between rural and urban households and between Niger and Nigeria. We also perform analysis of variance (ANOVA) to compare the means among the five welfare quintiles. Test results are presented in Appendices 1 and 2.

Households of the two countries share some common characteristics. In both countries, urban households are of smaller size, have fewer children, and are more likely to be headed by a female than rural households. Urban household heads and their spouses are significantly better educated than their rural counterparts: only 4.5% and 23.6% of rural household heads in Niger and Nigeria attend secondary school while 27.2% and 52.7% do in urban areas. From the first to the fifth welfare quintile in both rural and urban areas, household size and number of children decrease, and unsurprisingly household head education improves. We also observe differences between the households of two countries. Households of Nigeria have smaller family size[9] and fewer children than households of Niger and are more likely to be headed by a female. Household heads have significantly more education in Nigeria than in Niger. 35.4% of household heads in Nigeria have some secondary education or higher, but only 8.6% do in Niger. On average, heads of Nigerien households are 7.5 years younger than their Nigerian counterparts, and female heads or spouses of male head are 8.3 years younger.

Similarly, we find both similarities and differences of food consumption structures between the two countries. In both countries, rural households allocate a larger share of their budget to food than urban households do (71.1% vs. 53.9% in Niger, 77.0% vs. 66.8% in Nigeria), and the majority of food budget is spent on FAH (93% in Niger and 88.4% in Nigeria). The share of FAH in household total expenditure also is larger in rural areas than in urban areas (66.3% vs. 49.5% in Niger, 70.5% vs. 55.9% in Nigeria). In rural areas, the budget share of FAH does not change significantly between the first and fourth quintile but decrease at the fifth quintile, while it decreases between the first and the fifth quintile in urban areas. Households in both countries spend the largest share of FAH expenditure on staple foods (51.7% in Niger and 40.6% in Nigeria). Animal source products account for the second largest share of FAH (16.2% in Niger and 20.6% in Nigeria), and oil, fat, sugar, spices and other food compliments account for the third largest share (13.9% in Niger and 12.1% in Nigeria). Rural households spend a smaller share on animal source products and a larger share on legumes, nuts, and seeds than urban households. The share of FAH on animal products increases between the first and the fifth quintiles in both rural and urban areas. All these descriptive statistics are consistent with our expectation, except that the shares of food and FAH in household total expenditure are greater in Nigeria than in Niger. Since households of Niger are at an inferior economic status to households of

[9] The difference in family size is insignificant when comparing rural Niger and Nigeria.

Nigeria, we expect Nigerien households to spend more of their budget on food. A possible explanation is that the aggregated consumptions of two countries include different items. We use the aggregated consumptions provided in the data sets as denominators to calculate the budget share of food and FAH. Besides food, the aggregated consumption of Niger includes purchase of new non-durable goods and services, housing expenditure[10], and use value of durables goods, while that of Nigeria includes expenditure on education, health, and housing. Therefore, consumption aggregation of Niger includes more items than that of Nigeria. This could lead to a lower food budget share for Niger.

In both countries, rural households spend a larger share of FAH on staple foods than urban households do (54.4% vs. 39.4% in Niger, 41.7% vs. 39.0% in Nigeria). From the first to the fifth welfare quintile, the share of staple foods in FAH decreases from 60.7% to 48.7% in rural Niger, from 52.6% to 28.2% in urban Niger, from 50.3% to 36.4% in rural Nigeria, and from 45.9% to 32.8% in urban Nigeria. Comparing the two countries, households in Niger allocate a larger share of FAH expenditure to staple foods than Nigerian households do in both rural and urban areas. All of these facts imply that households with inferior economic status allocate a larger budget share to staples.

We also observe significant differences in the structure of staple food consumption between countries. The cereal product with the largest share in staple foods is millet in Niger (47.4%) and rice in Nigeria (32.9%), while rice accounts for the second largest share in Niger (15.7%). In Nigeria, tubers and roots account for a share of staple foods (39.3%) that is larger than any cereal product, while it is insignificant for Nigerien households (7.2%). The structure of consumption is consistent with the structure of production: millet occupies almost one-third of cultivated land in Niger (Serra, 2015), while Nigeria produces world's 19% of cassava and 68% of yam (Sanginga and Mbabu, 2015). In both countries, rural households spend larger shares on millet and sorghum and smaller shares on rice, tubers and roots than urban households. In Niger, the share of millet in staple foods decreases while the shares of rice, tubers and roots increase through quintiles. In Nigeria, the shares of millet, sorghum, and corn in staple foods decreases while the shares of other subgroups increase or keep stable through quintiles.

Summary of estimation

We estimate four demand systems (rural and urban Niger, rural and urban Nigeria) using the following demographic variables: number of household members in each of the age groups 0-5, 6-15, and 16-60; gender of household head; age and education of female household head or head's spouse if the head is male. We also include dummy variables for geographic areas. Since most female household heads or the spouses of male heads in rural Niger do not received any formal education, we include only one binary variable that distinguishes some level of education from none education. Adjusted R^2 of the first stage regression in each of the four demand systems is over 0.9, indicating that the explanatory variables have a strong power in explaining the variations of FAH budget share across households.

In each of the four demand systems, the λ parameters of the second stage are jointly significant at the significance level of 1%. This supports the superiority of the quadratic AIDS specification over a

[10] This is the imputed rent if the household own the house.

linear one to model food group and staple expenditures. For the third stage, the λ parameters are also jointly significant at the level of 1% in all four cases, so do the δ parameters. Therefore, the censoring problem indeed exists and needs to be addressed. All demographic variables and geographic dummy variables are jointly significant at the level of 1% based on a Wald test with the null hypothesis that all ρ and η parameters are equal to zero. For Nigeria, each demographic variable is significant at the level of 1% by testing the ρ and η parameters associated with the variable. For rural Niger, number of children under five and number of adults between 16 and 60 are significant at the level of 10% in the second stage. For urban Niger, number of children under five is insignificant even at the level of 10%. Except these variables, each of the other demographic variables in the Nigerien demand systems is significant at the level of 1%.

Expenditure and price elasticities of demand for FAH and food categories

Unconditional expenditure and own-price elasticities of FAH (Stage 1) and its six major categories (Stage 2) are presented in Table 4 for Niger and Table 5 for Nigeria.

Expenditure elasticities

Expenditure elasticities of FAH and its six categories are all positive and significant at the level of 1%. Except the first quintile of rural Niger and Nigeria and urban Nigeria, expenditure elasticity of FAH is below one. In both countries, rural and poor households' demand for FAH is more responsive to income change than their urban and rich counterparts: expenditure elasticity of FAH is larger in rural areas than in urban areas (0.939 vs. 0.840 in Niger, 0.953 vs. 0.884 in Nigeria) and decreases between the first and fifth welfare quintile. Staple foods are necessity goods in Niger and Nigeria: in both countries, unconditional expenditure elasticity of staple foods is below one for all welfare quintiles in both rural and urban areas. The expenditure elasticity of staple foods is larger in rural areas than in urban areas (0.923 vs. 0.641 in Niger, 0.687 vs. 0.621 in Nigeria) and larger in Niger than in Nigeria, and it decreases from the first to the fifth quintile. This implies that staple foods contribute to a greater share of calorie intakes for rural and poor households. For households of the poorest two welfare quintiles in rural Niger, the expenditure elasticity is close to one meaning that demand for staple foods increases at a similar rate to household total expenditure. Therefore, for rural poor households in Niger, current consumption of staple foods still cannot meet their demand for calories. By contrast, expenditure on staple foods for urban households in the wealthiest quintile increases by 0.453% as total expenditure increases by 1%. The expenditure elasticity of staple foods is smaller than those of the other five categories, except in rural Niger where it is higher than that of oil, fat, sugar, spices, and other compliments. Therefore, as income grows, the priority of households is to increase consumption of foods other than staple.

In Niger, the expenditure elasticity of animal source products is over one and larger than those of the other five categories in both rural and urban areas. Beside animal products, only the expenditure elasticity of other FAH is over one in rural Niger. Therefore, animal products are luxury goods for Nigerien households. When other FAH is excluded, the expenditure elasticities of Group 3 (vegetables and fruits) and Group 4 (legumes, nuts, and seeds) are the second are third largest among staple subgroups in both rural and urban Niger. In Nigeria, the expenditure elasticity of animal products is only larger than staple foods. Except staple foods, animal products, and vegetables and fruits (in urban areas), expenditure elasticities of other categories are over one in rural and urban Nigeria. Therefore, animal products are necessity goods for Nigerian households; expenditure on Groups 3 and 4 will increase by a larger percentage than animal products when income grows. This contradicts to our expectation that animal products is a priority for households in developing countries when income grows. It is difficult for us to find comparable studies that use nationally representative data and cover similar period to check our results. By Muhammad, et al. (2011) that uses data collected under the 2005 International Comparison Program, targeting at comparing food consumption patterns across countries, the unconditional expenditure elasticity is 0.783 for meat and 0.630 for fruits and vegetables in Nigeria. For low-income countries, the expenditure elasticity is between 0.707 and 0.846 for meat and between 0.512 and 0.728 for fruits and vegetables. By contrast, our study provides a higher estimate of the expenditure elasticity for fruits and vegetables.

Own-price elasticities

Uncompensated own-price elasticities of FAH and its six categories are all negative and significant at the level of 1%. Own-price elasticity[11] of FAH demand is larger than one in rural Niger and urban Nigeria, and vice versa in urban Niger and rural Nigeria. It is larger in rural areas than in urban areas in Niger, and vice versa in Nigeria. It keeps stable through welfare quintiles in rural Niger and Nigeria, and it decreases in urban Niger and increases in urban Nigeria, though the variation is insignificant. Comparing the two countries, it is larger in rural Niger than in rural Nigeria, and vice versa for the urban areas. By our result, the relationship between the uncompensated own-price elasticity of FAH and economic status is unclear. Timmer (1981) showed that compensated own-price elasticity of food falls with income in general, which is supported by many studies. However, the relationship is unclear for uncompensated elasticity. By Slutsky decomposition:

$$\varepsilon_{ii}^{U} = \varepsilon_{ii}^{C} - w_i \eta_i \tag{28}$$

In general w_i and η_i decrease with income. Therefore, we would expect the uncompensated elasticity also decreases with income. However, it is not uncommon to find that poorest households have lower uncompensated own-price elasticities than middle income households (Alderman, 1986). If the assumption that w_i and η_i fall with income does not hold, it is possible for us to observe some "abnormal" patterns. For instance, in our study, the share of FAH in total expenditure does not change significantly except the fifth quintile in rural areas of both countries. Consequently, Marshallian own-price elasticity of FAH is almost the same through quintiles in rural areas.

Own-price elasticity of staple foods is below one for each welfare quintile in both countries. Demand for staples is more price responsive among rural households than among urban households in Niger, while the reverse is true for Nigeria. From the poorest quintile to the wealthiest, demand for staples becomes less responsive to price change among rural and urban households in both countries. Comparing the two countries, own-price elasticity is larger in rural Niger than in rural Nigeria, and vice versa for urban areas. "Abnormal" patterns happen for Nigeria, similar to the own-price elasticity of FAH. However, budget share and expenditure elasticity of staple foods reveals a normal pattern for Nigeria. Therefore, the abnormal pattern of staple food unconditional own-price elasticity is possibly a result of the abnormal FAH own-price elasticity. When other FAH is excluded, own-price elasticities

[11] When price elasticities are negative, we refer to their absolute values.

of Group 5 (oil, fat, sugar, spices, and other food compliments) and Group 3 (vegetables and fruits) are larger than the other categories except in rural Niger. In rural Niger, Group 4 (legumes, nuts, and seeds) and Group 2 (animal products) have the largest own-price elasticities.

Expenditure and price elasticities of demand for staple food items

Unconditional expenditure and uncompensated own-price elasticities of staple food subgroups are presented in Table 6 for Niger and Table 7 for Nigeria. Unconditional uncompensated cross-price elasticities are presented in Table 8 for Niger and Table 9 for Nigeria.

Expenditure elasticities

All staple food subgroups are considered a necessity in the diet of households in rural and urban Nigeria, regardless of their income status. In Niger, millet, rice, and corn are necessities in the diet of rural and urban households in each quintile. The expenditure elasticities of sorghum, tubers, and roots are slightly greater than one for rural households of the first to the third welfare quintiles in Niger, meaning that the demand for these items will grow at a higher rate than that of income as income grows. In Niger, demand for each staple food subgroup is more expenditure elastic in rural areas than urban areas, and the expenditure elasticity decreases from the first to the fifth quintile. This is also true for Nigeria with a few exceptions: demand for rice, other cereals and cereal-based food is less expenditure elastic in rural than in urban Nigeria. Therefore, demand for staple in general is more responsive to income change among rural and poor households' than among the urban and better-off households. This coincides with our expectation that the responsiveness of staple demand to income falls as economic status improves.

Comparing expenditure elasticities among staple items, we cannot find a universal pattern when comparing rural and urban areas or comparing two countries. Demand for tubers and roots is more expenditure elastic than millet and rice in rural and urban Niger, while the reverse is true for urban Nigeria. In rural Nigeria, the expenditure elasticity of tubers and roots is between millet and rice. In rural areas of both countries, demand for sorghum is more expenditure elastic than the demand for millet, rice, tubers and roots, and vice versa in urban areas. These patterns hardly change across welfare quintiles. Comparing the two countries, demand for each staple food subgroup is more expenditure elastic in rural Niger than in rural Nigeria. Demand of millet, rice, and corn is less expenditure elastic in urban Niger than in urban Nigeria, and vice versa for other staple items.

Own-price elasticities

Unconditional uncompensated own-price elasticities of all staple items are negative and significant at the level of 1% in both countries. Demand for millet and sorghum is own-price elastic (absolute value of own-price elasticity > 1) for all wealth quintiles in urban Niger and Nigeria; it is also elastic in rural Nigeria but inelastic (absolute value of own-price elasticity < 1) in rural Niger. Demand for rice reveals an opposite pattern. In both countries, corn is own-price elastic in rural areas but inelastic in urban areas. Tubers and roots is elastic in Niger but inelastic in Nigeria.

In Niger, demand for millet and sorghum is less own-price elastic in rural areas than in urban areas, and vice versa for the other subgroups. In Nigeria, demand for corn, tubers and roots is more elastic in rural areas than in urban areas, and vice versa for the other subgroups. In both countries, own-price elasticities of rice, tubers, and roots decrease between the first and fifth quintile in rural areas. In urban areas, own-price elasticities of millet and sorghum increase, while those of rice and corn decrease through quintiles. In Niger and rural Nigeria, demand for tubers and roots becomes less elastic through quintiles, while the variation is not significant between the first and the fourth quintile in urban Nigeria. Our results show that the relationship between own-price elasticities of staple items and economic status is complex. For a particular item, this relationship is determined by not only household preferences but also the availability of the item and its substitutes. It is not uncommon to find that own-price elasticity and income show an inverted-U shape relation (Anríquez, et al., 2013). Bouis (1996) argues that this complexity can be explained by modeling food demand as demand for characteristics.

Similar to the expenditure elasticity, we cannot find a universal pattern when comparing the own-price elasticities among staple items. The item that is least own-price elastic is millet in rural Niger, corn in urban Niger, other cereals and cereal-based food in rural Nigeria, and tubers and roots in urban Nigeria, while the most elastic items are tubers and roots, sorghum, corn, and millet, respectively. Comparing the two countries, millet and corn are less elastic in Niger than in Nigeria for both rural and urban areas, while the reverse is true for rice, tubers and roots. Sorghum is less elastic in rural Niger than in rural Nigeria, and vice versa for urban areas. This is consistent with the relative importance of the staple items in diet. Millet is in the center of Nigerien households' diet, while rice, tubers, and roots combined account for 72.2% of Nigerian households' expenditure on staple foods. Our results show that, in general when a staple item is allocated a large budget share, demand for it will be less responsive to price change.

Cross-price elasticities

Compared with expenditure and own-price elasticities, cross-price elasticities tend to be of small magnitude or insignificant. Therefore, we only discuss statistically significant cross-price elasticities. Food staples are more likely to be substitutes (cross-price elasticity>0) than to be complements (cross-price elasticity<0). This is intuitive since all staple items play the similar role of providing calorie in diet. The influences between two items are usually not symmetric: it is possible for ε_{ji} to be insignificant when ε_{ij} is significant; when both of them are significant, they may show a large difference in magnitude.

In rural Niger, tubers and roots are substitutes for millet and rice, and rice is also a substitute for tubers and roots; the corresponding cross-price elasticities decrease through quintiles. Therefore, the dependence between items fades as economic status improves, and better-off households tend to maintain their eating habits. Sorghum and rice are complements in the diet of households in all wealth quintiles except the best-off one. In urban Niger, millet and rice are substitutes; change in rice price has a strong effect on millet demand: a 1% increase in rice price increases millet demand by 0.45%. Sorghum and tubers and roots are substitutes for each welfare quintile. However, the effects are unbalanced: from the first to the fifth quintile, the influence of sorghum price on the demand for tubers and roots declines, while the influence of the price of tubers and roots on sorghum demand enhances.

In Nigeria and particularly rural areas, more cross-price elasticities are significant than in Niger and the magnitudes are usually large. In rural Nigeria, staples that are substitutes include (millet, sorghum), (sorghum, rice), (sorghum, corn), (millet, tubers and roots), and (rice, tubers and roots), while millet and rice are complements. In urban Nigeria, (millet, sorghum) and (corn, other cereals and cereal-based food) are substitutes, while rice is a complement to rice. Therefore, in Nigeria, consumptions of staple items are deeply intertwined; price change of one item universally influences the demand for other items.

5 Conclusion

This study contributes to the understanding of household food demand in Niger, one of the poorest countries in Africa with a rapidly growing population, and Nigeria, the most populous country on the continent. Income growth is normally associated with a reduction in food insecurity and malnutrition; however, it is not a guarantee. From 2008 to 2015, gross national income (GNI) per capita measured in 2010 constant US$ rose from 351 to 380 in Niger, and the prevalence of undernourishment[12] dropped steadily from 12.8% to 9.5%. However, during the same period in Nigeria, although GNI per capita increased from 2010 constant US$ 1947 to 2466, prevalence of undernourishment revealed a slight increase from 5.9% to 7.0%. Therefore, food insecurity and malnutrition is likely to continue to be a problem in both countries. Eliminating hunger and malnutrition is a fundamental part of development. It also plays a crucial role in enhancing health and productivity of the population, and thus not only an end but also a mean to achieve development. Therefore, addressing food issues will stay at the center of the agenda of researchers and policy makers in the foreseeable future.

Our study adds to the limited knowledge on food demand in these two West African countries by using national representative data and a rigorous econometrics approach to estimate income and price responsiveness of aggregate food, food group, and key staples. We applied similar data processing and model estimation procedures for the two countries, aiming at making the results comparable. One of our major contribution is that we have calculated elasticities for households in each welfare quintile of the rural and urban areas, instead of treating the population as a whole. This enables us to know how demand varies between rural and urban and between households of different economic status.

Our results prove that staple foods are necessities for households of Niger and Nigeria, and staple food items in general are substitutes when cross-price elasticities are significant. Structure of staple food consumption reveals significant differences between rural and urban households and households of different economic status. In comparison to urban and better-off households, rural poor households allocate a larger share of food budget to staple foods; their demand for staple foods as a whole as well as demand for each staple item are more responsive to income change. Therefore, rural poor households are more vulnerable to food insecurity when facing an income fall. The relationship between own-price elasticities and economic status is less clear. Within a country and a sector (rural or urban areas), responsiveness of demand for staple foods to price change decreases from the first

[12] Prevalence of undernourishment is defined as the percentage of population that is below the minimum level of dietary energy consumption.

to the fifth quintile. In Niger, demand for staple foods is more responsive to price change in rural areas than in urban areas, while the opposite is true for Nigeria. When comparing the two countries, the relative magnitudes of own-price elasticities change by items and by rural and urban areas.

This complexity reminds us that, when predicting the effects of an exogenous impact like the 2008 crisis or a natural trend like population growth, policy makers and researchers should distinguish rural households from the urban and distinguish households of different economic status. For instance, using population growth rates of the two countries in 2015, a 5% increase in income will induce total demand for rice to increase by almost the same percentages in rural (8.31%) and urban (8.37%) Niger, while the same income growth leads to a larger increase in total urban demand (7.72%) than total rural demand (3.92%) in Nigeria. Distinguishing different socio-economic groups is also essential in policy-making. If a policy aiming at relieving hunger is not properly designed, the benefits may not accrue to the target group. For instance, Wodon and Zaman (2010) argued that, the majority of benefits from cutting import tariff of foods, which is the major policy instrument adopted by Sub-Saharan African countries during the 2008 crisis, were received by the non-poor. For Niger, quantity of imported rice is 1.5 times of domestic supply. By our results, rice accounts for 11.4% and 35.1% of rural and urban households' expenditure on staple foods. Therefore, if the government of Niger cuts the import tariff of rice, urban households, who are economically better off, will be the major beneficiaries.

Our study could be extended in several respects in future work. First, we estimate a demand system independent of production in this study, implicitly assuming that production and consumption are separable. The separability assumption, which states that households make their production and consumption decisions separately, seldom holds in the scenario of developing countries since it requires that 1) each output and input has a complete market, and 2) households do not make their decisions at the corner (Singh, et al., 1986). Ignoring the dependence between consumption and production can potentially distort the elasticities and sometimes even change the signs. Therefore, when information about production is available, it is desirable to estimate consumption and production simultaneously.

Second, we would want to incorporate FAFH in analysis, considering the increasing importance of FAFH and processed food in the diet of households in developing countries. However, this requires additional information about FAFH collected during the survey. Foods consumed at restaurants or in street are usually a mixture of various ingredients (e.g., cereals, vegetables, meat, oil, and fat), and household survey in general does not collect such information. So we are unable to decompose the expenditure on FAFH into different categories. Besides, part of the expenditure on meals at restaurants is service fees, making it improper to aggregate the expenditure on FAFH directly with that on FAH. The characteristics of FAFH requires additional information to be collected during the survey.

References

Abdulai, A., and D. Aubert. 2004. "A cross-section analysis of household demand for food and nutrients in Tanzania." *Agricultural Economics* 31:67-79.

Alderman, H. 1986. *The effect of food price and income changes on the acquisition of food by low-income households*: Intl Food Policy Res Inst.

Anríquez, G., S. Daidone, and E. Mane. 2013. "Rising food prices and undernourishment: A cross-country inquiry." *Food Policy* 38:190-202.

Banks, J., R. Blundell, and A. Lewbel. 1997. "Quadratic Engel Curves and Consumer Demand." *The Review of Economics and Statistics* 79:527-539.

Bilgic, A., and S.T. Yen. 2013. "Household food demand in Turkey: A two-step demand system approach." *Food Policy* 43:267.

Bouis, H.E. 1996. "A food demand system based on demand for characteristics: If there is curvature in the Slutsky matrix, what do the curves look like and why?" *Journal of Development Economics* 51:239-266.

Boysen, O. 2016. "Food Demand Characteristics in Uganda: Estimation and Policy Relevance." *South African Journal of Economics* 84:260-293.

Carpentier, A., and H. Guyomard. 2001. "Unconditional Elasticities in Two-Stage Demand Systems: An Approximate Solution." *American Journal of Agricultural Economics* 83:222-229.

Cornelsen, L., et al. 2015. "What Happens to Patterns of Food Consumption when Food Prices Change? Evidence from A Systematic Review and Meta-Analysis of Food Price Elasticities Globally." *Health Economics* 24:1548-1559.

Deaton, A. 1997. *The analysis of household surveys: a microeconometric approach to development policy*. Baltimore, MD: Published for the World Bank [by] Johns Hopkins University Press.

---. 1988. "Quality, Quantity, and Spatial Variation of Price." *The American Economic Review* 78:418-430.

Deaton, A., and J. Muellbauer. 1980. "An almost ideal demand dystem." *The American Economic Review* 70:312-326.

---. 1980. *Economics and consumer behavior*. Cambridge;New York;: Cambridge University Press.

Ecker, O., and M. Qaim. 2011. "Analyzing Nutritional Impacts of Policies: An Empirical Study for Malawi." *World Development* 39:412-428.

Edgerton, D.L. 1997. "Weak Separability and the Estimation of Elasticities in Multistage Demand Systems." *American Journal of Agricultural Economics* 79:62-79.

Edgerton, D.L., et al. 1996. *The Econometrics of Demand Systems: With Applications to Food Demand in the Nordic Countries*. Boston, MA: Springer US.

Food and Agriculture Organization. Food and Agriculture Data. Retrieved from http://www.fao.org/faostat/en/#home

---. Food Security Statistics. Retrieved from http://www.fao.org/economic/ess/ess-fs/en/

Heien, D., and C.R. Wessells. 1990. "Demand Systems Estimation with Microdata: A Censored Regression Approach." *Journal of Business & Economic Statistics* 8:365-371.

Jiang, B., and J. Davis. 2007. "Household food demand in rural China." *Applied Economics* 39:373-380.

Lewbel, A. 1996. "Aggregation Without Separability: A Generalized Composite Commodity Theorem." *The American Economic Review* 86:524-543.

Melo, P.C., et al. 2015. "Income Elasticities of Food Demand in Africa: A Meta-Analysis." *Income elasticities of food demand in Africa: a meta-analysis*.

Muhammad, A., et al. 2011. "International evidence on food consumption patterns: an update using 2005 international comparison program data."

Ray, R. 1983. "Measuring the costs of children." *Journal of Public Economics* 22:89-102.

Sanginga, N., and A. Mbabu. "Root and Tuber Crops (Cassava, Yam, Potato and Sweet Potato)."

Seale, J.L., A. Regmi, and J. Bernstein. 2003. *International evidence on food consumption patterns*: Economic Research Service, US Department of Agriculture.

Serra, T. 2015. "Price volatility in Niger millet markets." *Agricultural Economics* 46:489-502.

Shonkwiler, J.S., and S.T. Yen. 1999. "Two-step estimation of a censored system of equations." *American Journal of Agricultural Economics* 81:972.

Singh, I., et al. 1986. *Agricultural household models: extensions, applications, and policy*. Baltimore: Johns Hopkins University Press.

Teklu, T. 1996. "Food demand studies in Sub-Saharan Africa: a survey of empirical evidence." *Food Policy* 21:479-496.

Timmer, C.P. 1981. "Is There ''Curvature'' in the Slutsky Matrix?" *The Review of Economics and Statistics* 63:395.

United Nations. 2011. *The Global Social Crisis: Report on the World Social Situation 2011*: United Nations Publications.

United Nations, Department of Economic and Social Affairs, Population Division. 2015. "World Population Prospects: The 2015 Revision, Key Findings and Advance Tables." *ESA/P/WP. 241.*

---. 2015. "World Urbanization Prospects: The 2014 Revision." *ST/ESA/SER.A/366*.

Verpoorten, M., et al. 2013. "Self-reported food insecurity in Africa during the food price crisis." *Food Policy* 39:51-63.

Wodon, Q., and H. Zaman. 2010. "Higher food prices in Sub-Saharan Africa: Poverty impact and policy responses." *The World Bank Research Observer* 25:157-176.

Table 1. Summary of household socio-demographic characteristics

		Niger (3,859 hhs)												
		Rural (2,343 hhs)						Urban (1,516 hhs)						Overall
		Welfare quintiles					Rural all	Welfare quintiles					Urban all	
		1	2	3	4	5		1	2	3	4	5		
hh size		8.8	7.9	7.0	6.1	4.9	6.6	8.2	7.3	6.6	6.2	4.7	6.4	6.6
# of children under 5		2.7	2.2	2.0	1.6	1.2	1.8	2.0	1.4	1.4	1.3	0.8	1.3	1.7
# of children between 6 and 15		2.9	2.5	2.1	1.7	1.1	1.9	2.9	2.4	1.9	1.6	1.0	1.8	1.9
# of adults between 16 and 59		2.9	2.8	2.5	2.5	2.2	2.5	2.9	3.1	3.1	3.0	2.8	3.0	2.6
# of seniors over 60		0.3	0.3	0.3	0.4	0.3	0.3	0.4	0.4	0.3	0.2	0.1	0.3	0.3
% hh headed by female		8.1	7.9	10.8	11.0	9.9	9.7	16.7	21.2	16.0	12.2	15.7	16.1	10.9
Education of hh head (%)	primary & =	42.6	43.0	45.8	46.0	51.4	46.4	59.5	50.8	53.1	47.3	30.2	46.2	46.4
	secondary & +	1.7	3.0	1.6	5.4	8.3	4.5	7.1	11.4	16.7	27.5	55.7	27.2	8.6
Education of female hh head or spouse (%)	primary & =	21.9	29.1	25.4	27.5	36.6	29.0	50.9	51.0	53.3	45.2	33.6	45.5	32.0
	secondary & +	0.5	1.3	0.6	3.6	4.6	2.4	2.9	4.9	8.1	20.2	51.0	20.9	5.8
Age of hh head (yr)		45.0	46.2	46.1	45.5	41.5	44.6	50.2	50.6	46.5	45.3	41.9	46.3	44.9
Age of female hh head or spouse (yr)		35.7	36.4	36.5	36.1	32.7	35.2	40.5	41.1	37.4	36.3	34.4	37.5	35.6

		Nigeria (4,532 hhs)												
		Rural (3,163 hhs)						Urban (1,369 hhs)						Overall
		Welfare quintiles					Rural all	Welfare quintiles					Urban all	
		1	2	3	4	5		1	2	3	4	5		
hh size		8.3	7.8	6.8	6.4	4.8	6.5	7.3	6.8	6.0	5.2	4.1	5.7	6.2
# of children under 5		1.6	1.4	1.1	0.9	0.5	1.0	1.3	0.9	0.9	0.6	0.3	0.7	0.9
# of children between 6 and 15		2.8	2.4	2.1	1.8	1.0	1.9	2.2	1.7	1.5	1.1	0.7	1.3	1.7
# of adults between 16 and 59		3.4	3.3	3.0	3.0	2.4	3.0	3.1	3.2	2.9	2.8	2.4	2.8	2.9
# of seniors over 60		0.4	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.5
% hh headed by female		7.6	7.9	11.9	15.4	24.2	14.8	17.6	20.2	18.3	18.1	19.4	18.8	16.4
Education of hh head (%)	primary & =	42.4	41.3	40.6	39.4	32.8	38.6	35.7	30.9	34.2	27.5	15.9	27.3	34.0
	secondary & +	9.9	16.3	19.2	22.1	39.4	23.6	30.1	37.0	49.2	57.0	73.0	52.7	35.4
Education of female hh head or spouse (%)	primary & =	36.1	38.4	35.8	36.7	31.0	35.1	39.2	29.2	25.8	25.1	19.3	26.4	31.6
	secondary & +	6.2	9.0	14.3	15.4	35.2	18.3	21.0	33.7	48.9	55.3	64.7	48.0	30.3
Age of hh head (yr)		51.6	52.2	51.6	53.7	53.8	52.8	54.2	54.4	50.1	52.3	50.1	51.9	52.4
Age of female hh head or spouse (yr)		40.5	41.1	41.4	43.8	46.8	43.2	44.6	46.4	43.5	44.7	45.1	44.9	43.9

Table 2. Summary of household food consumption structure

			Niger												
			Rural						Urban						Overall
			Welfare quintiles					rural all	Welfare quintiles					urban all	
			1	2	3	4	5		1	2	3	4	5		
Stage1	% of food in total exp.		72.6	72.9	73.3	72.2	66.7	71.1	62.4	59.9	56.7	54.4	43.0	53.9	68.0
	% of FAH in food exp.		94.0	94.2	93.5	93.6	91.9	93.3	91.2	91.2	92.6	91.1	92.5	91.8	93.0
	% of FAH in total exp.		68.2	68.8	68.4	67.5	61.3	66.3	56.9	54.6	52.6	49.6	39.8	49.5	63.3
Stage2	% each group in FAH	Staple food	60.7	57.2	56.6	53.1	48.7	54.4	52.6	46.0	41.4	37.1	28.2	39.4	51.7
		Animal products	7.8	11.7	13.0	15.1	18.5	14.0	14.3	19.7	23.7	30.2	36.6	26.4	16.2
		Vegetables & fruits	5.8	6.2	6.3	6.9	7.6	6.7	8.4	9.3	9.6	9.8	11.7	10.0	7.3
		Legumes, nuts, & seeds	6.3	6.0	5.8	5.9	5.5	5.8	3.9	3.4	3.1	2.1	2.2	2.8	5.3
		Oil, fat, sugar, & other	14.2	13.7	13.5	13.7	13.5	13.7	15.9	16.1	16.1	15.0	13.7	15.2	13.9
		Other FAH	5.2	5.3	4.9	5.3	6.1	5.4	4.9	5.5	6.0	5.7	7.7	6.2	5.6
Stage3	% each subgroup in staple food	Millet	67.7	57.3	59.8	51.9	42.5	54.1	28.9	19.1	18.0	13.9	9.6	16.7	47.4
		Sorghum	9.2	12.2	8.8	10.1	8.5	9.6	3.4	3.0	1.5	1.3	0.5	1.7	8.2
		Rice	5.4	9.2	10.7	12.0	16.1	11.4	28.7	38.8	37.5	35.8	34.0	35.1	15.7
		Corn	9.1	9.9	9.0	12.0	12.5	10.8	20.2	17.1	16.6	14.7	8.7	14.7	11.5
		Other cereals	3.4	5.5	6.4	7.6	12.0	7.6	9.8	13.3	16.7	23.0	31.4	20.4	9.9
		Tubers and roots	5.1	5.3	5.3	6.4	8.5	6.4	7.8	8.7	8.9	10.9	15.6	11.0	7.2

			Nigeria												
			Rural						Urban						Overall
			Welfare quintiles					rural all	Welfare quintiles					urban all	
			1	2	3	4	5		1	2	3	4	5		
Stage1	% of food in total exp.		79.1	79.4	78.9	77.9	72.7	77.0	71.9	70.9	68.7	66.2	60.9	66.8	72.9
	% of FAH in food exp.		93.3	93.0	92.7	91.8	88.6	91.5	90.5	87.1	83.7	84.8	77.8	83.9	88.4
	% of FAH in total exp.		73.8	73.9	73.2	71.4	64.4	70.5	64.9	61.7	57.4	55.8	46.7	55.9	64.6
Stage2	% each group in FAH	Staple food	50.3	44.5	42.7	39.7	36.4	41.7	45.9	43.1	40.3	38.0	32.8	39.0	40.6
		Animal products	13.0	16.5	17.9	21.5	24.5	19.6	18.0	19.2	20.8	23.2	25.9	22.1	20.6
		Vegetables & fruits	10.7	10.1	9.9	9.3	10.7	10.2	11.2	11.0	9.6	9.3	9.8	10.1	10.1
		Legumes, nuts, & seeds	11.7	12.8	12.9	12.1	10.7	11.9	9.9	9.4	9.0	9.3	7.9	9.0	10.7
		Oil, fat, sugar, & other	12.4	13.7	12.8	13.1	11.6	12.6	11.3	10.8	12.6	10.5	11.8	11.4	12.1
		Other FAH	1.9	2.5	3.8	4.2	6.1	4.0	3.7	6.5	7.6	9.7	11.8	8.5	5.8
Stage3	% each subgroup in staple food	Millet	13.0	10.1	8.7	7.6	3.0	7.7	3.6	2.6	1.5	0.7	0.3	1.5	5.2
		Sorghum	20.5	16.7	12.6	10.0	3.5	11.4	5.6	2.8	2.1	1.3	0.4	2.1	7.6
		Rice	22.1	26.3	28.1	31.4	32.3	28.7	36.4	40.6	40.5	39.8	37.5	38.9	32.9
		Corn	12.3	11.5	8.9	6.5	4.0	8.0	7.0	3.4	2.8	1.6	1.7	3.0	5.9
		Other cereals	2.8	4.3	5.2	6.0	9.2	6.0	8.0	9.4	12.2	13.4	19.4	13.4	9.0
		Tubers and roots	29.2	31.2	36.4	38.5	48.0	38.2	38.5	41.2	40.9	43.2	40.7	41.0	39.3

Table 3. Percentages of households consuming each staple item

	Niger												
	Rural						Urban						Overall
	Welfare quintiles					rural	Welfare quintiles					urban	
	1	2	3	4	5	all	1	2	3	4	5	all	
Millet	98.4	99.1	100.0	100.0	99.6	99.5	92.6	89.8	91.9	89.7	79.7	87.9	97.4
Sorghum	48.0	58.5	57.7	66.0	60.2	58.9	27.3	26.3	19.5	15.1	8.2	17.9	51.5
Rice	35.8	59.0	63.1	72.5	82.8	65.7	92.0	98.9	98.1	97.7	97.5	97.1	71.3
Corn	32.0	41.2	40.2	50.9	58.2	46.4	80.3	78.7	81.0	78.0	62.9	75.0	51.5
Other cereals	46.2	62.5	65.9	71.0	81.5	67.7	77.1	85.5	94.2	96.5	99.3	91.9	72.1
Tubers and roots	68.9	79.3	81.2	83.8	91.4	82.4	90.4	92.0	91.9	91.9	93.9	92.2	84.1
	Nigeria												
	Rural						Urban						Overall
	Welfare quintiles					rural	Welfare quintiles					urban	
	1	2	3	4	5	all	1	2	3	4	5	all	
Millet	49.2	47.0	40.3	36.2	17.4	35.4	21.2	15.2	12.0	7.7	5.4	11.1	25.6
Sorghum	65.7	60.3	50.7	45.0	22.8	45.5	27.6	17.5	15.3	13.0	7.0	14.7	33.0
Rice	82.5	89.5	93.6	95.2	97.8	92.8	94.7	98.2	99.0	97.8	96.8	97.4	94.6
Corn	55.1	54.8	48.2	42.8	30.8	44.3	38.7	28.6	23.6	18.5	19.5	24.5	36.3
Other cereals	44.5	52.7	64.8	73.1	87.5	67.9	78.6	86.0	91.7	93.7	97.3	90.8	77.1
Tubers and roots	76.0	83.6	85.6	90.3	96.4	87.8	89.8	95.7	96.9	98.4	98.7	96.4	91.3

Table 4. First and second stages elasticities, Niger

		Rural						Urban					
		Welfare quintiles					Rural all	Welfare quintiles					Urban all
		1	2	3	4	5		1	2	3	4	5	
Stage 1	FAH exp. elas.	1.008***	0.973***	0.951***	0.925***	0.871***	0.939***	0.952***	0.902***	0.864***	0.816***	0.685***	0.840***
		(0.019)	(0.013)	(0.011)	(0.010)	(0.015)	(0.010)	(0.026)	(0.018)	(0.014)	(0.012)	(0.025)	(0.013)
	FAH uncompensated price elas.	-1.008***	-1.008***	-1.008***	-1.008***	-1.009***	-1.009***	-0.962***	-0.960***	-0.959***	-0.956***	-0.946***	-0.956***
		(0.011)	(0.011)	(0.011)	(0.011)	(0.012)	(0.011)	(0.038)	(0.039)	(0.041)	(0.043)	(0.054)	(0.043)
Stage 2 Unconditional exp. elas.	Staple food	0.997***	0.959***	0.935***	0.908***	0.853***	0.923***	0.788***	0.721***	0.670***	0.609***	0.453***	0.641***
		(0.021)	(0.015)	(0.013)	(0.012)	(0.017)	(0.013)	(0.026)	(0.021)	(0.019)	(0.019)	(0.025)	(0.019)
	Animal products	1.198***	1.108***	1.076***	1.034***	0.958***	1.055***	1.579***	1.341***	1.216***	1.080***	0.869***	1.147***
		(0.066)	(0.047)	(0.043)	(0.038)	(0.035)	(0.040)	(0.104)	(0.060)	(0.044)	(0.031)	(0.033)	(0.038)
	Vegetables and fruits	1.066***	1.022***	0.996***	0.964***	0.904***	0.981***	1.181***	1.080***	1.022***	0.953***	0.774***	0.985***
		(0.037)	(0.031)	(0.028)	(0.024)	(0.024)	(0.026)	(0.054)	(0.036)	(0.030)	(0.028)	(0.035)	(0.029)
	Legumes, nuts, and seeds	1.042***	1.001***	0.976***	0.947***	0.890***	0.963***	0.813***	0.891***	0.911***	1.011***	0.964**	0.920***
		(0.031)	(0.028)	(0.027)	(0.025)	(0.028)	(0.026)	(0.144)	(0.111)	(0.152)	(0.331)	(0.407)	(0.190)
	Oil, fat, sugar, spices, and other	0.893***	0.854***	0.832***	0.810***	0.761***	0.823***	0.843***	0.756***	0.708***	0.631***	0.491***	0.671***
		(0.022)	(0.019)	(0.017)	(0.017)	(0.019)	(0.017)	(0.057)	(0.039)	(0.032)	(0.027)	(0.028)	(0.031)
	Other FAH	1.068***	1.045***	1.036***	1.007***	0.943***	1.015***	0.949***	0.973***	0.953***	0.945***	0.789***	0.935***
		(0.060)	(0.060)	(0.066)	(0.060)	(0.053)	(0.058)	(0.173)	(0.092)	(0.066)	(0.054)	(0.050)	(0.058)
Stage 2 Unconditional own-price elas.	Staple food	-0.979***	-0.975***	-0.974***	-0.970***	-0.966***	-0.972***	-0.827***	-0.806***	-0.789***	-0.767***	-0.707***	-0.778***
		(0.012)	(0.012)	(0.012)	(0.013)	(0.014)	(0.013)	(0.028)	(0.027)	(0.029)	(0.030)	(0.038)	(0.030)
	Animal products	-0.986***	-0.994***	-0.996***	-0.999***	-1.003***	-0.998***	-0.891***	-0.937***	-0.958***	-0.979***	-0.998***	-0.969***
		(0.043)	(0.029)	(0.027)	(0.023)	(0.020)	(0.025)	(0.089)	(0.065)	(0.057)	(0.049)	(0.050)	(0.054)
	Vegetables and fruits	-0.518***	-0.543***	-0.555***	-0.593***	-0.629***	-0.580***	-0.994***	-0.993***	-0.992***	-0.991***	-0.991***	-0.992***
		(0.076)	(0.073)	(0.071)	(0.065)	(0.059)	(0.067)	(0.094)	(0.085)	(0.082)	(0.080)	(0.068)	(0.079)
	Legumes, nuts, and seeds	-1.020***	-1.020***	-1.021***	-1.020***	-1.021***	-1.020***	-0.972***	-0.965***	-0.961***	-0.942***	-0.941***	-0.956***
		(0.022)	(0.024)	(0.024)	(0.024)	(0.026)	(0.024)	(0.126)	(0.146)	(0.162)	(0.244)	(0.255)	(0.183)
	Oil, fat, sugar, spices, and other	-0.896***	-0.891***	-0.889***	-0.890***	-0.887***	-0.890***	-1.080***	-1.064***	-1.058***	-1.055***	-1.051***	-1.060***
		(0.031)	(0.032)	(0.033)	(0.032)	(0.033)	(0.032)	(0.065)	(0.064)	(0.064)	(0.069)	(0.076)	(0.068)
	Other FAH	-1.189***	-1.186***	-1.203***	-1.186***	-1.163***	-1.182***	-1.234***	-1.210***	-1.196***	-1.207***	-1.158***	-1.191***
		(0.112)	(0.110)	(0.120)	(0.110)	(0.096)	(0.108)	(0.079)	(0.070)	(0.065)	(0.068)	(0.052)	(0.063)

Table 5. First and second stages elasticities, Nigeria

		Rural						Urban					
		Welfare quintiles					Rural all	Welfare quintiles					Urban all
		1	2	3	4	5		1	2	3	4	5	
Stage 1	FAH exp. elas.	1.013*** (0.019)	0.982*** (0.011)	0.963*** (0.008)	0.941*** (0.009)	0.888*** (0.021)	0.953*** (0.007)	1.004*** (0.022)	0.942*** (0.016)	0.902*** (0.015)	0.859*** (0.017)	0.740*** (0.030)	0.884*** (0.016)
	FAH uncompensated price elas.	-0.989*** (0.018)	-0.989*** (0.018)	-0.989*** (0.018)	-0.989*** (0.018)	-0.987*** (0.020)	-0.989*** (0.018)	-1.185*** (0.038)	-1.195*** (0.040)	-1.209*** (0.043)	-1.215*** (0.045)	-1.257*** (0.053)	-1.215*** (0.044)
Stage 2 Unconditional exp. elas.	Staple food	0.787*** (0.023)	0.727*** (0.019)	0.700*** (0.018)	0.662*** (0.019)	0.600*** (0.023)	0.687*** (0.018)	0.748*** (0.030)	0.689*** (0.025)	0.642*** (0.025)	0.597*** (0.025)	0.479*** (0.029)	0.621*** (0.025)
	Animal products	0.986*** (0.056)	0.894*** (0.038)	0.869*** (0.033)	0.845*** (0.027)	0.804*** (0.028)	0.867*** (0.030)	1.029*** (0.055)	0.930*** (0.044)	0.880*** (0.040)	0.839*** (0.036)	0.723*** (0.040)	0.869*** (0.038)
	Vegetables and fruits	1.125*** (0.056)	1.117*** (0.051)	1.103*** (0.051)	1.094*** (0.055)	1.016*** (0.052)	1.088*** (0.050)	1.026*** (0.047)	0.958*** (0.043)	0.917*** (0.047)	0.873*** (0.046)	0.752*** (0.046)	0.899*** (0.044)
	Legumes, nuts, and seeds	1.387*** (0.081)	1.298*** (0.061)	1.266*** (0.057)	1.250*** (0.058)	1.218*** (0.067)	1.278*** (0.061)	1.188*** (0.055)	1.076*** (0.049)	1.019*** (0.049)	0.964*** (0.046)	0.844*** (0.054)	1.009*** (0.048)
	Oil, fat, sugar, spices, and other	1.516*** (0.074)	1.498*** (0.056)	1.523*** (0.056)	1.502*** (0.054)	1.494*** (0.066)	1.514*** (0.056)	1.523*** (0.070)	1.523*** (0.078)	1.395*** (0.070)	1.429*** (0.082)	1.181*** (0.079)	1.406*** (0.072)
	Other FAH	0.909** (0.409)	1.077*** (0.249)	1.050*** (0.152)	1.053*** (0.126)	0.967*** (0.084)	1.034*** (0.141)	1.892*** (0.267)	1.473*** (0.148)	1.354*** (0.127)	1.201*** (0.097)	0.983*** (0.076)	1.273*** (0.109)
Stage 2 Unconditional own-price elas.	Staple food	-0.728*** (0.012)	-0.691*** (0.011)	-0.677*** (0.011)	-0.651*** (0.012)	-0.615*** (0.013)	-0.668*** (0.012)	-0.959*** (0.053)	-0.948*** (0.056)	-0.938*** (0.060)	-0.928*** (0.063)	-0.906*** (0.073)	-0.932*** (0.062)
	Animal products	-0.340*** (0.090)	-0.462*** (0.071)	-0.503*** (0.065)	-0.579*** (0.054)	-0.626*** (0.048)	-0.543*** (0.060)	-0.994*** (0.125)	-0.981*** (0.118)	-0.984*** (0.109)	-0.995*** (0.099)	-1.014*** (0.090)	-0.995*** (0.103)
	Vegetables and fruits	-0.834*** (0.075)	-0.829*** (0.079)	-0.825*** (0.082)	-0.816*** (0.087)	-0.841*** (0.077)	-0.830*** (0.080)	-1.104*** (0.112)	-1.105*** (0.115)	-1.115*** (0.131)	-1.117*** (0.133)	-1.119*** (0.130)	-1.113*** (0.125)
	Legumes, nuts, and seeds	-0.638*** (0.146)	-0.669*** (0.133)	-0.673*** (0.132)	-0.652*** (0.140)	-0.607*** (0.160)	-0.646*** (0.143)	-0.827*** (0.192)	-0.805*** (0.202)	-0.793*** (0.210)	-0.802*** (0.204)	-0.761*** (0.242)	-0.795*** (0.212)
	Oil, fat, sugar, spices, and other	-1.290*** (0.047)	-1.280*** (0.043)	-1.305*** (0.046)	-1.309*** (0.045)	-1.361*** (0.051)	-1.313*** (0.046)	-1.428*** (0.095)	-1.461*** (0.099)	-1.421*** (0.086)	-1.492*** (0.102)	-1.478*** (0.093)	-1.456*** (0.094)
	Other FAH	-0.942*** (0.243)	-0.960*** (0.186)	-0.975*** (0.121)	-0.979*** (0.107)	-0.986*** (0.074)	-0.976*** (0.113)	-0.929*** (0.202)	-0.989*** (0.116)	-1.007*** (0.100)	-1.024*** (0.080)	-1.050*** (0.067)	-1.014*** (0.090)

Table 6. Third stage expenditure and own-price elasticities, Niger

		Rural						Urban					
		Welfare quintiles					Rural all	Welfare quintiles					Urban all
		1	2	3	4	5		1	2	3	4	5	
Stage 3 Unconditional exp. elas.	Millet	0.972*** (0.020)	0.930*** (0.015)	0.908*** (0.013)	0.878*** (0.013)	0.818*** (0.017)	0.894*** (0.013)	0.761*** (0.031)	0.687*** (0.031)	0.638*** (0.029)	0.574*** (0.031)	0.418*** (0.034)	0.609*** (0.029)
	Sorghum	1.061*** (0.028)	1.008*** (0.021)	1.002*** (0.022)	0.965*** (0.020)	0.916*** (0.024)	0.983*** (0.021)	0.710*** (0.036)	0.654*** (0.030)	0.567*** (0.039)	0.514*** (0.036)	0.353*** (0.039)	0.561*** (0.032)
	Rice	0.989*** (0.037)	0.957*** (0.024)	0.934*** (0.021)	0.908*** (0.019)	0.853*** (0.020)	0.922*** (0.020)	0.708*** (0.036)	0.666*** (0.027)	0.616*** (0.026)	0.558*** (0.025)	0.413*** (0.027)	0.586*** (0.026)
	Corn	0.945*** (0.022)	0.913*** (0.017)	0.886*** (0.016)	0.873*** (0.014)	0.822*** (0.018)	0.883*** (0.015)	0.814*** (0.032)	0.746*** (0.028)	0.692*** (0.026)	0.630*** (0.026)	0.477*** (0.031)	0.663*** (0.026)
	Other cereals and cereal-based food	1.253*** (0.108)	1.106*** (0.065)	1.053*** (0.052)	1.006*** (0.044)	0.910*** (0.029)	1.023*** (0.045)	0.843*** (0.059)	0.762*** (0.041)	0.703*** (0.032)	0.632*** (0.026)	0.465*** (0.027)	0.667*** (0.028)
	Tubers and roots	1.050*** (0.057)	1.025*** (0.051)	1.006*** (0.049)	0.967*** (0.040)	0.895*** (0.033)	0.979*** (0.041)	1.139*** (0.089)	1.001*** (0.067)	0.920*** (0.058)	0.791*** (0.043)	0.549*** (0.032)	0.835*** (0.046)
Stage 3 Unconditional own-price elas.	Millet	-0.980*** (0.010)	-0.978*** (0.011)	-0.976*** (0.011)	-0.976*** (0.011)	-0.975*** (0.012)	-0.977*** (0.011)	-1.021*** (0.043)	-1.071*** (0.064)	-1.075*** (0.067)	-1.110*** (0.084)	-1.157*** (0.108)	-1.080*** (0.069)
	Sorghum	-0.991*** (0.039)	-0.993*** (0.031)	-0.991*** (0.042)	-0.992*** (0.037)	-0.991*** (0.043)	-0.991*** (0.038)	-1.333*** (0.032)	-1.317*** (0.030)	-1.542*** (0.051)	-1.559*** (0.053)	-1.781*** (0.073)	-1.435*** (0.041)
	Rice	-1.144*** (0.109)	-1.087*** (0.067)	-1.075*** (0.058)	-1.066*** (0.053)	-1.047*** (0.040)	-1.069*** (0.055)	-0.997*** (0.174)	-0.955*** (0.129)	-0.952*** (0.134)	-0.949*** (0.140)	-0.936*** (0.147)	-0.956*** (0.143)
	Corn	-1.075*** (0.015)	-1.064*** (0.013)	-1.070*** (0.014)	-1.049*** (0.010)	-1.044*** (0.010)	-1.057*** (0.012)	-0.829*** (0.057)	-0.808*** (0.066)	-0.806*** (0.067)	-0.794*** (0.071)	-0.721*** (0.106)	-0.795*** (0.072)
	Other cereals and cereal-based food	-0.961*** (0.040)	-0.975*** (0.025)	-0.979*** (0.021)	-0.982*** (0.018)	-0.988*** (0.012)	-0.982*** (0.018)	-0.890*** (0.109)	-0.906*** (0.082)	-0.910*** (0.068)	-0.907*** (0.050)	-0.878*** (0.039)	-0.910*** (0.056)
	Tubers and roots	-1.443*** (0.075)	-1.424*** (0.072)	-1.420*** (0.071)	-1.343*** (0.058)	-1.262*** (0.045)	-1.349*** (0.059)	-1.493*** (0.256)	-1.435*** (0.228)	-1.421*** (0.222)	-1.333*** (0.180)	-1.207*** (0.125)	-1.336*** (0.180)

Table 7. Third stage expenditure and own-price elasticities, Nigeria

		Rural						Urban					
		Welfare quintiles					Rural all	Welfare quintiles					Urban all
		1	2	3	4	5		1	2	3	4	5	
Stage 3 unconditional exp. elas.	Millet	0.858***	0.807***	0.775***	0.731***	0.677***	0.759***	0.778***	0.720***	0.692***	0.684***	0.586***	0.665***
		(0.031)	(0.029)	(0.027)	(0.027)	(0.033)	(0.027)	(0.036)	(0.031)	(0.036)	(0.050)	(0.062)	(0.035)
	Sorghum	0.873***	0.819***	0.804***	0.767***	0.746***	0.785***	0.655***	0.579***	0.541***	0.471***	0.304***	0.520***
		(0.028)	(0.025)	(0.025)	(0.026)	(0.035)	(0.025)	(0.030)	(0.026)	(0.025)	(0.027)	(0.030)	(0.026)
	Rice	0.640***	0.609***	0.593***	0.570***	0.519***	0.584***	0.808***	0.735***	0.686***	0.638***	0.517***	0.665***
		(0.026)	(0.021)	(0.020)	(0.019)	(0.022)	(0.019)	(0.033)	(0.027)	(0.026)	(0.026)	(0.030)	(0.026)
	Corn	0.840***	0.780***	0.761***	0.733***	0.673***	0.747***	0.829***	0.807***	0.753***	0.743***	0.568***	0.720***
		(0.028)	(0.025)	(0.025)	(0.028)	(0.032)	(0.025)	(0.034)	(0.032)	(0.030)	(0.034)	(0.035)	(0.030)
	Other cereals and cereal-based food	0.390***	0.483***	0.497***	0.489***	0.487***	0.508***	0.551***	0.534***	0.527***	0.497***	0.422***	0.519***
		(0.081)	(0.051)	(0.043)	(0.037)	(0.029)	(0.038)	(0.043)	(0.036)	(0.031)	(0.030)	(0.029)	(0.030)
	Tubers and roots	0.759***	0.704***	0.681***	0.644***	0.586***	0.668***	0.723***	0.668***	0.623***	0.579***	0.464***	0.602***
		(0.027)	(0.024)	(0.022)	(0.022)	(0.025)	(0.022)	(0.032)	(0.027)	(0.026)	(0.026)	(0.029)	(0.026)
Stage 3 unconditional own-price elas.	Millet	-1.059***	-1.081***	-1.080***	-1.079***	-1.118***	-1.081***	-1.084***	-1.096***	-1.161***	-1.311***	-1.478***	-1.149***
		(0.036)	(0.044)	(0.042)	(0.041)	(0.051)	(0.042)	(0.048)	(0.055)	(0.092)	(0.178)	(0.274)	(0.085)
	Sorghum	-1.030***	-1.047***	-1.073***	-1.087***	-1.171***	-1.072***	-1.067***	-1.091***	-1.091***	-1.123***	-1.210***	-1.093***
		(0.006)	(0.007)	(0.008)	(0.008)	(0.013)	(0.008)	(0.061)	(0.080)	(0.079)	(0.105)	(0.177)	(0.081)
	Rice	-0.897***	-0.878***	-0.870***	-0.855***	-0.843***	-0.866***	-0.947***	-0.940***	-0.936***	-0.935***	-0.934***	-0.935***
		(0.079)	(0.067)	(0.062)	(0.056)	(0.055)	(0.061)	(0.081)	(0.075)	(0.075)	(0.077)	(0.083)	(0.078)
	Corn	-1.060***	-1.063***	-1.087***	-1.122***	-1.148***	-1.091***	-0.996***	-0.993***	-0.992***	-0.989***	-0.991***	-0.993***
		(0.031)	(0.032)	(0.038)	(0.048)	(0.055)	(0.039)	(0.032)	(0.051)	(0.051)	(0.073)	(0.055)	(0.047)
	Other cereals and cereal-based food	-0.386***	-0.590***	-0.642***	-0.673***	-0.744***	-0.673***	-1.048***	-1.038***	-1.024***	-1.018***	-0.996***	-1.018***
		(0.135)	(0.088)	(0.076)	(0.068)	(0.049)	(0.068)	(0.099)	(0.087)	(0.070)	(0.065)	(0.046)	(0.063)
	Tubers and roots	-1.003***	-0.983***	-0.951***	-0.933***	-0.872***	-0.940***	-0.800***	-0.806***	-0.800***	-0.803***	-0.786***	-0.799***
		(0.046)	(0.044)	(0.038)	(0.037)	(0.032)	(0.037)	(0.066)	(0.064)	(0.065)	(0.063)	(0.067)	(0.065)

Table 8. Third stage cross-price elasticities, Niger

		Rural						Urban					
		Subgroups						Subgroups					
		1	2	3	4	5	6	1	2	3	4	5	6
All	1	-0.977*** (0.011)	-0.001 (0.006)	0.008 (0.006)	0.011*** (0.004)	-0.016*** (0.005)	0.035*** (0.008)	-1.080*** (0.069)	0.024 (0.016)	0.448*** (0.087)	0.019 (0.047)	-0.085 (0.052)	-0.071 (0.068)
	2	-0.032 (0.020)	-0.991*** (0.038)	-0.126*** (0.023)	0.065*** (0.014)	0.010 (0.010)	0.042* (0.025)	0.077** (0.031)	-1.435*** (0.041)	0.049 (0.095)	0.109** (0.052)	0.166*** (0.033)	0.348*** (0.055)
	3	0.031* (0.017)	-0.118*** (0.021)	-1.069*** (0.055)	0.030 (0.028)	0.071*** (0.016)	0.085*** (0.023)	0.221*** (0.046)	-0.022 (0.025)	-0.956*** (0.143)	-0.089 (0.064)	0.047 (0.034)	0.084 (0.087)
	4	0.070*** (0.010)	0.043*** (0.009)	0.025 (0.021)	-1.057*** (0.012)	0.004 (0.006)	-0.013 (0.010)	0.027 (0.046)	0.039 (0.026)	-0.148 (0.116)	-0.795*** (0.072)	0.074** (0.029)	-0.008 (0.073)
	5	-0.140*** (0.039)	0.021 (0.014)	0.109*** (0.026)	0.010 (0.015)	-0.982*** (0.018)	-0.095*** (0.015)	-0.074 (0.045)	0.050*** (0.014)	0.061 (0.054)	0.062** (0.025)	-0.910*** (0.056)	-0.003 (0.026)
	6	0.215*** (0.053)	0.091* (0.053)	0.191*** (0.052)	-0.040 (0.030)	-0.137*** (0.021)	-1.349*** (0.059)	-0.087 (0.110)	0.279*** (0.045)	0.166 (0.266)	-0.016 (0.121)	-0.026 (0.049)	-1.336*** (0.180)
Quintile 1	1	-0.980*** (0.010)	0.002 (0.006)	0.009* (0.005)	0.008** (0.003)	-0.015*** (0.004)	0.040*** (0.008)	-1.021*** (0.043)	0.020** (0.010)	0.297*** (0.055)	0.041 (0.031)	-0.061* (0.033)	-0.030 (0.043)
	2	-0.040* (0.021)	-0.991*** (0.039)	-0.128*** (0.023)	0.061*** (0.014)	0.005 (0.011)	0.051** (0.025)	0.075*** (0.025)	-1.333*** (0.032)	0.041 (0.075)	0.103** (0.040)	0.109*** (0.025)	0.276*** (0.042)
	3	0.033 (0.032)	-0.236*** (0.041)	-1.144*** (0.109)	0.049 (0.056)	0.139*** (0.031)	0.177*** (0.046)	0.260*** (0.056)	-0.029 (0.031)	-0.997*** (0.174)	-0.112 (0.077)	0.012 (0.042)	0.098 (0.105)
	4	0.078*** (0.013)	0.057*** (0.012)	0.033 (0.028)	-1.075*** (0.015)	0.005 (0.008)	-0.005 (0.013)	0.026 (0.037)	0.031 (0.021)	-0.137 (0.095)	-0.829*** (0.057)	0.023 (0.025)	-0.012 (0.059)
	5	-0.355*** (0.089)	0.052* (0.031)	0.244*** (0.058)	0.015 (0.033)	-0.961*** (0.040)	-0.195*** (0.033)	-0.172* (0.089)	0.098*** (0.028)	0.017 (0.110)	0.112** (0.052)	-0.890*** (0.109)	0.000 (0.055)
	6	0.265*** (0.070)	0.111 (0.068)	0.235*** (0.066)	-0.061 (0.038)	-0.182*** (0.026)	-1.443*** (0.075)	-0.148 (0.156)	0.391*** (0.065)	0.137 (0.385)	-0.036 (0.171)	-0.120* (0.071)	-1.493*** (0.256)
Quintile 2	1	-0.978*** (0.011)	0.003 (0.007)	0.012* (0.006)	0.010*** (0.004)	-0.016*** (0.005)	0.047*** (0.010)	-1.071*** (0.064)	0.026* (0.015)	0.435*** (0.082)	0.036 (0.046)	-0.093* (0.049)	-0.051 (0.064)
	2	-0.029* (0.016)	-0.993*** (0.031)	-0.100*** (0.019)	0.049*** (0.011)	0.002 (0.009)	0.043** (0.020)	0.062*** (0.024)	-1.317*** (0.030)	0.067 (0.071)	0.099** (0.038)	0.111*** (0.024)	0.266*** (0.040)
	3	0.023 (0.020)	-0.145*** (0.025)	-1.087*** (0.067)	0.030 (0.034)	0.081*** (0.019)	0.112*** (0.028)	0.189*** (0.042)	-0.020 (0.023)	-0.955*** (0.129)	-0.075 (0.057)	0.015 (0.032)	0.075 (0.077)
	4	0.074*** (0.011)	0.052*** (0.010)	0.032 (0.024)	-1.064*** (0.013)	0.004 (0.007)	-0.001 (0.012)	0.009 (0.042)	0.035 (0.024)	-0.138 (0.110)	-0.808*** (0.066)	0.033 (0.029)	-0.011 (0.068)
	5	-0.207*** (0.055)	0.036* (0.019)	0.158*** (0.036)	0.012 (0.021)	-0.975*** (0.025)	-0.115*** (0.021)	-0.130* (0.067)	0.076*** (0.021)	0.060 (0.083)	0.095** (0.040)	-0.906*** (0.082)	0.008 (0.043)
	6	0.238*** (0.063)	0.104 (0.065)	0.223*** (0.063)	-0.059 (0.036)	-0.180*** (0.026)	-1.424*** (0.072)	-0.149 (0.139)	0.349*** (0.058)	0.171 (0.341)	-0.030 (0.152)	-0.098 (0.064)	-1.435*** (0.228)

(continued)

Quintile 3	1	-0.976***	0.002	0.013**	0.010***	-0.015***	0.046***	-1.075***	0.024	0.455***	0.038	-0.090*	-0.053
		(0.011)	(0.007)	(0.006)	(0.004)	(0.005)	(0.009)	(0.067)	(0.015)	(0.085)	(0.048)	(0.052)	(0.067)
	2	-0.044**	-0.991***	-0.138***	0.066***	0.005	0.056**	0.081**	-1.542***	0.049	0.141**	0.183***	0.440***
		(0.021)	(0.042)	(0.026)	(0.015)	(0.012)	(0.027)	(0.039)	(0.051)	(0.118)	(0.064)	(0.040)	(0.067)
	3	0.023	-0.127***	-1.075***	0.026	0.069***	0.098***	0.195***	-0.023	-0.952***	-0.077	0.023	0.079
		(0.017)	(0.022)	(0.058)	(0.030)	(0.017)	(0.025)	(0.043)	(0.023)	(0.134)	(0.059)	(0.033)	(0.080)
	4	0.082***	0.055***	0.035	-1.070***	0.005	-0.001	0.009	0.033	-0.133	-0.806***	0.041	-0.010
		(0.012)	(0.011)	(0.026)	(0.014)	(0.008)	(0.013)	(0.042)	(0.024)	(0.110)	(0.067)	(0.030)	(0.069)
	5	-0.165***	0.030*	0.135***	0.011	-0.979***	-0.093***	-0.098*	0.061***	0.074	0.089***	-0.910***	0.012
		(0.046)	(0.016)	(0.031)	(0.017)	(0.021)	(0.017)	(0.055)	(0.017)	(0.068)	(0.034)	(0.068)	(0.036)
	6	0.231***	0.102	0.221***	-0.059	-0.180***	-1.420***	-0.144	0.336***	0.176	-0.025	-0.085	-1.421***
		(0.061)	(0.064)	(0.063)	(0.036)	(0.026)	(0.071)	(0.135)	(0.056)	(0.331)	(0.148)	(0.062)	(0.222)
Quintile 4	1	-0.976***	0.003	0.015**	0.012***	-0.017***	0.053***	-1.110***	0.029	0.546***	0.034	-0.104	-0.066
		(0.011)	(0.008)	(0.007)	(0.004)	(0.006)	(0.011)	(0.084)	(0.019)	(0.106)	(0.059)	(0.064)	(0.084)
	2	-0.037**	-0.992***	-0.119***	0.059***	0.003	0.052**	0.078*	-1.559***	0.051	0.143**	0.202***	0.458***
		(0.019)	(0.037)	(0.023)	(0.013)	(0.011)	(0.024)	(0.040)	(0.053)	(0.121)	(0.066)	(0.041)	(0.069)
	3	0.021	-0.115***	-1.066***	0.025	0.061***	0.091***	0.198***	-0.025	-0.949***	-0.082	0.039	0.088
		(0.016)	(0.020)	(0.053)	(0.027)	(0.015)	(0.022)	(0.045)	(0.024)	(0.140)	(0.062)	(0.035)	(0.084)
	4	0.067***	0.042***	0.030	-1.049***	0.003	0.005	0.002	0.035	-0.144	-0.794***	0.061*	-0.005
		(0.010)	(0.008)	(0.019)	(0.010)	(0.006)	(0.010)	(0.045)	(0.026)	(0.118)	(0.071)	(0.032)	(0.073)
	5	-0.138***	0.027**	0.120***	0.012	-0.982***	-0.076***	-0.066	0.045***	0.089*	0.077***	-0.907***	0.021
		(0.039)	(0.014)	(0.026)	(0.015)	(0.018)	(0.015)	(0.041)	(0.013)	(0.051)	(0.026)	(0.050)	(0.028)
	6	0.187***	0.081	0.180***	-0.049*	-0.152***	-1.343***	-0.121	0.272***	0.168	-0.015	-0.044	-1.333***
		(0.049)	(0.053)	(0.052)	(0.030)	(0.021)	(0.058)	(0.109)	(0.045)	(0.268)	(0.120)	(0.052)	(0.180)
Quintile 5	1	-0.975***	0.003	0.018**	0.014***	-0.019***	0.064***	-1.157***	0.033	0.691***	0.022	-0.113	-0.075
		(0.012)	(0.009)	(0.009)	(0.005)	(0.007)	(0.013)	(0.108)	(0.025)	(0.136)	(0.075)	(0.084)	(0.108)
	2	-0.047**	-0.991***	-0.138***	0.070***	0.006	0.062**	0.093*	-1.781***	0.043	0.175*	0.294***	0.644***
		(0.021)	(0.043)	(0.026)	(0.015)	(0.013)	(0.028)	(0.055)	(0.073)	(0.167)	(0.091)	(0.057)	(0.096)
	3	0.018	-0.088***	-1.047***	0.019	0.044***	0.072***	0.204***	-0.027	-0.936***	-0.096	0.072*	0.109
		(0.012)	(0.015)	(0.040)	(0.020)	(0.012)	(0.017)	(0.047)	(0.026)	(0.147)	(0.065)	(0.038)	(0.088)
	4	0.064***	0.040***	0.031*	-1.044***	0.004	0.009	-0.009	0.050	-0.241	-0.721***	0.114**	0.008
		(0.009)	(0.008)	(0.018)	(0.010)	(0.005)	(0.010)	(0.066)	(0.038)	(0.174)	(0.106)	(0.045)	(0.108)
	5	-0.075***	0.019**	0.081***	0.010	-0.988***	-0.037***	-0.046	0.033***	0.117***	0.061***	-0.878***	0.045*
		(0.024)	(0.008)	(0.017)	(0.010)	(0.012)	(0.009)	(0.031)	(0.010)	(0.041)	(0.021)	(0.039)	(0.024)
	6	0.141***	0.059	0.138***	-0.038*	-0.120***	-1.262***	-0.084	0.189***	0.165	-0.012	0.020	-1.207***
		(0.037)	(0.041)	(0.040)	(0.023)	(0.017)	(0.045)	(0.076)	(0.032)	(0.188)	(0.083)	(0.040)	(0.125)

Table 9. Third-stage cross-price elasticities, Nigeria

		Rural						Urban					
		Subgroups						Subgroups					
		1	2	3	4	5	6	1	2	3	4	5	6
All	1	-1.081*** (0.042)	0.169*** (0.026)	-0.422*** (0.051)	0.029 (0.029)	-0.021 (0.028)	0.604*** (0.037)	-1.149*** (0.085)	0.357*** (0.117)	-0.287** (0.134)	-0.056 (0.075)	-0.223*** (0.086)	0.363*** (0.095)
	2	0.134*** (0.021)	-1.072*** (0.008)	0.243*** (0.051)	0.131*** (0.028)	-0.097*** (0.031)	-0.086** (0.043)	0.142*** (0.049)	-1.093*** (0.081)	0.183** (0.093)	-0.006 (0.052)	0.020 (0.054)	-0.026 (0.072)
	3	-0.315*** (0.034)	0.183*** (0.041)	-0.866*** (0.061)	0.077** (0.032)	0.067** (0.030)	0.298*** (0.051)	-0.029 (0.018)	-0.003 (0.030)	-0.935*** (0.078)	-0.006 (0.023)	0.057** (0.029)	-0.080 (0.064)
	4	0.034 (0.034)	0.197*** (0.040)	0.150*** (0.057)	-1.091*** (0.039)	0.143*** (0.037)	-0.144** (0.057)	-0.023 (0.035)	0.004 (0.059)	-0.206** (0.084)	-0.993*** (0.047)	0.208*** (0.048)	-0.069 (0.068)
	5	-0.054 (0.068)	-0.279*** (0.088)	0.309*** (0.110)	0.301*** (0.075)	-0.673*** (0.068)	-0.087 (0.085)	-0.097*** (0.033)	-0.012 (0.049)	0.306*** (0.082)	0.156*** (0.038)	-1.018*** (0.063)	-0.112** (0.057)
	6	0.258*** (0.018)	-0.091*** (0.025)	0.239*** (0.036)	-0.086*** (0.023)	-0.016 (0.017)	-0.940*** (0.037)	0.042*** (0.013)	-0.001 (0.023)	-0.086 (0.061)	-0.047** (0.018)	-0.010 (0.021)	-0.799*** (0.065)
Quintile 1	1	-1.059*** (0.036)	0.169*** (0.024)	-0.444*** (0.048)	0.032 (0.025)	-0.048* (0.026)	0.489*** (0.033)	-1.084*** (0.048)	0.203*** (0.066)	-0.120 (0.078)	-0.031 (0.042)	-0.141*** (0.049)	0.192*** (0.056)
	2	0.120*** (0.017)	-1.030*** (0.006)	0.125*** (0.044)	0.112*** (0.022)	-0.101*** (0.025)	-0.093*** (0.034)	0.112*** (0.038)	-1.067*** (0.061)	0.188*** (0.070)	0.001 (0.040)	0.010 (0.041)	-0.026 (0.056)
	3	-0.385*** (0.043)	0.266*** (0.051)	-0.897*** (0.079)	0.117*** (0.041)	0.078** (0.039)	0.339*** (0.065)	-0.049** (0.019)	-0.020 (0.033)	-0.947*** (0.081)	-0.025 (0.025)	-0.010 (0.031)	-0.169** (0.069)
	4	0.045* (0.027)	0.183*** (0.032)	0.062 (0.047)	-1.060*** (0.031)	0.092*** (0.030)	-0.136*** (0.046)	-0.017 (0.024)	0.001 (0.040)	-0.101* (0.056)	-0.996*** (0.032)	0.117*** (0.032)	-0.072 (0.048)
	5	-0.117 (0.134)	-0.568*** (0.175)	0.463** (0.220)	0.584*** (0.149)	-0.386*** (0.135)	-0.314* (0.166)	-0.149*** (0.052)	-0.018 (0.077)	0.528*** (0.131)	0.253*** (0.061)	-1.048*** (0.099)	-0.207** (0.084)
	6	0.323*** (0.022)	-0.101*** (0.031)	0.192*** (0.047)	-0.105*** (0.028)	-0.052** (0.022)	-1.003*** (0.046)	0.051*** (0.013)	0.002 (0.025)	-0.039 (0.064)	-0.043** (0.020)	-0.021 (0.021)	-0.800*** (0.066)
Quintile 2	1	-1.081*** (0.044)	0.187*** (0.028)	-0.519*** (0.058)	0.034 (0.030)	-0.053* (0.031)	0.586*** (0.039)	-1.096*** (0.055)	0.231*** (0.076)	-0.137 (0.089)	-0.036 (0.048)	-0.160*** (0.056)	0.224*** (0.065)
	2	0.128*** (0.019)	-1.047*** (0.007)	0.157*** (0.050)	0.125*** (0.025)	-0.111*** (0.028)	-0.098** (0.039)	0.144*** (0.049)	-1.091*** (0.080)	0.229** (0.090)	-0.002 (0.052)	0.011 (0.053)	-0.034 (0.071)
	3	-0.319*** (0.036)	0.233*** (0.043)	-0.878*** (0.067)	0.110*** (0.035)	0.078** (0.033)	0.322*** (0.055)	-0.043** (0.017)	-0.015 (0.029)	-0.940*** (0.075)	-0.021 (0.022)	-0.014 (0.029)	-0.154** (0.064)
	4	0.041 (0.029)	0.185*** (0.033)	0.081 (0.050)	-1.063*** (0.032)	0.101*** (0.032)	-0.127*** (0.048)	-0.026 (0.038)	0.001 (0.064)	-0.176** (0.087)	-0.993*** (0.051)	0.192*** (0.052)	-0.112 (0.072)
	5	-0.064 (0.087)	-0.350*** (0.114)	0.340** (0.144)	0.396*** (0.097)	-0.590*** (0.088)	-0.157 (0.108)	-0.130*** (0.046)	-0.017 (0.067)	0.467*** (0.114)	0.221*** (0.053)	-1.038*** (0.087)	-0.171** (0.075)
	6	0.308*** (0.021)	-0.100*** (0.029)	0.202*** (0.046)	-0.099*** (0.027)	-0.046** (0.022)	-0.983*** (0.044)	0.047*** (0.012)	0.000 (0.023)	-0.027 (0.060)	-0.041** (0.018)	-0.017 (0.020)	-0.806*** (0.064)

(continued)

Quintile 3	1	-1.080***	0.171***	-0.489***	0.027	-0.048	0.592***	-1.161***	0.383***	-0.256*	-0.059	-0.264***	0.367***
		(0.042)	(0.027)	(0.056)	(0.029)	(0.030)	(0.038)	(0.092)	(0.126)	(0.146)	(0.081)	(0.093)	(0.102)
	2	0.141***	-1.073***	0.184***	0.134***	-0.126***	-0.106**	0.142***	-1.091***	0.232***	-0.002	0.014	-0.030
		(0.022)	(0.008)	(0.058)	(0.029)	(0.033)	(0.045)	(0.048)	(0.079)	(0.089)	(0.051)	(0.053)	(0.071)
	3	-0.301***	0.212***	-0.870***	0.100***	0.080***	0.330***	-0.043**	-0.013	-0.936***	-0.018	-0.015	-0.152**
		(0.034)	(0.040)	(0.062)	(0.032)	(0.031)	(0.051)	(0.017)	(0.029)	(0.075)	(0.022)	(0.030)	(0.065)
	4	0.040	0.198***	0.095	-1.087***	0.121***	-0.145**	-0.026	0.001	-0.169*	-0.992***	0.194***	-0.107
		(0.034)	(0.039)	(0.059)	(0.038)	(0.037)	(0.057)	(0.038)	(0.064)	(0.087)	(0.051)	(0.052)	(0.073)
	5	-0.053	-0.301***	0.311**	0.341***	-0.642***	-0.103	-0.103***	-0.013	0.394***	0.178***	-1.024***	-0.127**
		(0.075)	(0.098)	(0.124)	(0.083)	(0.076)	(0.093)	(0.037)	(0.054)	(0.093)	(0.042)	(0.070)	(0.062)
	6	0.269***	-0.091***	0.191***	-0.088***	-0.037*	-0.951***	0.047***	-0.001	-0.021	-0.042**	-0.014	-0.800***
		(0.018)	(0.026)	(0.041)	(0.024)	(0.019)	(0.038)	(0.012)	(0.023)	(0.061)	(0.018)	(0.021)	(0.065)
Quintile 4	1	-1.079***	0.163***	-0.460***	0.021	-0.044	0.601***	-1.311***	0.736***	-0.541*	-0.115	-0.512***	0.699***
		(0.041)	(0.026)	(0.055)	(0.028)	(0.029)	(0.037)	(0.178)	(0.244)	(0.278)	(0.156)	(0.180)	(0.192)
	2	0.149***	-1.087***	0.214***	0.135***	-0.133***	-0.103**	0.188***	-1.123***	0.292**	-0.004	0.015	-0.046
		(0.024)	(0.008)	(0.062)	(0.032)	(0.035)	(0.048)	(0.064)	(0.105)	(0.118)	(0.068)	(0.070)	(0.093)
	3	-0.269***	0.189***	-0.855***	0.088***	0.080***	0.329***	-0.043**	-0.012	-0.935***	-0.017	-0.016	-0.150**
		(0.030)	(0.036)	(0.056)	(0.029)	(0.028)	(0.046)	(0.018)	(0.030)	(0.077)	(0.022)	(0.031)	(0.067)
	4	0.041	0.233***	0.122*	-1.122***	0.153***	-0.194***	-0.037	0.000	-0.257**	-0.989***	0.278***	-0.150
		(0.042)	(0.049)	(0.073)	(0.048)	(0.046)	(0.071)	(0.054)	(0.091)	(0.122)	(0.073)	(0.073)	(0.101)
	5	-0.045	-0.270***	0.303***	0.305***	-0.673***	-0.064	-0.095***	-0.013	0.376***	0.163***	-1.018***	-0.110*
		(0.067)	(0.088)	(0.110)	(0.074)	(0.068)	(0.083)	(0.034)	(0.050)	(0.087)	(0.039)	(0.065)	(0.058)
	6	0.260***	-0.092***	0.204***	-0.090***	-0.032*	-0.933***	0.044***	-0.002	-0.011	-0.040**	-0.009	-0.803***
		(0.018)	(0.025)	(0.040)	(0.023)	(0.019)	(0.037)	(0.012)	(0.022)	(0.059)	(0.017)	(0.021)	(0.063)
Quintile 5	1	-1.118***	0.174***	-0.568***	0.016	-0.041	0.767***	-1.478***	1.131***	-0.851**	-0.175	-0.780***	1.070***
		(0.051)	(0.032)	(0.067)	(0.035)	(0.036)	(0.046)	(0.274)	(0.375)	(0.427)	(0.240)	(0.277)	(0.293)
	2	0.197***	-1.171***	0.306***	0.191***	-0.191***	-0.168**	0.313***	-1.210***	0.457**	-0.009	0.019	-0.100
		(0.037)	(0.013)	(0.093)	(0.048)	(0.054)	(0.074)	(0.108)	(0.177)	(0.197)	(0.114)	(0.118)	(0.154)
	3	-0.284***	0.161***	-0.843***	0.077***	0.095***	0.374***	-0.042**	-0.010	-0.934***	-0.014	-0.010	-0.154**
		(0.030)	(0.036)	(0.055)	(0.029)	(0.027)	(0.045)	(0.019)	(0.031)	(0.083)	(0.023)	(0.036)	(0.072)
	4	0.026	0.238***	0.144*	-1.148***	0.187***	-0.182**	-0.028	0.000	-0.171*	-0.991***	0.218***	-0.101
		(0.048)	(0.055)	(0.082)	(0.055)	(0.053)	(0.080)	(0.041)	(0.068)	(0.094)	(0.055)	(0.058)	(0.079)
	5	-0.039	-0.203***	0.257***	0.221***	-0.744***	0.042	-0.065***	-0.009	0.300***	0.114***	-0.996***	-0.057
		(0.048)	(0.063)	(0.080)	(0.054)	(0.049)	(0.060)	(0.023)	(0.034)	(0.064)	(0.027)	(0.046)	(0.045)
	6	0.210***	-0.092***	0.198***	-0.080***	-0.013	-0.872***	0.045***	-0.003	-0.004	-0.043**	-0.001	-0.786***
		(0.015)	(0.021)	(0.034)	(0.019)	(0.017)	(0.032)	(0.013)	(0.023)	(0.063)	(0.019)	(0.024)	(0.067)

Appendix 1. Test of demographic variables

		Niger			Nigeria			Niger vs. Nigeria		
		Rural all vs. urban all	Rural quintiles	Urban quintiles	Rural all vs. urban all	Rural quintiles	Urban quintiles	Rural	Urban	All
hh size		1.762* (0.078)	63.53*** (0.000)	34.921*** (0.000)	7.865*** (0.000)	118.132*** (0.000)	45.813*** (0.000)	1.147 (0.252)	5.861*** (0.000)	5.658*** (0.000)
# of children under 5		9.14*** (0.000)	48.724*** (0.000)	28.585*** (0.000)	6.361*** (0.000)	66.127*** (0.000)	25.26*** (0.000)	22.624*** (0.000)	13.496*** (0.000)	29.519*** (0.000)
# of children between 6 and 15		1.367 (0.172)	49.788*** (0.000)	41.478*** (0.000)	9.539*** (0.000)	105.441*** (0.000)	41.902*** (0.000)	1.416 (0.157)	8.078*** (0.000)	7.062*** (0.000)
# of adults between 16 and 59		-6.132*** (0.000)	11.114*** (0.000)	1.139 (0.337)	1.961** (0.050)	20.703*** (0.000)	5.692*** (0.000)	-9.272*** (0.000)	2.112** (0.035)	-7.53*** (0.000)
# of seniors over 60		2.782*** (0.005)	0.899 (0.464)	8.202*** (0.000)	3.307*** (0.001)	2.913** (0.020)	1.358 (0.246)	-10.407*** (0.000)	-6.977*** (0.000)	-11.381*** (0.000)
% hh headed by female		-4.619*** (0.000)	0.678 (0.607)	1.326 (0.258)	-2.638*** (0.008)	19.521*** (0.000)	0.114 (0.978)	-5.808*** (0.000)	-1.868* (0.062)	-7.475*** (0.000)
Education of hh head (%)	primary & =	0.086 (0.931)	1.479 (0.206)	12.402*** (0.000)	6.342*** (0.000)	3.523*** (0.007)	8.399*** (0.000)	5.852*** (0.000)	10.799*** (0.000)	11.626*** (0.000)
	secondary & +	-15.187*** (0.000)	5.471*** (0.000)	49.296*** (0.000)	-15.471*** (0.000)	38.664*** (0.000)	27.327*** (0.000)	-22.045*** (0.000)	-14.41*** (0.000)	-31.876*** (0.000)
Education of female hh head or spouse (%)	primary & =	-8.066*** (0.000)	4.099*** (0.003)	6.67*** (0.000)	4.884*** (0.000)	1.945 (0.100)	4.64*** (0.001)	-4.804*** (0.000)	10.912*** (0.000)	0.389 (0.697)
	secondary & +	-14.152*** (0.000)	5.464*** (0.000)	64.649*** (0.000)	-16.051*** (0.000)	50.039*** (0.000)	28.518*** (0.000)	-20.966*** (0.000)	-15.858*** (0.000)	-31.548*** (0.000)
Age of hh head (yr)		-2.805*** (0.005)	4.861*** (0.001)	15.518*** (0.000)	1.456 (0.145)	2.606** (0.034)	4.136*** (0.002)	-19.869*** (0.000)	-10.666*** (0.000)	-23.111*** (0.000)
Age of female hh head or spouse (yr)		-3.792*** (0.000)	3.623*** (0.006)	8.989*** (0.000)	-2.801*** (0.005)	15.618*** (0.000)	0.944 (0.437)	-20.287*** (0.000)	-13.681*** (0.000)	-26.032*** (0.000)

"Rural all vs. urban all": t-test between rural and urban households; t-test statistics and p-values are presented.
"Rural quintiles" and "Urban quintiles": ANOVA among five quintiles; F-test statistics and p-values are presented.
"Niger vs. Nigeria": "Rural" is t-test between rural Niger and rural Nigeria; "Urban" is t-test between urban Niger and urban Nigeria; "All" is t-test between Niger and Nigeria.
"***": p-value<0.01; "**": p-value<0.05; "*": p-value<0.1.

Appendix 2. Test of budget shares

			Niger			Nigeria			Niger vs. Nigeria		
			Rural all vs. urban all	Rural quintiles	Urban quintiles	Rural all vs. urban all	Rural quintiles	Urban quintiles	Rural	Urban	All
Stage1	% of food in total exp.		34.899*** (0.000)	19.407*** (0.000)	127.551*** (0.000)	19.156*** (0.000)	26.887*** (0.000)	19.865*** (0.000)	-19.798*** (0.000)	-25.631*** (0.000)	-16.964*** (0.000)
	% of FAH in food exp.		3.668*** (0.000)	2.365* (0.051)	1.31 (0.264)	12.023*** (0.000)	17.655*** (0.000)	14.454*** (0.000)	6.337*** (0.000)	14.968*** (0.000)	17.504*** (0.000)
	% of FAH in total exp.		32.893*** (0.000)	21.74*** (0.000)	93.114*** (0.000)	23.798*** (0.000)	44.084*** (0.000)	40.221*** (0.000)	-12.536*** (0.000)	-11.727*** (0.000)	-4.249*** (0.000)
Stage2	% each group in FAH	Staple food	26.121*** (0.000)	38.1*** (0.000)	138.448*** (0.000)	4.88*** (0.000)	55.426*** (0.000)	24.782*** (0.000)	33.33*** (0.000)	1.497 (0.135)	35.122*** (0.000)
		Animal products	-21.956*** (0.000)	43.304*** (0.000)	95.934*** (0.000)	-5.685*** (0.000)	72.895*** (0.000)	18.2*** (0.000)	-16.889*** (0.000)	9.156*** (0.000)	-15.332*** (0.000)
		Vegetables & fruits	-17.625*** (0.000)	9.654*** (0.000)	13.698*** (0.000)	0.172 (0.863)	3.284** (0.011)	2.233* (0.063)	-24.476*** (0.000)	-3.54*** (0.000)	-25.763*** (0.000)
		Legumes, nuts, & seeds	17.262*** (0.000)	1.071 (0.369)	16.144*** (0.000)	8.813*** (0.000)	4.221*** (0.002)	2.325* (0.055)	-25.558*** (0.000)	-26.391*** (0.000)	-30.737*** (0.000)
		Oil, fat, sugar, & other	-7.483*** (0.000)	0.709 (0.585)	12.126*** (0.000)	2.655*** (0.008)	2.127* (0.075)	1.216 (0.302)	4.78*** (0.000)	11.324*** (0.000)	9.671*** (0.000)
		Other FAH	-3.039*** (0.002)	2.87** (0.022)	6.937*** (0.000)	-10.729*** (0.000)	24.242*** (0.000)	20.291*** (0.000)	7.534*** (0.000)	-6.587*** (0.000)	-1.384 (0.166)
Stage3	% each subgroup in staple food	Millet	50.101*** (0.000)	69.259*** (0.000)	46.953*** (0.000)	20.726*** (0.000)	58.884*** (0.000)	14.996*** (0.000)	94.059*** (0.000)	37.176*** (0.000)	98.175*** (0.000)
		Sorghum	20.68*** (0.000)	2.573** (0.036)	12.509*** (0.000)	25.159*** (0.000)	130.792*** (0.000)	18.982*** (0.000)	-4.658*** (0.000)	-1.562 (0.118)	1.995** (0.046)
		Rice	-38.555*** (0.000)	30.219*** (0.000)	8.493*** (0.000)	-15.775*** (0.000)	27.54*** (0.000)	2.433** (0.046)	-43.83*** (0.000)	-6.334*** (0.000)	-47.134*** (0.000)
		Corn	-6.872*** (0.000)	4.073*** (0.003)	33.588*** (0.000)	14.233*** (0.000)	44.513*** (0.000)	9.49*** (0.000)	7.232*** (0.000)	29.344*** (0.000)	18.939*** (0.000)
		Other cereals	-22.792*** (0.000)	38.257*** (0.000)	82.926*** (0.000)	-15.029*** (0.000)	64.655*** (0.000)	19.329*** (0.000)	6.755*** (0.000)	13.238*** (0.000)	3.63*** (0.000)
		Tubers and roots	-13.327*** (0.000)	11.719*** (0.000)	29.518*** (0.000)	-3.268*** (0.001)	45.062*** (0.000)	1.026 (0.393)	-58.541*** (0.000)	-50.71*** (0.000)	-78.994*** (0.000)