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Modelling household demand for sorghum in the Northwestern Nigeria

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Abstract

This work aimed at modelling households demand for sorghum in the Northwestern Nigeria. A multi-stage sampling design was used to select 200 households consuming sorghum. Primary data of the cross-sectional sources were collected by well-organized questionnaire. The data were analyzed using descriptive statistics and Linearized Almost Ideal Demand System (LA/AIDS) model. The result shows that the average age of the respondents is 45 years. Approximately, 87% of respondents are male and 89% are married. The households have an average monthly income of 66.93 US Dollars. The own-price sorghum elasticity is -0.492. This represents that, for every one-unit increase in sorghum price, there is a resultant decrease in quantity by 0.492. This indicates inelastic sorghum demand. Sorghum is identified as a normal good, exhibiting an income elasticity of 0.898. Findings from the study showed that millet and maize can substitute sorghum, although at varying level. Additionally, socio-economic characteristics such as marital status and, total household expenditure on food, unit price of sorghum, total income of households, total expenditures of maize, sorghum and millet significantly influence the demand of sorghum. Others characteristics such as age, gender, experience and education do not have significant effect on demand. Well-structured policies should be implemented to increase household income levels and encourage sorghum production in Nigeria.

Keywords: demand modelling, LA-AIDS model, sorghum consumption, household demand, consumer behaviour

INTRODUCTION

Globally, sorghum (*Sorghum bicolor*) is one of the most used cereals crops. Sorghum serves as staple food for millions of people not only in the semi-arid regions of the world but also in the tropical regions (FAO, 2021). Sorghum is a widely planted staple crop in Asia and Africa because it can withstand drought and can be cultivated at varying agro-climatic conditions (ICRISAT, 2020). Sorghum is also among the highly consumed cereal crops in Nigeria. It has a significant role in livestock feed production and processing, food security and

industrial applications (USDA, 2022). Sorghum is a key ingredient for feed and breweries (FAO, 2015). The sorghum production in Nigeria in 2021 and 2022 reached approximately 6725500 tons and 6806370 tons, respectively (FAO, 2024). The area for sorghum in Nigeria in 2021 and 2022 approximately 5930900 ha and 5700000 ha, respectively (FAO, 2024). Sorghum output in sub-Saharan Africa is characterized as traditional, subsistence and small-scale with low-yield (Omonona et al., 2019). Nigeria is the largest producer of sorghum in West Africa, accounting for approximately 71% of the total output in the

sub-region (Ogbonna, 2011). The persistent rise in food prices, particularly sorghum, has been identified as a key factor contributing to household food demand instability in Nigeria and other regions, driven by limited global food reserves and growing demand (Ben-Chendo et al. 2017). Consumption demand analysis is one of the most common topics in applied economics. Sorghum production and consumption are common in Nigeria, where it serves as a primary dietary ingredient for households (NBS, 2021). There are several socio-economic variables influencing the demand of sorghum which include household incomes, close substitutes, and prices elasticity (Kakuru et al., 2021). According to Vukadinovic et al. (2017), price elasticity is defined as the measure of the relative responsiveness of the demand of sorghum to prices changes. This is fundamental for understanding consumers' behavior and market stability. The demand for energy-supplying foods such as sorghum (with maize, millet as close substitutes) depends on commodity preference and product price (Ben-Chendo et al., 2017).

Significant variables which are vital in determining food consumption pattern by demonstrating whether sorghum is regarded as a luxury food or necessity are the income and expenditure elasticities (Elzaki et al., 2020). Close substitutes such as millet and maize may become alternatives to households possessing higher disposable income and may influence sorghum demand (Cheng & Larochelle, 2016). Furthermore, concepts such as cross-price elasticity determine the effect of close substitutes on sorghum consumption (Cheng & Larochelle, 2016; Yahaya et al., 2022).

Estimating food demand functions at household level is necessary and sufficient condition for income and price elasticities, since they are needed to formulate policies, engender investments and set priorities in the food sector (Ezedinma et al., 2006). The study employed the Linear Approximation–Almost Ideal Demand

System (LA-AIDS) model to estimate household demand for sorghum because it is simple to estimate, flexible, and provides an arbitrary first-order approximation to any demand system. It satisfies the axioms of choice exactly, has a functional form consistent with known household budget data, aggregates perfectly over consumers without invoking parallel linear Engel curves, largely avoids the need for non-linear estimation, and allows testing of homogeneity and symmetry restrictions through linear constraints on fixed parameters (Omodara et al., 2024). The findings are useful for agricultural policy development towards enhanced sorghum production and consumption in Nigeria (World Bank, 2022).

Objectives of the study

The aim of the research focused on modelling households demand for sorghum in the Northwestern Nigeria. Specifically, the objectives were: (i) to describe the socio-economic features of sorghum consuming households, (ii) to estimate the own price and cross-price elasticities of sorghum, (iii) to estimate the income and expenditure elasticities of sorghum, (iv) to model the factors affecting households demand for sorghum in the study area.

Hypotheses of the study

The research study was guided by the following null-hypotheses: (i) price elasticities of sorghum are not elastic; (ii) sorghum is not considered a necessary commodity; (iii) there is no influence of close substitute on sorghum consumption; (iv) socio-economic features of sorghum consuming households do not significantly influence the household demand for sorghum in the study area.

MATERIALS AND METHODS

This study was carried out in the northwestern region of Nigeria. The study selected Kano and Kaduna states because they

are predominantly known for sorghum farming in the region due to their favorable climate for the crop. A multi-stage sampling approach was utilized for several reasons, including cost reduction, time efficiency, flexibility, and increase reliability. The approach can be applied to large, geographically dispersed samples and enables the selection of a probability sample without requiring a complete list of respondents. It also facilitates more reliable estimation of population parameters, such as the mean. In this sampling design, a sample is drawn from the population by progressively selecting smaller and smaller units at each stage. In the first stage, two states were selected being known predominantly for sorghum farming in Nigeria. In the second stage, 2 local government areas were randomly selected in each state. In the third stage, 5 villages for each local government area were randomly selected making a total of 20 villages. In the fourth stage, a simple random sampling approach was employed, approximately 10 sorghum growers were selected from each village making a total of 200 sorghum producers. The sample frame of sorghum producers comprises of approximately 400 respondents. The total sample number includes of 100 sorghum producers selected from each of the states, respectively. Primary data of cross-sectional sources were utilized based on a well-planned questionnaire that was subjected to reliability and validity test. The questionnaire was validated by the team of experts and appropriate reliability test was carried out. The questionnaire was pre-tested on selected sorghum growers to evaluate the appropriateness of the design, clarity, and relevance of the questions. The appropriate modification was made on the pre-tested questionnaire in order to capture the relevant information required to achieve the objectives of the study, questions that proved vague or ambiguous, attracted additional corrections on the questionnaire to ensure its appropriateness, and reliability. The result of the pre-test was collated and subjected to reliability test using

Pearson product moment correlation analysis. The correlation coefficient of 0.94 (94%) shows that there was a strong degree of correlation between the tested variables. The Cronbach's alpha coefficient for variables was 0.894 (89.4%), suggesting that the variables included in the research instrument had relatively high internal consistency and are highly reliable. The sample number was estimated based on the formula of Yamane (1967) as follows:

$$n = \frac{N}{1+N(e^2)} = \frac{400}{1+400(0.05^2)} = 200 \quad (1)$$

Where: n = sample numbers,

N = total number of sorghum growers, $e = 5\%$

The data obtained were evaluated using descriptive statistics, and linearized almost ideal demand system (LA/AIDS).

Linearized Almost Ideal Demand System (LA/AIDS)

The LA/Almost Ideal Demand System (LA/AIDS) following Buse (1994), Taljaard *et al.* (2003), and Akinbode & Bamire (2015) was employed in estimating the expenditure share, respondent's price elasticity, cross elasticity and income elasticity for improved seed variety in the study area. The LA-AIDS can be written as:

$$w_i = \alpha_i + \sum_{j=1}^n \gamma_{ij} \ln P_j + \beta_i \ln \left(\frac{M}{P^*} \right) + \sum_{k=1}^m \lambda_k D_k + e_i \quad (2)$$

$$M = \sum_{i=1}^n (q \times p) \quad (3)$$

$$\ln P^* = \sum_{i=1}^n w_i^0 \ln P_i \quad (4)$$

Where:

w_i = budget (expenditure) share of the i th seed,
 n = number of improved seed varieties commonly used, M = total expenditure on improved maize seed in the study area,

P_i = price of i th improved seed,

P^* = Laspeyre Price Index,

q = quantity demanded for the i th good, α_i , γ_{ij} , λ_k , and β_i are parameters, e_i = disturbance term, and D_k = demographic attributes.

If the following restrictions are imposed on the Equation (1), it satisfies the adding-up, homogeneity and symmetry requirement for properties derived from standard demand theory:

$$\sum_i \alpha_i = 1; \sum_i \gamma_{ij} = 0; \sum_i \beta_i = 0; \sum_i \gamma_{ij} = 0; \text{ and } \gamma_{ij} = \gamma_{ji} \quad (5)$$

According to Koc & Alpay (2002), Akinbode & Bamire (2015), expenditure and price elasticity can be derived easily from the parameter estimates obtained in Equation (1) thus:

$$\eta_i = 1 + \left(\frac{\beta_i}{w_i} \right) \quad (6)$$

$$\varepsilon_{ii} = -1 + \left(\frac{\gamma_{ii}}{w_i} \right) - \beta_i \quad (7)$$

$$\varepsilon_{ij} = \left(\frac{\gamma_{ij}}{w_i} \right) - \frac{\beta_i w_i}{w_i} \quad (8)$$

Where: η_i = expenditure elasticity, w_i = budget share of good, ε_{ij} = own-price elasticity, and ε_{ij} represents the cross-price elasticity, in Marshallian terms (uncompensated).

Compensated (Hicksian) price elasticities e_{ij} can be derived by using η_i , ε_{ii} , and ε_{ij} by using the following relation:

$$e_{ij} = \varepsilon_{ij} + \eta_i \times w_i \quad (9)$$

This was used to determine the derived demand for new improved maize quality seeds in the study area.

RESULTS AND DISCUSSION

Socio-Economic Features of Sorghum Consuming Households

Averagely, the age of the respondents is 45 years, SD 13.08 (Table 1) which corresponds with the results of Ezech et al. (2018). Majority of the respondents – 87% are male, and 89% are married. This suggested that many people in study region practicing sorghum farming are adult male with family responsibilities.

The average level of education of respondents is 9 years, suggesting basic education which may significantly influence the adoption of modern farming techniques. Farmers in the region have an average of 8 years farming experience in sorghum cultivation. This suggested that the farmers in the region are moderately experienced. The households of the respondents of the study had an average monthly income of 66.93 US Dollars. This suggested that the farming households experienced a relatively low-income bracket, highlighting that the households are economically vulnerable and could significantly affect their livelihoods.

The household sizes are large with an average of 7 members per household. The dependency per household approximately 10 members. This indicates that there is a relatively high dependency ratio suggesting that sorghum production plays a relevant role in guaranteeing food security for these households.

Table 1. Socio-economic features of sorghum consuming households

Variables	Description of Variables	Mean	SD
Age	Age of the respondents (years)	45	13.08
Gender	1, if the farmers are male; 0, if female	0.87	0.40
Marital Status	1, if the farmers are married; 0, if otherwise	0.89	0.38
Education	Number of years of formal schooling	9	1.93
Experience	Number of years engaged in sorghum farming	8	1.62
Monthly Income	Amount of money (US Dollar)	66.93	12.01
Household Size	Number of people per household	7	2.36
Dependents	Number of people dependent on the household head	10	3.83

Source: Field Survey (2024), 1 USD = 1, 450 Naira

Marshallian price elasticities of sorghum

The elasticities for sorghum, maize, and millet lie between -0.442 and -0.492 (Table 2). The elasticities put forward indicate that the quantity demanded for maize, millet, and sorghum is sensitive to price changes. The own-price elasticity for cereals is inelastic and carries negative signs, as expected on a priori grounds. All the Marshallian cross-price elasticities carry positive signs, which conform to economic theory. Positive cross-price elasticities suggest that the two goods are substitutes, while negative cross-price elasticities indicate that the goods are complementary. Cross-price elasticity refers to the percentage change in the quantity demanded of one item resulting from a 1% change in the price of another good. The own-price sorghum elasticity is -0.492. This indicates that, for every one-unit increase in sorghum price, there is a resultant decrease in quantity demanded by 0.492. This implies that sorghum demand is inelastic and changes in price have a minimal resultant effect on the quantity demanded. This finding is in line with the publication of Vitale (2017) on the role of prices and demand on agricultural product.

The cross-price sorghum elasticity relative to maize is 0.078, suggesting a weak substitute relationship. This represents that, for every one-unit increase in maize price, there is a resultant increase in quantity demanded for sorghum by 0.078. The cross-price for sorghum relative to millet is 0.413. This implies that there is a stronger substitute relationship and for every one-unit increase in millet price, there is a

resultant increase in quantity demanded for sorghum by 0.413.

The own-price maize elasticity is -0.442. This suggests an inelasticity of maize demand. The cross-price maize elasticity relative to sorghum is 0.704. This represents a strong substitute relationship. It highlights that for every one-unit increase in sorghum price, there is a resultant increase in maize quantity demanded by 0.704. The cross-price maize elasticity relative to millet is 0.501 which also indicates a strong substitute relationship.

The own-price millet elasticity is -0.468. This indicates that millet demand is inelastic. The cross-price millet elasticity relative to sorghum is 0.769. This represents a very strong substitute relationship. The cross-price millet elasticity relative to maize is 0.068. This indicates a weak substitute relationship.

From the own-prices and cross-prices results on sorghum, maize and millet in the northwestern part of Nigeria, there is an inelastic demand. This implies that most of the household respondents are moderately insensitive to changes in prices for these staple foods. This result is in consonance with the finding of Daniel et al. (2022).

The cross-prices elasticity on commodity such as sorghum, millet and maize indicates that they are substitutes for each at varying levels. The strongest substitutes are sorghum and millet, followed by sorghum and maize. This result is important for understanding the effect of price fluctuations in commodities on consumption patterns and for developing effective policies on food security.

Table 2. Marshallian price elasticities of sorghum

S/N	Commodity	Sorghum	Maize	Millet
1	Sorghum	-0.492	0.078	0.413
2	Maize	0.704	-0.442	0.501
3	Millet	0.769	0.068	-0.468

Source: Data Analysis (2024), Values in Bold are Marshallian Own Price Elasticities, others are Cross-Price Elasticities.

Income elasticities of sorghum

The income elasticity of sorghum is estimated at 0.898. This indicates that for every 1% increase in household income, there is a resultant increase in quantity of sorghum demanded by 0.898%. This suggests that sorghum is a normal good or commodity in the northwestern parts of Nigeria. It implies that as the household income of rises, there is a corresponding increase in sorghum demand, although not at a proportional level. The elasticity value is close to 1, which means that sorghum is a necessary food commodity for households. The finding aligns with the results of Gierend & Orr (2015) and highlights that stable economy growth, as well as an increase in household income levels in the region, will raise the demand for sorghum, which in the long run has positive implications for agricultural production.

Modelling and determinants of household demand for sorghum

Table 3 below shows determinant of household demand for sorghum in the Northwestern Nigeria. Some variable

statistically indicated significant relationship with demand of sorghum. Total household expenditure appeared to be a very strong predictor having a statistically positive and significant influence (coefficient = 0.0283, $p < 0.001$). This result indicates that the increase in the total household expenditure on food by 1% would increase the share of sorghum demand by 2.83%, so it affects the demand for sorghum positively while keeping other variables constant. This supports the notion that sorghum is a normal good or commodity in this study.

Marital status showed a higher demand for sorghum (coefficient = 0.3298, $p < 0.001$). Marital status positively and significantly played a role in sorghum demand. This could be as a result of larger households and increased food needs associated solely to married individuals and their families. This agrees with the work of Udomkun et al. (2021) who reported that married individuals have different dietary habits, meal patterns, and food preferences compared to unmarried individuals due to factors such as family responsibilities, shared meals, and cultural norms.

Table 3. Determinants of household demand for sorghum

Variables	Coefficients	Standard Error	Z	P > z
Total household expenditure	0.0283***	0.00307	9.22	0.000
Age	-0.00353	0.00256	-1.38	0.192
Gender	-0.6521	0.5871	-1.11	0.286
Marital status	0.3298***	0.0725	4.54	0.000
Education	0.0247	0.0429	0.57	0.768
Experience	0.0050	0.0069	0.72	0.592
Household size	-0.003	0.0037	-0.81	0.468
Unit price of sorghum	-0.00068***	0.00042	-3.40	0.000
Unit price of maize	-0.0000437	0.0000898	-0.48	0.898
Unit price of millet	-0.000295	0.000827	-0.36	0.813
Total income of households	0.00329*	0.000166	1.98	0.081
Total expenditure of sorghum	-0.000478***	0.0000548	-8.71	0.000
Total expenditure of maize	-0.0003297***	0.00004522	-7.29	0.000
Total expenditure of millet	-0.0004225***	0.0000908	-4.65	0.000
Constant	0.8797***	0.2673	3.29	0.001

Significant Level: *10%, **5%, ***1%

Source: Field Survey (2024)

Unit of price for sorghum had a statistically significant and negative influence on demand (coefficient = -0.00068, $p < 0.001$). This study indicates that the increase in the unit price of sorghum by one-unit would decrease the share of sorghum demanded by 0.68, so it affects the demand for sorghum negatively, while keeping other variable constant. This satisfies the law of demand that states that as price of a commodity decreases the quantity demand for same commodity increases and vice versa. This result aligns with the findings of Zeynalova & Mammadli, (2020).

Total expenditure on sorghum, millet and maize has a significant and negative influence on demand of sorghum (maize coefficient = -0.0003297, $p < 0.001$), (sorghum coefficient = -0.000478, $p < 0.000$) and millet coefficient 0.00042225, $p < 0.000$).

Total household income affects the sorghum demand share positively, and the variable is statistically significant at the 10% level (coefficient = 0.00329, $p < 0.081$). The result implies that farm household heads who earn income from annual agricultural production could allocate a portion of that income to purchase sorghum produce. On the other hand, variables such as age, gender, experience, household size, and education do not have statistically significant effects on sorghum demand. This suggests that these factors do not influence the shaping of sorghum consumption and demand patterns in the region.

CONCLUSIONS

This study aimed at modelling household demand for sorghum in the northwestern parts of Nigeria. A multi-stage sampling design is used to select 200 sorghum producers. The conclusions are based on the following research null-hypotheses:

The price elasticity of sorghum is not elastic

This null hypothesis is rejected. The result shows that the own-price elasticity of sorghum

is -0.492, thereby implying that sorghum demand is inelastic.

The sorghum is not considered a necessary commodity

This null hypothesis is rejected. The income elasticity of sorghum is estimated at 0.898 and identifies it as a normal good or commodity. The closeness of the elasticity value to 1 further indicates that sorghum is a necessity and plays relevant role in food security.

There is no influence of close substitutes on sorghum consumption

This null hypothesis is rejected. Cross-price elasticity showed that millet and maize can be used as substitute for sorghum, although at varying levels.

The socio-economic features of sorghum consuming households do not significantly influence the household demand for sorghum in the study area.

This null hypothesis is rejected. Socio-economic characteristics such as marital status, total income of households, and total household expenditure on food, significantly and positively influence the sorghum demand, while the unit price of sorghum has significant negative influence on demand.

In terms of recommendations, households should be encouraged to actively engage in farming and sorghum production to ensure year-round availability of sorghum and other products. Price and income-generating policies that enhance the purchasing power of urban households for sorghum should be implemented. In addition, credit facilities should be provided to producers to finance sorghum farming and help reduce the price of the staple.

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