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Farmers' choice of varieties and demand for improved cassava stems in Nigeria

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ABSTRACT

In this study, we used a household level survey to assess choices of varieties and demand for improved cassava varieties. A multivariate probit model was used to examine the determinants of choice decisions of the farmers for different varieties preventing potential endogeneity and measurement error. A Linearized Almost Ideal Demand System (LA/AIDS) model was used to analyze the demand system for improved cassava varieties. The results of the (LA/AIDS) model indicated farmers were very price sensitive to changes in improved stem prices and incomes. We suggest that intervention program that will improve the purchasing power of the farmers should be targeted towards the smallholder cassava farmers to accelerate adoption of improved cassava varieties.

Keywords: Improved cassava, Varieties demand, Multivariate probit, Nigeria

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Introduction

Cassava is the most widely eaten staple food in Nigeria (Kolapo *et al.*, 2020a). About 177,948 million tonnes of cassava were produced in Africa (Otekunrin and Sawicka (2019). Consequently, Nigeria is regarded as the world's largest producer of cassava with about 20.4 percent of the world export in year 2017 (Otekunrin and Sawicka, 2019).

In 2002, the International Institute of Tropical Agriculture (IITA) in Nigeria raised concern about a new strain of the cassava mosaic disease in Africa. IITA rapidly developed varieties that were resistant to this virus, and these were introduced through a fast-track approach of releasing new varieties, and a massive approach of reaching out to farmers (HarvestPlus, 2010). This campaign has overall been successful. The improved varieties were not only resistant to the virus but also performed better than previous varieties, especially producing more than 40 percent higher yields without fertilizers. The most important traits of this new variety are: Mosaic virus resistance, Multiple pest resistance/tolerance, High and stable yields (minimum 11 t ha^{-1}, optimum 20–30 t ha^{-1}), and High dry matter content (minimum 24%, optimum >30%) (HarvestPlus, 2010). From 2006-2014, not less than twenty improved cassava varieties were leased giving an optimum yield to the farmers (Kolapo *et al.*, 2020b).

Even though the new improved cassava varieties were available, it was reported that larger proportion of the cassava producers still cultivate traditional cassava varieties, which are less resistant to drought and diseases (e.g., mosaic disease), have low productivity and low market value (Ilona *et al.*, 2017; Kolapo *et al.*, 2020a; Afolami *et al.*, 2015). The estimated market price for improved cassava varieties was found to be greater than that of tradition cassava, which means an increased income for the farmers. This price difference might be attributed to greater yield. The cassava market is expanding in Nigeria, which might be attributed to a rapid population growth rate, the multiple uses of cassava products and exports of about 20.4% of the world cassava (Otekunrin and Sawicka, 2019). Considering the promising demand forecast, it is important to understand the factors hindering farmers to use improved cassava varieties. Unfortunately, recent literature about this subject is limited.

According to Serapius *et al.* (2019), research carried out on factors hindering the adoption of new technology in developing countries can be grouped into three broad categories. These categories are: (i) factors related to the characteristics of farmers, (ii) factors related to the characteristics and relative performance of the technology, and (iii) communication of the new technologies. Individual adoption decisions depend on the choices of others in the same social groups. Since farmers anticipate that they will share information with others, they are expected to be more likely to adopt when they know many other adopters (Serapius *et al.*, 2019).

Despite the significance of improved cassava varieties in the livelihood of many farmers as one of cash and income generating crop in Nigeria, it is only recently that several studies have been done on its adoption. Moreover, recent studies have been made on the determinants of improved cassava adoption both in Nigeria and other countries (Afolami *et al.*, 2015; Kolapo *et al.*, 2020b; Olamide *et al.*, 2019; Ayinde *et al.*, 2017; Abdoulaye *et al.*, 2015; Ayinde and Adewumi, 2016; Etuk and Umoh, 2014).

However, there is no research that shows the nature of demand for improved cassava or choice of improved cassava varieties, which is very important to increase production and productivity in Nigeria. Thus, knowing farmers' responsiveness to market outcomes may assist in providing policy recommendations pertaining to stem supply based on farmers' stem expenditure patterns. Hence, this study attempted to fill in the gaps by identifying factors that determine the choice among improved cassava varieties, and analyzing the responsiveness of improved cassava stem demand to changes in price and income elasticity in Nigeria.

The study first analyzed the key factors influencing the adoption of improved cassava varieties. Secondly, it analyzed the demand for improved and recently released cassava varieties among farmers. Thirdly, it estimates the Marshallian and Hicksian own-price elasticity and expenditure elasticity for the improved cassava varieties.

Material and Methods

Data source, Data description and Econometric techniques

The data for this study were collected from randomly selected sample of the respondents using face-to-face interview or from published and unpublished sources. This study uses a household survey cross sectional data collected by the researcher and well-trained data enumerators in 2020. A multi-stage sampling procedure was used to select sampled areas from each Local Government Areas and households from each selected sampled areas. Following the NBS recommendation for a nationally representative data collection (NBSN, 2010), 10% of the LGAs in each of the selected States and 5% of the total sampled areas per LGA were randomly selected. Finally, from the households in each of the selected sampled areas, eight farming households were randomly selected which resulted in a sample size of 735 households. The data were collected using well-structured questionnaire, which was pre-tested before final enumeration. The survey questionnaire was designed to gather detailed information on socio-economic characteristics of households, input use and allocation, awareness of the improved cassava varieties, yield of improved cassava and adoption of improved cassava varieties. In addition, extensive village-level data were collected on the incidence of shocks, prices of key inputs, among others. The data for this study were collected electronically using the "ODK Collect" App. Secondary data on the variety names, traits, expected yields, and time of release of the improved cassava varieties was also collected.

Econometric model specification

We employed multivariate probit model to identify factors affecting choices of improved varieties. Seemingly, Unrelated Regression model was also employed to analyze Almost Ideal Stem Demand System for improved cassava stems.

Determinants of adoption and interaction: Multivariate probit model

Following Mesfin and Zemedu (2018), to identify the factors that influence the decision to adopt improved cassava varieties and to correct for selection bias resulting from zero expenditure, a selection model was required. The probit model was used because its likelihood function is well behaved as it gives consistent Maximum Likelihood Estimate (MLE) coefficients (ù) and standard error of the estimate(s) (Maddala, 1992; Mesfin and Zemedu (2018). The demand model requires data for all varieties and estimates adoption equations for those varieties using probit equation separately. However, the data for different varieties were collected from individual farmer at a given point in time. This may bring endogeneity within the data set, and decision on a particular variety choice may affect the probability of selecting another variety, which could be avoided by employing multivariate probit model. Following Cappellari and Jenkins (2003), Mesfin and Zemedu (2018), the multivariate probit model was structured as follows:

$$\gamma im^* = \beta m' Xim + \varepsilon im \quad (m=1, \ldots\ldots, M) \ldots\ldots\ldots(3)$$

$\gamma im^* = 1$ if $\gamma im^* > 0$ and 0 otherwise

Where, εim is error terms distributed as multivariate normal, each with a mean of zero, and variance-covariance matrix V, where V has value of 1 on the leading diagonal and correlations as off diagonal elements. The γim might represent outcomes for M different choices at the same point in time, for example, whether a farmer cultivates M varieties of crops. The Xim is a vector of explanatory variables and are unknown parameters to be estimated. The probability function of the probit model is usually the standard normal density, which provides predicted values within the range of 0–1.

The multivariate probit model was estimated by simulated maximum likelihood. The log-likelihood function for a sample of independent observations was given by an optional weight for the observations with multivariate normal distribution. The Inverse Mills Ratio (IMR) was computed.

Most demand models start with specification of an arbitrary direct or indirect utility function or cost functions (Mesfin and Zemedu, 2018). However, the AIDS starts from a specific class of preferences, which permit exact aggregation over consumers and are represented via the cost or expenditure function. This function defines the minimum expenditure necessary to attain a specific utility level at given prices (Mesfin and Zemedu, 2018). Denoting the expenditure function as for utility u and price vector p, our PIGLOG class can be defined as:

$$lnc(\mu, p) = \mu ln\beta(p) + (1 - \mu)\, ln\alpha(p) \quad (4)$$

Where $\alpha_i(p) = (\alpha_i ln\beta - \beta ln\, \alpha_i) / (ln\beta - ln\, \alpha)$ and $\beta_i(p) = \beta_i / (ln\, \beta - ln\alpha)$ for $\alpha_i = \partial\, ln\alpha / \partial\, lnp_i$ and $\beta_i = \partial\, ln\, \beta_i / \partial\, lnp_i$.

To ensure flexibility in the functional form, we ensured that the functional form has enough parameters so that at any single point, its derivatives can be set equal to its arbitrary cost functional form (Mesfin and Zemedu, 2018).

The improved cassava stem demand system estimated in this study involved ten stems with their respective prices and expenditures. The system estimated involved ten equations since the improved cassava stem varieties could grow in the region in Nigeria, all the aforementioned varieties should be considered to avoid bias.

$$X_j = \alpha_0 + \beta_{i1}lnPTME\text{-}419 + \beta_{i2}lnpNR93/0199 + \beta_{i3}lnpNR01/0004 + \beta_{i4}lnpTMS1961089A + \beta_{i5}lnpCR\text{-}41\text{-}10 + \beta_{i6}lnpNR03/0211 + \beta_{i7}lnpCR36\text{-}5 + \beta_{i8}lnpNR07/0220 + \beta_{i9}lnpTMS1070593 + \beta_{i10}lnpTMS105539 + \ldots + \delta_1 ln_{expend} + \mu_1 \quad (5)$$

$$W_{NR93/0199} = \alpha_0 + \beta_{i1}lnP\ TME\text{-}419 + \beta_{i2}lnpNR93/0199 + \beta_{i3}lnpNR01/0004 + \beta_{i4}lnpTMS1961089A + \beta_{i5}lnpCR\text{-}41\text{-}10 + \beta_{i6}lnpNR03/0211 + \beta_{i7}lnpCR36\text{-}5 + \beta_{i8}lnpNR07/0220 + \beta_{i9}lnpTMS1070593 + \beta_{i10}lnpTMS105539 + \ldots + \delta_2 ln_{expend} + \mu_2 \quad (6)$$

$$W_{NR01/0004} = \alpha_0 + \beta_{i1}lnP\ TME\text{-}419 + \beta_{i2}lnpNR93/0199 + \beta_{i3}lnpNR01/0004 + \beta_{i4}lnpTMS1961089A + \beta_{i5}lnpCR\text{-}41\text{-}10 + \beta_{i6}lnpNR03/0211 + \beta_{i7}lnpCR36\text{-}5 + \beta_{i8}lnpNR07/0220 + \beta_{i9}lnpTMS1070593 + \beta_{i10}lnpTMS105539 + \ldots + \delta_3 ln_{expend} + \mu_3 \quad (7)$$

$$W_{TMS1961089A} = \alpha_0 + \beta_{i1}lnP\ TME\text{-}419 + \beta_{i2}lnpNR93/0199 + \beta_{i3}lnpNR01/0004 + \beta_{i4}lnpTMS1961089A + \beta_{i5}lnpCR\text{-}41\text{-}10 + \beta_{i6}lnpNR03/0211 + \beta_{i7}lnpCR36\text{-}5 + \beta_{i8}lnpNR07/0220 + \beta_{i9}lnpTMS1070593 + \beta_{i10}lnpTMS105539 + \ldots + \delta_4 ln_{expend} + \mu_4 \quad (8)$$

$$W_{CR\text{-}41\text{-}10} = \alpha_0 + \beta_{i1}lnP\ TME\text{-}419 + \beta_{i2}lnpNR93/0199 + \beta_{i3}lnpNR01/0004 + \beta_{i4}lnpTMS1961089A + \beta_{i5}lnpCR\text{-}41\text{-}10 + \beta_{i6}lnpNR03/0211 + \beta_{i7}lnpCR36\text{-}5 + \beta_{i8}lnpNR07/0220 + \beta_{i9}lnpTMS1070593 + \beta_{i10}lnpTMS105539 + \ldots + \delta_5 ln_{expend} + \mu_5 \quad (9)$$

$$W_{NR03/0211} = \alpha_0 + \beta_{i1}lnP\ TME\text{-}419 + \beta_{i2}lnpNR93/0199 + \beta_{i3}lnpNR01/0004 + \beta_{i4}lnpTMS1961089A + \beta_{i5}lnpCR\text{-}41\text{-}10 + \beta_{i6}lnpNR03/0211 + \beta_{i7}lnpCR36\text{-}5 + \beta_{i8}lnpNR07/0220 + \beta_{i9}lnpTMS1070593 + \beta_{i10}lnpTMS105539 + \ldots + \delta_6 ln_{expend} + \mu_6 \quad (10)$$

$$W_{CR36\text{-}5} = \alpha_0 + \beta_{i1}lnP\ TME\text{-}419 + \beta_{i2}lnpNR93/0199 + \beta_{i3}lnpNR01/0004 + \beta_{i4}lnpTMS1961089A + \beta_{i5}lnpCR\text{-}41\text{-}10 + \beta_{i6}lnpNR03/0211 + \beta_{i7}lnpCR36\text{-}5 + \beta_{i8}lnpNR07/0220 + \beta_{i9}lnpTMS1070593 + \beta_{i10}lnpTMS105539 + \ldots + \delta_7 ln_{expend} + \mu_7 \quad (11)$$

$$W_{NR07/0220} = \alpha_0 + \beta_{i1}lnP\ TME\text{-}419 + \beta_{i2}lnpNR93/0199 + \beta_{i3}lnpNR01/0004 + \beta_{i4}lnpTMS1961089A + \beta_{i5}lnpCR\text{-}41\text{-}10 + \beta_{i6}lnpNR03/0211 + \beta_{i7}lnpCR36\text{-}5 + \beta_{i8}lnpNR07/0220 + \beta_{i9}lnpTMS1070593 + \beta_{i10}lnpTMS105539 + \ldots + \delta_8 ln_{expend} + \mu_8 \quad (12)$$

$$W_{TMS1070593} = \alpha_0 + \beta_{i1}lnPTME\text{-}419 + \beta_{i2}lnpNR93/0199 + \beta_{i3}lnpNR01/0004 + \beta_{i4}lnpTMS1961089A + \beta_{i5}lnpCR\text{-}41\text{-}10 + \beta_{i6}lnpNR03/0211 + \beta_{i7}lnpCR36\text{-}5 + \beta_{i8}lnpNR07/0220 + \beta_{i9}lnpTMS1070593 + \beta_{i10}lnpTMS105539 + \ldots + \delta_9 ln_{expend} + \mu_9 \quad (13)$$

$$W_{TMS105539} = \alpha_0 + \beta_{i1}lnP\ TME\text{-}419 + \beta_{i2}lnpNR93/0199 + \beta_{i3}lnpNR01/0004 + \beta_{i4}lnpTMS1961089A + \beta_{i5}lnpCR\text{-}41\text{-}10 + \beta_{i6}lnpNR03/0211 + \beta_{i7}lnpCR36\text{-}5 + \beta_{i8}lnpNR07/0220 + \beta_{i9}lnpTMS1070593 + \beta_{i10}lnpTMS105539 + \ldots + \delta_{10} ln_{expend} + \mu_{10} \quad (14)$$

Where $(\alpha_0 + \beta_{ij})$ and δ_i are parameters to be estimated and are unknown; μ_i represents the error term of ith equation. We used Zellner's seemingly unrelated regression to estimate the systems of the equation.

Table 1. Variables used in the almost ideal demand system.

Variables	Definition	Unit	Expected sign
$W_{TME-419}$	Share of TME-419	%	+
$W_{NR93/0199}$	Share of NR93/0199	%	+
$W_{NR01/0004}$	Share of NR01/0004	%	+
$W_{TMS1961089A}$	Share of TMS1961089A	%	+
$W_{CR-41-10}$	Share of CR-41-10	%	+
$W_{NR03/0211}$	Share of NR03/0211	%	+
W_{CR36-5}	Share of CR36-5	%	+
$W_{NR07/0220}$	Share of NR07/0220	%	+
$W_{TMS1070593}$	Share of TMS1070593	%	+
$W_{TMS105539}$	Share of TMS105539	%	+
$P_{TME-419}$	Price of TME-419	Naira/kg	+/-
$P_{NR93/0199}$	Price of NR93/0199	Naira/kg	+/-
$P_{NR01/0004}$	Price of NR01/0004	Naira/kg	+/-
$P_{TMS1961089A}$	Price of TMS1961089A	Naira/kg	+/-
$P_{CR-41-10}$	Price of CR-41-10	Naira/kg	+/-
$P_{NR03/0211}$	Price of NR03/0211	Naira/kg	+/-
P_{CR36-5}	Price of CR36-5	Naira/kg	+/-
$P_{NR07/0220}$	Price of NR07/0220	Naira/kg	+/-
$P_{TMS1070593}$	Price of TMS1070593	Naira/kg	+/-
$P_{TMS105539}$	Price of TMS1961932	Naira/kg	+/-
Income	Income	Naira	+/-

Results and Discussion

Determinants of the Farmers Choices of Improved Cassava Varieties:

Multivariate probit model

We used the multivariate probit model to identify the factors that influence the farmers' choices of improved cassava varieties cultivation including the interdependence of their choice decisions of the improved cassava varieties. We presented the results on Table 2. For the purpose of our study and to reduce ambiguity, we reported the ten most popular varieties among the farmers.

Our results indicate that age significantly affect farmers choice of TME-419 varieties. The coefficient revealed that age positively and significantly influenced the decision of the farmers to adopt TME-419 varieties. Thus, age increases the likelihood of adopting TME-419. This is consistent with Afolami *et al.* (2015) and Kolapo *et al.* (2020a). Education was found to positively and significantly affect farmers' decision to participate in TME-419. This indicates that the likelihood of adopting TME-419 varieties is increased by the educational status of the farmers. This is consistent with Kolapo *et al.* (2020b). Marital status was found to positively and significantly influence the decision of the farmers to adopt CR-41-10 and NR07/0220 varieties. This indicates that the marital status of the farmers increases the likelihood of adopting CR-41-10 and NR07/0220 varieties. Thus, these two varieties might be common among the married farmers.

We found that membership in farmers group positively and significantly influence farmer's choices of CR-41-10 and CR36-5 varieties. This indicate that membership in association increases the likelihood of adopting CR-41-10 and CR36-5 varieties. This might be due to the fact that these varieties were profoundly disseminated through the farmers group, hence influence farmers choices of these varieties. Household size was found to negatively and significantly influence farmers' choice of adopting CR-41-10. This implies that household size decreases the likelihood of adopting CR-41-10 varieties.

Risk aversion by the farmers positively and significantly affect farmers' choices of CR36-5 and TMS105539 varieties. Thus, farmers' decision/aversiveness to try new agricultural technology increases the likelihood of adopting CR36-5 and TMS105539 varieties. This corroborates the findings of Abdoulaye *et al.* (2015), Kolapo *et al.* (2020b), Kolapo and Kolapo (2021).

The expected multivariate interdependence of adoption of different varieties (TME-419, NR93/0199, NR01/0004, TMS196/089A, CR-41-10, NR03/0211, CR36-5, NR07/0220, TMS1070593 and TMS105539) was accounted for employing the multivariate probit simulation of the ten cultivars. The null that the correlations are jointly zero and the ten adoption decisions are independent was rejected at the 1%

significance level. The SML estimation results suggested that there was significantly positive interdependence between households' decisions to adopt (choose) between TME-419 and NR93/0199 varieties, NR01/0004 and TMS196/089A varieties, CR36-5 and NR07/0220 varieties, while significantly negative interdependence for adoption of CR-41-10 and NR03/0211 varieties.

Our results imply that TME-419 enhanced the adoption of NR93/0199 (rho21), since the farmers' decision to adopt NR93/0199 was influenced by long time cultivation of TME-419. Thus, TME-419 farming experience built the farmers confidence to adopt NR93/0199 variety. We have earlier discussed the coefficients that influence the choice of varieties adoption by the farmers.

The interaction between farmers' decision choice of NR01/0004 and TMS196/089A varieties (rho31) and CR36-5 and NR07/0220 varieties (rho42) was positive and significant. This indicated that adoption of one variety contributes to adoption of the other variety. It further implied that the farmers' decision to adopt NR01/0004 does not affect the decision to adopt TMS196/089A Vis-à-vis, adoption of CR36-5 does not alter the adoption of NR07/0220.

However, the interaction of CR-41-10 and NR03/0211 (rho32) was found to be negative and significant. This shows that adoption of CR-41-10 altered the adoption of NR03/0211. The reason may be that the two improved varieties compete for the same resources of the individual households while farmers usually avert risk and cultivate both varieties. In order to solve this confusion, Mesfin and Zemedu (2018) who found similar results proposed that farmers may be required to participate in varietal selection and research activities so as to further widen their knowledge of the varieties. Furthermore, farmers' engagement in technology generation, popularization and dissemination activities will help to articulate the farmers demand to individual cultivars, and thus in turn helps to appropriate seed delivery system and minimize wastage of resources in producing and delivering a particular variety to the households Mesfin and Zemedu (2018).

In addition, the joint probability (Table 2) revealed that, if farmers were able to adopt all the ten improved cassava varieties, their joint likelihood of adopting these varieties would be only 1%. However, it was unlikely for farmers to adopt all the ten improved cassava varieties simultaneously. This was justified either by the fact that simultaneous adoption of all the varieties was unaffordable for the smallholders, or that all the ten varieties were not simultaneously accessible in the farmers localities. This finding is consistent with Goshu *et al*. (2013) and Mesfin and Zemedu (2018).

Moreover, the joint probability of not adopting all the improved cassava varieties of the farmers was also 1%, implying that the farmers adopted at least one improved cassava variety. Evident from our result, we suggested that improved cassava varieties adoption would be accelerated by the need to launch a progressively developing package and scheme of cassava technology generation, and points to the importance of mobilizing additional resources to augment farmers' efforts at popularization and promotion of improved cassava varieties.

Demand for improved cassava stems

From our result presented on Table 3, the TME-419 equation shows that own price, price of NR01/0004, price of CR36-5, price of TMS1070593 were highly significant. For NR93/0199, own price, price of TME-419 and price of NR01/0004 were highly significant. For NR01/0004, own price, price of NR93/0199, price of TME-419, price of CR36-5 and price of TMS1070593 were highly significant. For TMS1961089A, own price, price of NR93/0199, price of TME-419, price of CR36-5, price of NR01/0004 and price of TMS1070593 were highly significant. For CR-41-10, own price, price of NR93/0199, price of TME-419, price of CR36-5, price of NR01/0004 and price of TMS1070593 were highly significant. For NR03/0211, own price, price of NR93/0199, price of TME-419, price of CR36-5 and price of TMS1070593 were highly significant. For CR36-5, own price, price of TMS1961089A, price of NR93/0199, price of TME-419, price of NR01/0004 and price of TMS1070593 were highly significant. For NR07/0220, own price, price of CR36-5, price of TMS1961089A, price of NR93/0199, price of TME-419, price of NR01/0004 and price of TMS1070593 were highly significant. For TMS1070593, own price, income, price of NR07/0220, price of CR36-5, price of TMS1961089A, price of NR93/0199, price of TME-419, price of NR01/0004 and price of TMS1070593 were highly significant.

Table 2. Multivariate probit determinants of adoption of ten popular improved cassava varieties.

Variables	Improved cassava varieties									
	TME-419	NR93/0199	NR01/0004	TMS196/089A	CR-41-10	NR03/0211	CR36-5	NR07/0220	TMS1070593	TMS105539
Age	0.0153243 (0.054)***	0.011486 (0.137)	-0.0104197 (0.213)	0.0137913 (0.169)	0.021096 (0.192)	-0.010084 (0.375)	-0.00184 (0.813)	-0.00083 (0.928)	0.0047052 (0.602)	0.000037 (0.984)
Gender	-0. 163715 (0.677)	-0.28719 (0.451)	0. 4163494 (0.3156	-0.274737 (0.518)	-0.174052 (0.767)	0.19042 (0.734)	-0.23256 (0.543)	0.82459 (0.105)	-0.0097086 (0.982)	-0.44620 (0.615)
Education	1.330755 (0.003)*	-1.168047 (0.003)	-0.7521578 (0.068)	-0.2708899 (0.530)	-0.44385 (0.476)	0.841721 (0.223)	0.529711 (0.239)	-0.30190 (0.478)	-0.1090115 (0.800)	-0.134990 (0.132)
Marital status	-0. 033542 (0.268)	0.016923 (0.571)	-0. 0556185 (0.090)	-0.0150054 (0.648)	0.096019 (0.040)**	0.0621423 (0.115)	-0.00088 (0.978)	0.075401 (0.020)**	0.0144027 (0.663)	-0.001591 (0.958)
Association membership	0. 005328 (0.964)	0.311538 (0.012)	0. 5103292 (0.000)	0.0480714 (0.714)	0.292729 (0.067)***	-0.033655 (0.833)	0.024292 (0.036)**	0.107347 (0.396)	0.0133074 (0.916)	0.456229 (0.001)
Household size	-0.002314 (0.665)	0.001262 (0.478)	-0.0060239 (0.573)	-0.0291719 (0.008)	-0.03630 (0.044)**	-0.004747 (0.743)	-0.00242 (0.711)	-0.00342 (0.742)	-0.0008244 (0.756)	-0.003741 (0.109)
Farm size	2.38e-06 (0.043)**	2.09e-07 (0.849)	-3.20e-06 (0.041)	9.04e-07 (0.474)	-5.32e-07 (0.730)	1.66e-06 (0.210)	-6.57e-07 (0.803)	1.70e-07 (0.886)	3.46e-06 (0.009)	-1.97e-07 (0.445)
Years of farming experience	-0.0001335 (0.117)	-7.41e-06 (0.930)	-0.0000517 (0.548)	0.0000598 (0.521)	6.36e-05 (0.638)	8.79e-05 (0.473)	3.10e-05 (0.724)	-0.000045 (0.634)	-0.0001236 (0.223)	8.67e-06 (0.656)
Land ownership	-2.64e-06 (0.030)**	-2.57e-07 (0.821)	3.29e-06 (0.038)	1 1.19e-07 (0.928)	7.74e-07 (0.646)	-1.57e-06 (0.257)	1.30e-08 (0.944)	-1.17e-08 (0.992)	-2.96e-06 (0.027)	-1.52e-07 (0.569)
Awareness of improved varieties	-0.2731661 (0.326)	0.845072 (0.003)	-0.4910686 (0.087)	--0.188556 (0.548)	0.686364 (0.131)	-0.272374 (0.493)	-0.06225 (0.827)	0.657538 (0.044)**	0.8587163 (0.007)	0.06000 (0.828)
Stem cost	0.4405754 (0.106)	0.10205 (0.705)	0.4249291 (0.556)	-0.0450318 (0.885)	0.389211 (0.400)	-0.078491 (0.836)	0.46509 (0.104)	0.18009 (0.571)	-0.2117297 (0.482)	0.64118 (0.020)**
Availability of improved stem cuttings	0.5762594 (0.034)**	1.175058 (0.000)	0.1040713 (0.125)	0.2668576 (0.397)	0.86160 (0.074)***	0.76559 (0.068)***	0.174229 (0.597)	0.23507 (0.454)	0.7466937 (0.015)	-0.45377 (0.091)***
Risk aversion	0.0096669 (0.763)	0.089626 (0.017)	0.0729902 (0.027)	0.0369164 (0.302)	0.027302 (0.532)	0.42615 (0.290)	0.12512 (0.001)*	-0.047304 (0.256)	-0.0182294 (0.603)	0.08382 (0.015)**
Access to extension services	-0.2860339 (0.334)	-0.409916 (0.165)	-0.0896623 (0.771)	-0.1637807 (0.629)	0.45261 (0.307)	0.42446 (0.290)	0.15202 (0.619)	0.167325 (0.605)	0.2197941 (0.494)	-0.03655 (0.902)
Access to land resources	-0. 010971 (0.387)	0.003555 (0.794)	0.0042423 (0.776)	-0.0412454 (0.073)	-0.01292 (0.657)	0.009173 (0.594)	0.016445 (0.221)	-0.11029 (0.484)	0.0007101 (0.962)	-0.01677 (0.241)
Predicted probability	0.75	0.29	0.24	0.32	0.21	0.26	0.25	0.33	0.22	0.28
rho21	0.014927***									
rho31	0.040342**									
rho32	-0.006061*									
rho41	0.0008914									
rho42	0.063972**									
Joint probability of success 0.01										
Joint probability of failure 0.01										
Probability (LR stat)	52.37									
Prob >chi²	0.0001*									
Wald chi²	0.1294									

*Note: *, ** and *** represent 10%, 5% and 1% levels of significant, respectively.*

Table 3. Seemingly Unrelated Regression (SUR) results of Almost-Ideal Stem Demand System.

Determinants	Total expenditure of improved cassava stems								
	TME-419	NR93/0199	NR01/0004	TMS1961089A	CR-41-10	NR03/0211	CR36-5	NR07/0220	TMS1070593
Price of TME-419	0.0153243 (0.054)***								
Price of NR93/0199	-0. 163715 (0.677)	-0.28719 (0.451)**							
Price of NR01/0004	-1.330755 (0.003)*	-1.168047 (0.003)	-0.7521578 (0.068)*						
Price of TMS1961089A	-0. 033542 (0.268)	0.016923 (0.571)	-0. 0556185 (0.090)	-0.0150054 (0.648)***					
Price of CR-41-10	0. 005328 (0.964)	0.311538 (0.012)	0. 5103292 (0.000)	0.0480714 (0.714)	0.292729 (0.067)***				
Price of NR03/0211	-0.002314 (0.665)	0.001262 (0.478)	-0.0060239 (0.573)	-0.0291719 (0.008)	-0.03630 (0.044)**	-0.004747 (0.743)**			
Price of CR36-5	2.38e-06 (0.043)**	2.09e-07 (0.849)	-3.20e-06 (0.041)	9.04e-07 (0.474)	-5.32e-07 (0.730)	1.66e-06 (0.210)	-6.57e-07 (0.803)*		
Price of NR07/0220	-0.0001335 (0.117)	-7.41e-06 (0.930)	-0.0000517 (0.548)	0.0000598 (0.521)	6.36e-05 (0.638)	8.79e-05 (0.473)	3.10e-05 (0.724)	-0.00004 (0.634)*	
Price of TMS1070593	-2.64e-06 (0.030)**	-2.57e-07 (0.821)	3.29e-06 (0.038)	1 1.19e-07 (0.928)	7.74e-07 (0.646)	-1.57e-06 (0.257)	1.30e-08 (0.944)	-1.17e-08 (0.992)	-2.96e-06 (0.027)**
Income	-0.2731661 (0.326)	0.845072 (0.003)	-0.4910686 (0.087)	--0.188556 (0.548)	0.686364 (0.131)	-0.272374 (0.493)	-0.06225 (0.827)	0.657538 (0.044)**	0.8587163 (0.007)
Inverse Mill's ratio ()	0.4405754 (0.106)	0.10205 (0.705)	0.4249291 (0.556)	-0.0450318 (0.885)	0.389211 (0.400)	-0.078491 (0.836)	0.46509 (0.104)	0.18009 (0.571)	-0.2117297 (0.482)
Constant	0.5762594 (0.034)**	1.175058 (0.000)	0.1040713 (0.125)	0.2668576 (0.397)	0.86160 (0.074)***	0.76559 (0.068)***	0.174229 (0.597)	0.23507 (0.454)	0.7466937 (0.015)
Probability (LR stat)	75.44								
Prob >chi2	0.0001*								
McFadden R-squared	0.1294								

*Note: *, ** and *** represent 10%, 5% and 1% levels of significant, respectively.*

Table 4. Own, cross and income elasticity for improved cassava stems.

	TME-419	NR93/0199	NR01/0004	TMS1961089A	CR-41-10	NR03/0211	CR36-5	NR07/0220	TMS1070593	TMS105539
TME-419	**-5.64**	0.09	0.94	0.27	0.84	0.45	0.85	0.06	0.48	0.38
NR93/0199	0.04	**-4.71**	0.95	0.65	0.71	0.47	0.12	0.04	0.08	0.27
NR01/0004	0.04	0.38	**-1.11**	0.94	0.49	0.83	0.38	0.94	1.39	0.36
TMS1961089A	0.41	0.02	1.04	**-2.61**	0.03	0.27	0.31	0.22	0.29	0.29
CR-41-10	0.36	0.37	0.48	3.16	**-1.82**	0.39	0.37	0.48	0.84	0.32
NR03/0211	0.47	0.94	0.73	0.62	0.75	**-1.93**	0.61	0.74	0.78	2.38
CR36-5	0.85	0.44	0.85	0.54	0.36	0.64	**-1.63**	0.27	0.33	0.32
NR07/0220	0.04	0.47	0.51	0.81	0.71	0.19	0.29	**-1.37**	0.81	0.43
TMS1070593	0.87	0.39	0.84	0.21	0.39	0.48	0.92	0.84	**-1.42**	0.73
TMS105539	0.35	0.29	0.51	0.78	0.82	0.71	0.28	0.29	0.19	**-1.38**
Compensated elasticity demand										
TME-419	**-4.25**	1.93	0.32	1.38	1.21	0.29	0.38	3.19	2.16	1.29
NR93/0199	3.25	**-3.93**	1.27	2.46	2.22	1.23	1.83	3.17	2.17	2.14
NR01/0004	2.32	3.21	**- 2.16**	2.18	1.98	3.19	2.17	1.29	1.89	3.11
TMS1961089A	3.44	3.91	1.22	**-1.28**	3.22	2.13	4.17	1.11	1.56	2.17
CR-41-10	4.42	0.29	0.32	0.31	**-4.11**	1.28	2.11	2.19	1.32	4.18
NR03/0211	1.79	1.32	1.99	0.49	2.19	**-1.31**	1.45	4.11	1.09	4.28
CR36-5	1.75	3.11	2.18	4.31	3.10	0.32	**-1.27**	5.27	1.29	1.27
NR07/0220	1.77	2.39	2.33	3.23	1.26	2.38	6.28	**-4.23**	1.67	2.66
TMS1070593	2.18	2.93	2.49	3.29	2.18	2.19	3.19	2.23	**-5.21**	2.11
TMS105539	2.22	1.92	2.11	2.22	1.89	1.92	2.14	2.17	1.29	**-1.28**
Expenditure elasticity	1.29	1.39	0.23	3.48	2.19	3.28	3.76	0.22	6.25	1.99

Bold values are own and cross price elasticity.

Estimation of Marshallian, Hicksian elasticities and income elasticities

We presented the estimates of the Marshallian and Hicksian own-price elasticity and expenditure elasticity in Table 4. Consistent with the economic theory, our result shows that the own-price elasticities were negative with relatively high elasticity. It was shown that the improved cassava varieties had high price elasticites. From Table 4, TME-419 had the highest own-price (5.64 and 4.25) elasticity in the Mashallian and Hicksian elasticity, respectively. This is followed by NR93/0199 with own-price elasticity of 4.71 and 3.93 in the Masshallian and Hicksian elasticity, respectively. TMS1070593 had own-price elasticity (1.42 and 5.21) in the Mashallian and Hicksian elasticity, respectively. This is followed by NR07/0220 with own-price elasticitiy's of 1.37 and 4.23 in the Mashallian and Hicksian elasticity, respectively. CR-41-10 had own-price elasticity's (1.82 and 4.11) in the Mashallian and Hicksian elasticity. TMS1961089A had own-price elasticity (2.61 and 1.28) in the Mashallian and Hicksian elasticity. This is followed by NR01/0004 with own-price elasticity of 1.11 and 2.16 in the Mashallian and Hicksian elasticity, respectively. NR03/0211 had own-price elasticity (1.93 and 1.31) in the Mashallian and Hicksian elasticity. This is followed by CR36-5 with own-price elasticity of 1.63 and 1.27 in the Mashallian and Hicksian elasticity, respectively. We observed the lowest own-price elasticity in TMS105539 (1.38 and 1.28) in the Mashallian and Hicksian elasticity, respectively.

We observed that the price elasticity of demand for marketed stem of the improved cassava varieties were relatively high. This improved cassava stems are usually distributed by agro-dealers, farmers cooperatives and research institutes like IITA. The high price elasticity observed might be because the smallholder farmers regarded the marketed improved cassava stem varieties to be expensive. Moreover, farmers opt for other stem cuttings sources that are not market-based such as stem recycling which sometimes loose its productivity value with time.

Regarding the cross-price elasticity, our results revealed that all the improved cassava varieties have substitute relationship. TME-419 had had more than a unitary substitutive relation with all varieties in the Marshallian and Hicksian demand elasticity. Likewise, other improved varieties, NR93/0199 showed more than unitary substitutive relationship with the other improved varieties. Thus, it implied that the improved varieties were highly substitutable with each other.

However, for farmers to substitute their improved cultivar more times there is a need for the promotion of activities that will accelerate dissemination of these improved varieties. The elastic demand findings from our results are also consistent with the results of Legume demand analysis in Malawi (Hennry *et al.*, 2012) and rice seed demand in Ethiopia (Mesfin and Zemedu, 2018).

The expenditure elasticity presented in Table 4 revealed that all varieties were unitarily elastic. The positive income elasticity indicated that as income increased, the expenditure for improved cassava varieties also increased with the same style. This income elasticity showed almost near to unitary style. Thus, the improved cassava stems are considered at the critical point to necessity and luxury for the smallholder cassava farmers. For the past years, cassava cultivation increased tremendously in Nigeria and the output market for cassava tubers fetched good prices for the farmers.

In this study, we established that small proportional changes in own-prices if the improved cassava varieties led to greater unitary changes in their purchases. Thus, our result implies that farmers were price and income sensitive. This implies that any intervention program targeted at improving farmers stem cuttings purchases must take into consideration, efforts to increase farmers' purchasing power. One sure way to achieve this is to subsidize the stem inputs and ensure that the varietal choices of the farmers were delivered to them.

Conclusions

In this study, we assessed the nature of the demand for improved cassava stems in Nigeria. We examined the determinants of the choice decisions of the farmers for improved cassava varieties. We analyzed the responsiveness of improved cassava stem demand to changes in own, cross and income elasticity. From our study; Age of the household's head, education level of the household head, marital status, membership in farmers association, household size, farm size, land ownership status, awareness, risk aversiveness and stem cost influenced farmer's choices and decision to adopting improved cassava varieties. Although stem cost negatively affected the adoption of improved cassava varieties. In order to increased and accelerate adoption of these improved cassava varieties, we therefore suggested that there should be massive promotion and dissemination of the recently released varieties together with complementary agronomic practices simultaneously which would incentivize the farmers. Furthermore, intervention program inform of subsidy should be organized in order to improved stem purchasing power of the farmers. Government, private agencies, research institutes and stakeholders should ensure that farmers have access to extension services, productive resources and infrastructure, and market linkages, which would accelerate farmer's adoption of the improved cassava varieties.

Conflict of interest statement

Authors have declared that no conflict of interest exists.

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References

Abdoulaye, T, Bamire, A.S and Oparinde, A. 2015. Determinants of adoption of improved cassava varieties among farming household in Oyo, Benue and Akwa Ibom States of Nigeria HarvestPlus working paper no 20. Washington DC: HarvestPlus. pp. 1-17.

Afolami, C.A., Obayelu, A.E. and Vaughan, I.I. 2015. Welfare impact of adoption of improved cassava varieties by rural households in South Western Nigeria. *Agric. Food Econ.* 3: 18-34. https://doi.org/10.1186/s40100-015-0037-2

Ayinde, O.E. and Adewumi, M.O. 2016. Risk and adoption analysis of innovation in cassava production in Oyo state, Nigeria: A case study for vitamin A variety. World Congress on Root and Tuber Crops Nanning, Guangxi, China, January 18–22, 2016. pp. 1-24.

Ayinde, O.E., Adewumi, M.O., Ajewole, O.O. and Ologunde, O.O. 2017. Determinants of adoption of vitamin A bio-fortified cassava variety among farmers in Oyo State, Nigeria. *Croat. J. Food Sci. Tech.* 9(1): 74-79. https://doi.org/10.17508/CJFST.2017.9.1.10

Cappellari, L. and Jenkins, S. 2003. Multivariate probit regression using simulated maximum likelihood. *Stat. J.* 3(3): 278–294. https://doi.org/10.1177/1536867X0300300305

Etuk, U. and Umoh, I. 2014. Adoption pattern of pro-vitamin A Technology among farmers in Akwa Ibom State. *Nigerian J. Agric. Food Environ.* 10: 35–138.

Goshu, D., Kassa, B. and Ketema, M. 2013. Is food security enhanced by agricultural technologies in rural Ethiopia? *African J. Agric. Resour. Econ.* 8(1): 58–68.

HarvestPlus. 2010. Households reached. Nigeria database 2015. Available from www.harvestplus.org/data

Hennry, K., Julius, M., Franklin, S., Kai, M. and Moses, S. 2012. Improved legume seed demand systems in central Malawi. pp. 1-26. *In:* International Association of Agricultural Economists (IAAE) Triennial Conference. 18–24 August, 2012. Foz do Iguaçu, Brazil.

Ilona, P., Bouis, H.E. and Palenberg, M. 2017. Vitamin A cassava in Nigeria: Crop development and delivery. *African J. Food Agric. Nutr. Dev.* 17: 12000–12025. https://doi.org/10.18697/ajfand.78.HarvestPlus09

Kolapo, A. and Kolapo, A.J. 2021. Welfare and Productivity Impact of Adoption of Biofortified Cassava by Smallholder Farmers in Nigeria. *Cogent Food Agric.* 7: 1: 1886662 https://doi.org/10.1080/23311932.2021.1886662

Kolapo, A., Olayinka, J.Y. and Muhammed, O.A. 2020a. Market Participation and Food Security Status of Bio-Fortified Cassava Processors in South Western Nigeria. *Int. J. Sust. Agril. Res.* 7(3): 174-184. https://doi.org/10.18488/journal.70.2020.73.174.184

Kolapo, A., Ologundudu, O.M. and Adekunle, I.A. 2020b. Gender, Membership in Farmers' Association and Adoption of Biofortification in Nigeria: The Case of Bio-Fortified Cassava. *SSRG Int. J. Agric. Environ. Sci.* 7(3): 38-45. https://doi.org/10.14445/23942568/IJAES-V7I3P105

Maddala, G.S. 1992. Introduction to Econometrics. Second Edition. New York: Macmillan Publishing Company. 637p.

Mesfin, H.A. and Zemedu, L. 2018. Choices of Varieties and Demand for Improved Rice Seed in Fogera District of Ethiopia. *Rice Sci.* 25(6): 350-356. https://doi.org/10.1016/j.rsci.2018.10.005

NBSN. 2010. Nigeria poverty profile 2010. National Bureau of Statistics Nigeria. http://www.nigerianstat.gov.ng/pdfuploads/Nigeria%20Poverty%20Profile%202010.pdf.

Olamide, O., Bello, A., Durodola, O., Adedayo, O., Olufemi A., Ilona, P., Muheebwa, A., Teekena, B., Iluebbeya, P., Kulakowa, P., Bakare, M. and Parkes, E. 2019. Gender-based constraints affecting biofortified cassava production, processing and marketing among men and women adopters in Oyo and Benue States, Nigeria. *Physiol. Mole. Plant Path.* 105: 17-27. https://doi.org/10.1016/j.pmpp.2018.11.007

Otekunrin, O.A. and Sawicka, B. 2019. Cassava, a 21st century staple crop: How can Nigeria harness its Enormous Trade potentials? *Acta Sci. Agric.* 3(8): 194-202. https://doi.org/10.31080/ASAG.2019.03.0586

Serapius, M., Essegbemon, A., Lukurugu, G.A., Muricho, G., Vernooy, R., Minja, A., Ojiewo, C., Njuguna, E., Otieno, G. and Varshney, R. 2019. Factors Influencing Preferences and Adoption of Improved Groundnut Varieties among Farmers in Tanzania. *Agron.* 10: 1-15. https://doi.org/10.3390/agronomy10091271