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Are Farmers "Efficient but Poor"? The Impact of Crop Choices on Agricultural Productivity and Poverty in Nigeria

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Abstract

This paper aims to test the "efficient-but-poor" hypothesis" by estimating the determinants of smallholders' crop choices and whether their crop choices affect productivity and poverty using the national household panel data in Nigeria. As crop choices are endogenous in the sense that the farmers' crop choice is also influenced by resulting revenue from the crop, we carry out stochastic frontier analyses with the Greene (2010) correction for sample selection about farmers' crop choices and find that smallholders are generally efficient in their resource allocations. However, they are not necessarily rational in making their crop choices - defined in terms of the degree of crop's exportability or commercialization. This is because, even when some crops are found to be more productive than others, the "less productive" crop is often chosen for production. To figure out why, a treatment effects model is employed to estimate farmers' selection into the choice of a type of crop in the first stage and the impact of their choices on productivity and poverty outcomes in the second. The results show that farmers' access to free inputs, non-farm income and the use of seeds from the previous growing season are important determinants of crop choice. The choice of tuber and root crops is found to improve productivity and reduce poverty, while choosing highly commercialised crops reduces poverty but does not improve productivity.

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Are Farmers "Efficient but Poor"? The Impact of Crop Choice on Agricultural Productivity and Poverty in Nigeria

1. Introduction

The main purpose of this study is to test the "efficient-but-poor" hypothesis by estimating the determinants of smallholders' crop choices and whether their 'endogenous' crop choices affect their productivity - defined in terms of technical efficiency - and consumption poverty. Crop choices are defined based on the crop's exportability - whether it is the most exportable cash crop or not - , whether it is a tuber/root crop or not, or the extent to which the crop is commercialised. The challenge in estimating the effect of crop choices on productivity is that crop choice is endogenous in the sense that that the farmers' crop choice is also influenced by resulting revenue from the crop. To address this issue, we have carried out stochastic frontier analyses (SFA) by using the Greene (2010) correction for sample selection in estimating farmers' technical efficiency. The study is based on the household panel data constructed by using two waves of Nigeria's General Household Survey-Panel, which is part of the World Bank's Living Standards Measurement Study. This is to our knowledge the first application of SFA with the Greene (2010) correction to Nigeria and one of the few applications to the agricultural productivity of households in developing countries.[1]

Producing cash crops was traditionally regarded as the forte of large-scale commercial farmers. However, there has been argument in recent years that smallholder farmers could also take advantage of the large international market of their products while they attempt to raise overall productivity and improve their income from farming. We propose to examine this argument in closer detail by asking a research question - "Have smallholder farmers who chose to grow a specific type of crops, such as cash crops with a higher degree of exportability or commercialisation or tuber/root crops, improved their productivity or reduced poverty?". In answering the main question, we also explore the underlying reasons for choosing to grow specific types of crops as well as the mechanisms for achieving, or not achieving, better productivity or reducing, or not reducing, household poverty.

Nigeria has been selected because it is a country where the agricultural sector is trapped in a cycle of low productivity. Nigeria is classified as a lower-middle-income country with a national GDP of US$449.1 billion as of 2019 (which is about half a per cent of the global economy), an estimated population of 201.0 million people, and a gross national per capita GDP of US$2,230 (World Bank, 2021). The average growth rate of Nigeria's GDP between

[1] They include Rahman (2011) and Martey et al. (2019).

2007 and 2014 was 6.49%, which is higher than the average of Sub Saharan Africa countries (4.84%, excluding high-income countries) and European Union Countries whose growth rate was only 0.59% in the same period. However, there has been a sharp decline in the GDP growth rate of Nigeria since then to an average of 0.61% between 2015 and 2017 due to a period of severe recession in 2016, after which it remained at around 2% in 2018 and 2019 (World Bank, 2021).

Despite the long period of high economic growth of Nigeria, about 23.2% (42.2%) of the population lived on less than US$1.90 (US$3.20) a day in 2009 (at 2011PPP) (World Bank, 2021). In 2017 Nigeria overtook India as the country with the largest amount of absolute poverty in the world; with a large proportion of the poor engaged in agriculture. Agriculture accounts for about 40% of the country's GDP and employs about 65% of the people (World Bank, 2021). Thus, the agricultural sector is important in determining the quality of life and welfare of a large proportion of people in the country. However, it has lagged behind other sectors and the rest of the world in terms of productivity.

The low agricultural productivity in Nigeria could be caused by many factors ranging from poor soil qualities due to erosion, pollution and leaching, to scarcity and high cost of inputs. Others may be continued use of crude implements and traditional or non-modern farming practices. However, this paper will examine whether the type of crop a farmer chooses to grow influences household outcomes in terms of productivity or poverty, even at the same level of underlying agricultural technologies or other factors.

To illustrate this point briefly, Table 1 summarises for selected crops the area of land planted with the crop, their prices, the average output in tonnes and their average revenues per hectare. The last column of Table 1 shows that some crops yield more revenue per hectare than others. While 'the revenue' in Table 1 does not take into account input and production costs that vary across different crops, this revenue variation will justify our focus on productivity differences across different crops. If there are crops that yield potentially higher revenues and a farmer is free to choose among all these crops, all other things (e.g., weather or soil variability) being equal, why would he choose to grow a crop that provides a smaller profit margin than the other crops? How much would crop choices impact their productivity and household welfare? These are the questions we will set out to answer in the paper.

[Table 1 to be inserted]

This research is important for several reasons. Firstly, our study would provide policymakers with policy implications on how productivity growth or poverty reduction is achieved by reallocating crops given the current set of available inputs and agricultural technology. Whenever a new government came into power in Nigeria, it would often seek to come up with an overarching agricultural agenda for the agricultural sector, for instance, encouraging the production of certain crops which it deems more "important" (Iwuchukwu and Igbokwe, 2012). Drawing upon the large-scale national household survey dataset this paper aims to provide policy implications for the government on the agricultural policy regarding the promotion of particular crops. It should also be noted that poverty and food security remain a major concern for many sub-Saharan African countries, including Nigeria. In these countries, the cropping decision could have far-reaching implications for national food security. If the production of certain crops is found to improve the welfare outcomes of farmers, such as poverty or food security, our results would provide an important policy lesson.

Our results show that farmers' access to free inputs, non-farm income, the use of seeds from the previous growing season, household size, gender and the different regional differences are the main determinants of their crop choice. Also, the choice influences the productivity and poverty of households. In addition, the choice of a highly commercialised crop is found to be important for poverty alleviation, but not for productivity improvements.

The rest of this paper is laid out as follows. The next section highlights recent empirical studies on the productivity of smallholders and the effects of decisions to grow a crop on productivity and welfare. Section 3 discusses the methodology, starting with how the key crop choice variables are defined in this paper, and then presents our main econometric models, namely, SFA and the treatment effects model. Section 4 explains the data and Section 5 presents the main results. The final section offers concluding observations.

2. Literature Review

Agricultural Productivity in Nigeria

Technical efficiency is defined as the farmer's 'ability to produce maximum output given a set of inputs and technology' (Bravo-Ureta et al., 2007, p. 58), which is empirically measured by 'the ratio of the produced output of an agricultural household over the maximally possible output, given a set level of inputs'. It takes the value between 0 and 1 where the higher value stands for higher efficient use of inputs in producing a unit of out given the agricultural technology. To measure agricultural farmers' technical efficiency, two groups of methods can be employed: parametric and non-parametric methods. Among the parametric methods, stochastic frontier models have been most commonly used in the literature. For Nigeria, these models have been used to compute farmers' technical efficiency for a large variety of crops including rice, wheat and cassava, among others (Adeyemo et al., 2010; Amaza et al., 2005;

Ebong et al., 2009; Onyenweaku and Ohajianya, 2009). We also apply the stochastic frontier method, not for specific crops, but for a group of crops with the same characteristics as discussed later. In addition, our analysis drawing upon the panel data takes account of unobservable household characteristics. The difference between the parametric (like SFA) and non-parametric methods is that, while production functions are of a specified form for parametric analysis, there are no restrictive functional forms employed for the non-parametric method. An example of the non-parametric approach is the data envelopment group of models (Charnes, 1978). Other studies have used some partial measures of productivity like yield per hectare in their analysis.

For example, Adeyemo et al. (2010) compute an average technical efficiency (TE) score of 0.89 for cassava farmers in Ogun state, while Ebong et al. (2009) do the same for food crop farmers in Akwa Ibom and recover an average TE of 0.81. In the South-East region, Onyenweaku and Ohajianya (2009) calculate an efficiency score of 0.65 for rice farmers in Ebonyi state. Finally, Amaza et al. (2005) do the same for food crop producers in Borno and calculate an average score of 0.68. Papers like these are an indication of the range of calculated efficiency scores in particular regions, but this paper carries out a nationwide analysis using the nationally representative household panel data of Nigeria. To the best of our knowledge, this is the first time the nationwide panel dataset has been used to perform the SFA to estimate technical efficiencies. This would make a valuable contribution to the empirical literature.

Crop Choice, Productivity and Welfare in Developing Countries

In the papers reviewed below, household welfare is measured by domestic household per capita consumption. Using national household surveys from Mali, Delarue et al. (2009) studied the relationship between cotton production and household consumption and discovered that cotton producers consumed 9 per cent more food on average than non-cotton producing households where food consumption is a proxy for total consumption. When the authors disaggregated the results by the farm size, they found that the largest cotton producers consume up to 22 per cent more than the smallest producers, though these results imply correlations rather than causations. Loveridge et al. (2002) did something similar with coffee for Rwanda and discovered a weak positive relationship between coffee production and the consumption outcomes of households. They speculated that this relationship could be explained by the low prices for coffee in the world market as at the time of the survey, 2001. Murekezi and Loveridge (2009) use the same methodology to compare the 2001 season data of Rwanda to that of 2007, to assess the impact of policy reforms and found that technology could be a factor in the efficiency of cash-cropping among smallholders because those that used modern techniques spent 15 per cent more on food and 17 per cent more on all goods than the traditional producers. However, in addition to the methodology of Murekezi and Loveridge (2009), this paper also takes into account differences in production technologies by distinguishing crops that are produced by vastly different methods of production from each other depending on the type of crops (i.e., tubers and roots as against the other types of crops). Similarly, Maertens and Swinnen (2009) found that the welfare of rural households vastly improved through their participation in high-yield vegetable exports in Senegal.

3. Methodology

Defining Crop Choice

The research hypothesis the present study proposes to test is whether choosing to grow a particular type of crops results in a higher level of agricultural productivity and better household welfare outcomes or a lower level of household poverty. This is closely related to "the cash-crop vs food-crop debate". As the name suggests, a cash crop is broadly defined as a crop that is grown primarily for sale to make a profit. Food crops are, on the other hand, grown primarily for the family of the farmer. However, in the literature of development economics, the term, 'cash crop', specifically denotes crops for exports and not necessarily crops that are sold in the domestic market. According to the US Environmental Protection Agency, cash crops are typically purchased by organisations or commercial entities separate from the farm[2]. Given these definitions, if crops were to be divided by such a straight classification, it would be quite confusing and perhaps impossible to empirically test, especially when faced with the real data. This is also important as this paper intends to group similar crops rather than study farmers who grow an isolated crop against all the others. This cash-crop/food-crop classification might be problematic due to the following reasons.

Firstly, when cash crops are mentioned, the first picture that may come to the mind of readers is that of tree cash crops such as cocoa, coffee, palm oil, rubber etc. However, one of the objectives of this paper is to identify what determined the choice of a crop planted and, if tree crops are used for cash crops, this purpose would be defeated. This is because if we try to measure the effect of a planting choice on productivity and poverty, we would need to capture the entire life cycle of the crop within one crop year. The production cycle of tree crops may span several years, which would make it difficult to compare their productivities with those of non-tree food crops. We have thus excluded all the agricultural households with livestock and tree crops listed as their primary output in creating the crop choice variable. This ensures that

[2] See: "Ag 101: Crop Glossary" (2009), US Environmental Protection Agency.

our comparisons will be restricted to annual crops (that is, the crops that can complete a life cycle within a crop year).

The second reason why a cash-crop versus food-crop categorization might be impractical is that it would be difficult to allocate one crop solely to one category, apart from a few strictly non-edible crops like cotton and rubber. For example, cassava is one of Nigeria's largest agricultural exports, with an average of over 45,000,000 metric tons exported per year on average, making the country the largest exporter of the product in the world. Cassava is often used in industry to produce ethanol and other biofuels. However, cassava is also the raw material for a major local staple food - *'garri'*, which is consumed by most households in the country. So we cannot easily classify cassava as either a cash crop or a food crop. For these reasons, this paper creates three different ways of defining the crop choice, denoted as **C_i,** in which the crop types are classified without given these practical problems of classifications.

1. **Crop-Choice Grouping 1 (C_1)** – defined by the most exported crops (most exported crops vs. others);
2. **Crop-Choice Grouping 2 (C_2)** – defined by type (tuber and root crops vs. others);
3. **Crop-Choice Grouping 3 (C_3)** – defined as a continuous variable for the degree of crop commercialization (i.e., how much a crop is sold or marketed versus how much of it is consumed within a household).

It should be noted that these are by no means an exhaustive list of ways in which crops could be classified. The point here is to simply illustrate that such divisions could be helpful to tell a story about the types of crops a farmer chooses to grow, depending on research objectives. For example, if a researcher is interested in the differences between farmers who choose to grow vegetables as opposed to those who do not (or those who grow cereals as opposed to those who do not), the sample could be so divided as such to estimate the difference in technical efficiency of these two types of farmers.

a. **Crop-Choice Grouping 1 (C_1)** – Classification by the most exported crops (most exported crops versus others)

To create the variable for the first category by most exported crops, data from the FAO were examined to determine which crops were the most exported ones in Nigeria, and the farmers who grew the top 5 crops (and listed them as their primary product output) were classified as Crop-Choice group 1 (**C_1**) households. The purpose of this variable is to capture those agricultural households that grow crops that are the most likely ones to be exported. As can be seen from Table 2, 11.06% of the sample planted one of the five crops in the first wave and 7.14% planted these in the second wave.

[Table 2 to be inserted]

b. **Crop-Choice Grouping 2 (C_2) –** Classification by type (tuber and root crops versus others) Secondly, we group crops by type, with tuber and root crops against all the other crops. This classification is important because root and tuber crops have long been recognised as particularly important for the food security of households in developing countries, especially those in Sub-Saharan African countries. According to the Commission for Africa Report (2010), these types of crops are an important component of the diet for 2.2 billion people in developing countries. In Nigeria, they serve traditionally as a store of wealth as one could tell how rich a person was by the size of his or her yam barn (Obidiegwu and Akpabio, 2017). To illustrate this point further, Figure 1 shows that, even though farmers on average kept allocating a larger land for the production of 'cereals' like rice and maize than 'roots and tubers', the gap has been narrowed quickly in favour of the latter after 2009. In fact, there has been an upsurge in the production of tubers from around 2006, which explains an increase in the land area for roots and tubers.

[Figure 1 to be inserted]

Figure 2 further compares 'cereals' and 'roots and tubers' in terms of 'yield per hectare' as a rough measure of productivity. Figure 2 shows that roots and tubers have for long been a higher-yielding crop type than cereals, and that this productivity gap has increased dramatically over the last three decades. These diagrams would justify Crop-Choice Grouping 2.

[Figure 2 to be inserted]

However, as important as tuber and roots crops are, they have not been given as much attention as they deserve in policymaking. One reason could be that, compared to the crops like wheat and rice, tuber crops are bulky, have higher water content and thus have relatively shorter shelf lives. This constrains the development of innovations in their value chains, as well as the expansion of production and delivery at scale to processors and the markets. In this paper, the crops classified under this category are shown in Table 3.

[Table 3 to be inserted]

c. **Crop-Choice Group 3 (C_3) –** Classification by the Household Commercialization Index (HCI)

Finally, an index for the degree of commercialization of crop production per household is used to capture the extent to which an agricultural household's crop production was oriented towards commercial agriculture. Following Govereh et al. (1999) and Von Braun et al. (1994), which laid a standard of measuring commercialization, we calculate this index can by taking the percentage of the value of the entire agricultural crop production in the year which is explained by the gross value of crops sold. This computation will result in the number between 0 (%) and 100 (%) in which a household with an HCI of 0 is the one with none of its total crop production sold, while a household with an index of 100 is the one with all its crop output sold.

$$HCI = \left[\frac{gross\ value\ of\ crop\ sales}{gross\ value\ of\ all\ crop\ production}\right] x\ 100 \qquad (1)$$

HCI transforms the binary crop choice variable into the continuous variable, reflecting a range of possibilities of crop choices. In addition, this variable allows for interactions to be made with the other crop choice variables to produce new parameters that would provide useful insights[3]. Although this approach is limited as it ignores the absolute value of crop sales, the measure is still useful for describing agriculture in developing countries like Nigeria, because the smaller the farm is, the more likely it would consume a larger proportion of their total output at home for subsistence reasons rather than selling them (except for cases of higher value-added crops like cut flowers or vegetables) (Govereh et al., 1999).

Stochastic Frontier Analysis (with the Greene (2010) Correction for Selection Bias)

To estimate the technical efficiency of crop production, we will aggregate the data at the household level where each observation represents a unique productive entity. Aigner et al. (1977) and Meeusen & Van den Broeck (1977) show how the error term in a stochastic frontier model can be split into: v_i, the stochastic error term and u_i, the inefficiency error term. To illustrate, the base model takes the form:

$$ln(Y_i) = ln(f(\boldsymbol{X}_i)) + v_i - u_i \quad with\ u \geq 0 \qquad (2)$$

[3] For example, interacting commercialization with the crop most likely to be exported would create a variable that represents how much of these crops are sold, rather than consumed at home.

where v_i is either positive or negative and is assumed to be normally distributed with a mean zero and constant variance, as v_i represents an unsystematic stochastic effect related with measurement errors and random influences (e.g. luck, drought, flood, or other weather shocks, as earlier mentioned). On the other hand, u_i is non-negative and either assumed to be half-normal or truncated normally distributed, measuring technical inefficiency, i.e., the stochastic shortfall of output from the most efficient farm on the production frontier (Coelli and Battese, 1996). However, as discussed earlier, the variable on crop choice is likely to be an exogenous variable. We have thus followed Greene (2010) who demonstrated that selection bias could make a significant difference if ignored in the computation of a production frontier. We estimated Greene's selection model for the stochastic frontier analysis in a panel data framework (Pitt and Lee, 1981) to take into account the household unobservable heterogeneity.

Three conventional inputs are used in the computation of the agricultural production frontier function. These are *land* (total agricultural land area under cultivation), *labour* (total wage expenditures for labour including family labour[4]) and *inputs* (intermediate input costs like seed, fertilizer, pesticides, cost of irrigation, and costs to rent farm equipment/machinery). To gain some perspective on the results of this analysis, it may be useful to examine the nature of land distribution in Nigeria, especially as it relates to agriculture.

In an ideal case, there would also be a variable for capital (the depreciated cost of machinery and buildings), but this is not included due to data constraints. However, this is not a problem in our study context because most smallholders in Nigeria usually own neither of these, apart from small implements like hoes and shovels and the farmers that want to mechanize would tend to rent the machines for the required period rather than purchase them. It should also be noted that these rental costs are included in the inputs variable already. These inputs are used to produce the output y_{it} defined as the total revenue generated at the farm level, including by-products. The Cobb-Douglas[5] model is employed to fit the production frontier as follows:

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[4] Family labour is costed by multiplying the number of hours supplied by family members with the market wage rate per hour.

[5] Cobb-Douglas models without restriction and with restrictions (where the parameters are forced to be homogenous) were tried, but there was no significant difference. The time varying decay (TVD) estimation is also used as it most closely simulates a fixed effects regression, against the time-invariant (TI) version. The Cobb-Douglas model is used in several similar studies on agricultural productivity such as Murillo-Zamorano (2004), Jiang and Sharp (2015), and Kumbhakar and Lovell (2003)

$$ln(Y_{it}) = \beta_0 + \beta_1 ln(land) + \beta_2 ln(labour) + \beta_3 ln(inputs) + v_{it} - u_{it} \qquad (3)$$

Because of the non-symmetry of the conventional error term, ε_{it}, the expected value is defined as $E(\varepsilon_{it}) = -E(\varepsilon_{it}) \leq 0,\ \varepsilon_{it} = v_{it} - u_{it}$. The estimation by OLS will provide inconsistent estimates of the parameters apart from the intercept and cannot extricate the technical efficiency component from its normal residual error. The maximum likelihood estimation (MLE) will be thus employed in our study. MLE selects values of the model parameters that produce the distribution most likely to have produced the observed data by maximizing the likelihood function. We assume that the technical inefficiency error term (u_{it}) has a positive half-normal distribution and that u_{it} and v_{it} are independent so that the efficiency estimates will be in the range between 0 and 1. This is useful because the standard deviation of the distribution can concentrate the efficiencies near zero or spread them out (with a zero cut off) (Aigner et al., 1977; Street, 2003).

Technical efficiency can then be derived by Equation (3) for each agricultural household. It is the ratio of the output y_{it} over the stochastic frontier output when $u_{it} = 0$. The resulting technical efficiency would have a value between 0 and 1 and gives information about how far away the observation data points are from the production frontier:

$$TE_{it} = \frac{y_{it}}{exp(x_{it}\beta + v_{it})} = \frac{exp(x_{it}\beta + v_{it} - u_{it})}{exp(x_{it}\beta + v_{it})}) = exp(-u_{it}) \qquad (4)$$

Treatment Effects Model

In this section, the intuition behind solving the problem of a potential selection bias in the creation of the key variables is discussed. Firstly, the categorical variables we have created for crop choice (**C**$_i$) might be biased by self-selection because farmers are unlikely to choose a particular crop to produce entirely at random. It is likely that there are certain unobservable household characteristics (e.g., entrepreneurship, psychological factors) that influence their decision to produce these types of crops (**C**$_i$,) and that **C**$_i$ is endogenous as it is correlated with the error term of Equation (3).

To try to mitigate these problems, we follow Greene (2010) and implement a treatment effects model, similar to the Heckit method (Heckman, 1979). It involves the use of a control function with an endogenous treatment variable which is the self-selection into the choice of crop an agricultural household has made. In addition, crop choice is likely to be an endogenous determinant of poverty and productivity.

The treatment effects model estimates the effect of an endogenous binary treatment, $\boldsymbol{C}_{it}$ (the crop choice in a binary case at time *t*), on a continuous, fully observed outcome variable, $\boldsymbol{Y_{it}}$ (in this case productivity and poverty in separate models); conditional on vectors of explanatory variables, $\boldsymbol{X}_{it}$ and $\boldsymbol{Z}_{it}$(which would include exclusion restrictions). This can be modelled in the following way.

$$Y_{it} \; = \; \beta \boldsymbol{C}_{it} + \eta \boldsymbol{X}_{it} + \mu_i + \nu_{it} \qquad (5)$$

In this case, β represents the parameter of interest as the average net effect of being treated on the outcomes, μ_i is the unobservable time fixed effect and ν_{it} is the error term. However, since $\boldsymbol{C}_{it}$, the crop choice, is endogenous, we would need to model the selection into treatment or the farmer's crop choice following Greene (2010). Further technical details of treatment effects model are shown in Appendix.

4. Data

General description of data

For this analysis, the Nigerian General Household Survey-Panel (GHS-Panel) for 2010/2011 and 2012/2013 is used, which is the official comprehensive household survey for Nigeria and is part of the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) series from the World Bank. The panel covers all the 36 states of the country including the Federal Capital Territory, Abuja. They used a two-stage probabilistic sampling technique to select clusters (or neighbourhoods) at the first stage and households at the second stage. Clusters were selected from each of the 36 states that the country has and from the capital city. Sampling was carried out on both urban and rural Enumeration Areas (EAs) and is thus nationally representative. The total number of EA is 500.

For the GHS-Panel, 5,000 households were randomly surveyed out of 22,000 in the cross-sectional part. The survey for each wave was done in two stages: the post-planting period (lean season), once in 2010 and once in 2012 and the post-harvest period, once in 2011 and once in 2013. In addition, the post-planting survey includes the 22,000 cross-sectional households while the post-harvest survey includes just the 5,000 households in the panel sample where 10 households were randomly selected in each of 500 EAs.

Descriptive Statistics

Table 4 presents descriptive statistics of some variables used for this study. The mean age of the household heads in the sample is about 50 years and about 89% of the agricultural households are headed by males. In addition, the sample is almost 90% made up of households in the rural areas and 75% of the household heads are married. With regards to educational status, about 47 per cent of the sample are literate and can at least read or write, and the average length of time in formal education is about 4 years. The mean household size in the sample is about 6 individuals with averages of about 1 adult male, 2 adult females, 2 dependant males and 2 dependant females.

[Table 4 to be inserted]

5. Results

Agricultural Productivity in Nigeria

Table 5 shows the results of the crop productivity estimation of agricultural households in Nigeria, using the SFA with Greene (2010) correction for sample selection bias regarding the crop choice. The Cobb-Douglas specification applied here does not force the coefficients to add up to one. This could be done by imposing constant returns to scale constraints on the maximum likelihood estimation of the production function, but there was no convergence in using this method and the estimates would not be very different. The result shows that all inputs are statistically significant in the production function, but labour and land jointly contribute about 84% to output, with coefficient estimates 0.372 and 0.470 respectively.

[Table 5 and to be inserted]

Other inputs, which includes seeds, fertilizer, equipment etc., has a coefficient of 0.110. These results are indicative of the nature of agriculture practices in Nigeria. The agricultural system is more labour intensive than capital intensive, which is typical for traditional developing economies. This also shows that there might be potential for an overall frontier improvement by increasing capital intensity whilst releasing the extra labour to other productive industries. Sigma_v^2 is the estimate of the σ_v^2, Sigma_v^2 is the estimate of σ_u^2, gamma is the estimate of $\gamma = \sigma_u^2/\sigma_S^2$, and sigma^2 is the estimate of $\sigma_S^2 = \sigma_v^2 + \sigma_u^2$. Due to the restrictions on gamma, the optimization is parameterised in terms of its inverse logit, and this estimate is reported as ilgtgamma. Likewise, because Sigma^2 must be positive, the optimization is parameterised in terms of ln(σ_S^2) or lnsigma^2. Mu is the estimate of μ, which is the mean of the truncated-normal distribution. The Wald test verifies the overall significance of the explanatory variables in the production function model and this is significantly different from 0 in the results.

The results, the overall productivity of the farmers in terms of technical efficiency averages about 68%. This is not very different from other estimates that have been obtained by more crop-specific studies (e.g., 89% by Adeyemo et al., 2010; 81% in Ebong et al., 2009; 65% in Onyenweaku and Ohajianya 2009; and 68% in Amaza et al., 2005). Given that technical efficiency represents how effectively inputs produce the output in comparison with the maximum output level which could be achieved by the same set of inputs, our estimates suggest that there is room for improvement in productivity given the current levels of inputs and technology.

Table 6 shows the cross-tabulation of the crop choice variables ($\mathbf{C_1}$ and $\mathbf{C_2}$) and the average productivities of households which were derived by SFA *without* Greene correction for sample selection bias. It will be noticed that there are, on average, higher productivities figures for households who grow either export-oriented crops or tubers and roots. These differences range from 1.5% to 4%. However, cross-tabulations should not provide any evidence on causality, as they do not take into account possible explanatory variables. Below we will carry out more formal tests by utilizing the panel time framework, and controlling for other extenuating characteristics.

[Table 6 to be inserted]

Table 7 shows the variation in productivity across the sample by gender and age of the household head as well as household land size based on the first wave.[6] It indicates that males in the sample are more productive than females with average productivity of 66% as opposed to 62%. As expected, the most productive age range is between 20 and 60. The results of Table 7 can be associated with the Schultz (1964) hypothesis of "the efficient small farmer". It is noted that Schultz formulated the hypothesis that small-scale farmers in developing countries were "poor-but-efficient", implying that they made the best decisions in allocating their scarce resources by responding to price incentives. Consistent with the Schultz hypothesis, the productivity is found to reduce as land size increases. Furthermore, in general, most of the proportions of the sections fall within the 50-75% range of productivity.

[Table 7 to be inserted]

[6] We have obtained similar results for the second wave. They will be furnished on request.

Impact of crop choice on productivity and poverty

This sub-section reports the results of the treatment effects model to estimate the determinants of crop choice and hence the impact of this choice on productivity and mean per capita consumption expenditure (MPCE). Here the low level of MPCE implies poverty. In essence, we will test whether the productivity and welfare differences between the two groups of farmers with different crop choices are significantly different from zero after controlling for household characteristics and addressing the endogeneity associated with the farmers' crop choice.

The results are reported in Tables 8 and 9. This analysis has been carried out using the two categorical crop choice variables as previously defined. Columns 1 and 2 show the results based on $\mathbf{C_1}$, and columns 3 and 4 report those based on $\mathbf{C_2}$. Columns 1 and 3 in both tables are the results of the first stage selection into the treatment equation, determining the probability of being treated (growing $\mathbf{C_1}$ and $\mathbf{C_2}$). However, since these are drawn from probabilistic functions and not from linear probability modelling, the coefficients cannot be interpreted as probabilities, but indicate the direction of the effect and its statistical significance. Columns 2 and 4 are the results of the impact equation of the second stage, showing the average treatment effect on the treated.

[Tables 8 and 9 to be inserted]

The exclusion restrictions used for the productivity equation are the amount of free input used in production, the amount of non-farm income the household possesses and the amount of seed used from the previous growing season. On the contrary, for the consumption expenditure equation, only the free input and previous year's seeds are used because non-farm income is directly related to household expenditure. These variables were positive and significant in determining participation in growing export-oriented crops and tubers or roots.

For the use of the previous year's seeds variable, the data show that the greater the amount of primary input like seeds that were saved from the previous year, the more likely it would be for that agricultural household to plant the same crop in the next growing season. The amount of free agricultural input received is positive and significant at the 1% significance level in all the regressions. This indicates that at the point where farmers decide on the crop to produce, there is scope to influence their decisions by the amount of free agricultural inputs they are given. The positive parameter estimate implies that the more inputs received, the more likely the households would choose to produce tuber or root crops and more export-oriented crops.

This is because some types of crops require a greater initial investment where free inputs act as a buffer to reduce the costs, or risks, of planting those crops.

Other major significant determinants of crop choice include the regions in which the household resides, the size of the household and the gender of the household head. The regions are important because some crops grow better in some areas than others, and the simple imposition of topological or geographic constraints could influence the determination of crop produced. The size of the household is significant and negative. This indicates that the larger a household is, the less likely they are to plant tubers, roots or exportable crops. This is possibly because different crops would require different capital outlays and the head of a larger household is likely to more reluctant to put up this sum.

On the impact of the choice on productivity, there is a mixed result. Using $\mathbf{C_1}$ as a measure of crop choice shows no statistically significant effect on productivity at all, but $\mathbf{C_2}$ is significant. This result is expected given the trend described earlier in Figure 2, which showed roots and tubers dominating cereals and fibres in productivity. However, the difference between the productivities of the agricultural households who engage in the more export-oriented crops is not that different from the rest.

Table 9 indicates, however, that both $\mathbf{C_1}$ and $\mathbf{C_2}$ have a significant effect and are important in explaining the differences in poverty outcomes of the two groups of farmers, but with an unexpected sign. The estimated coefficients are negative, implying that the farmer who has grown these types of crops (i.e., the most exported crops or tuber and root crops) has a lower mean household expenditure per capita (MPCE) on average. One possible explanation for this might be that cassava included in both $\mathbf{C_1}$ and $\mathbf{C_2}$ is the raw material for major staple food in Nigeria, and as such, a substantial portion of the produce is consumed within the household. If this is the case, such self-consumption is not included in the household expenditure in our dataset and therefore the coefficient on the MPCE may be negatively biased.

Finally, Tables 10 and 11 report the results of the impact of commercialization and its interactions with the categorical choice variables on productivity. In each table, columns 1 and 2 show the results for commercialization, columns 3 and 4 for the impact of commercializing the export-oriented crop grown and columns 5 and 6 for the impact of commercializing tuber and root crops. The results show that the household index of commercialization is not a statistically significant determinant of productivity, but it is significant for poverty. This is surprising because one might expect that the more commercialized a farm household is, the better its productivity should be due to the monetary incentives in producing the most output possible with the lowest amount of inputs. However, the incentives to the household head of increasing productivity to keep his family fed may be greater than the incentives from doing so for the sake of the possible monetary value of his goods. Our results thus imply that if the government is interested in increasing productivity, it should prioritise food security over commercialization. The result in Table 11 that commercialization is an important determinant of poverty implies that, if poverty alleviating policy is the main policy agenda, commercialization would be a policy to push forward and implement. It is not clear, however, how these two relationships come together. From the coefficients of the interactions, it appears they simply echo and amplify the effects of the commercialization variables.

[Tables 10 and 11 to be inserted]

6. Conclusion

The present study aims to examine the arguments on whether or not smallholder farmers in Nigeria who produce certain types of crops (export-oriented crops and roots and tubers) experience any productivity and welfare differences, and to examine the factors which determine the crop choices of these farmers. Using the two rounds of LSMS panel data from Nigeria in 2010/11 and 2012/13, we re-examined the old arguments surrounding whether small-holder farmers are indeed "efficient but poor". We have carried out stochastic frontier analysis with Greene's (2010) correction for sample selection about crop choices, and have found that smallholders are generally efficient in their allocation of resources. However, the smallholders were not necessarily rational in their crop choices because, even when some crops are found to be more productive than others, the less productive crop was often chosen. To figure out why, a treatment effects model was employed to determine farmer selection into the choice of a type of crop in the first stage and the impact of their choices on productivity and poverty – proxied by a low level of the household expenditure - in the second stage. It was discovered that access to free inputs, non-farm income, the use of seeds from the previous growing season, household size, gender and the different regional differences were the main determinants of crop choice. Also, crop choice influenced the productivity and poverty of the households in different ways. While the choice of tuber and root crop improved productivity, it also reduced consumption poverty. In addition, the choice of highly commercialized crops is found to be important for poverty alleviation, but not for productivity improvement.

Our results would provide a few important policy implications. Implications of our research may differ depending on the national poverty alleviation strategy of the government, but far less effort would be needed to lift these groups of farmers out of poverty. First, our results suggest that agricultural household crop choices are not random, but can be predicted by socioeconomic factors. This means that there are factors that could influence the eventual choice of the crop planted. If the government wishes to promote cash crop productions, the policies helping farmers purchase inputs at lower prices (e.g., microcredit programmes or subsidies for poor farming households) would be useful in this context. Second, our results indicate that crops grown for export purposes attract better financial benefits to the farmer and alleviate consumption poverty (albeit with reduced total factor productivity, at least, initially, mostly due to farmer's inexperience and the lack of mechanization). Third, educating farmers on the marketing opportunities for their products, if it results in greater commercialization, would also have positive welfare effects. Finally, the agricultural extension could be utilised to get more people within areas of comparative advantage to switch to these high productivity crops to improve their welfare outcomes.

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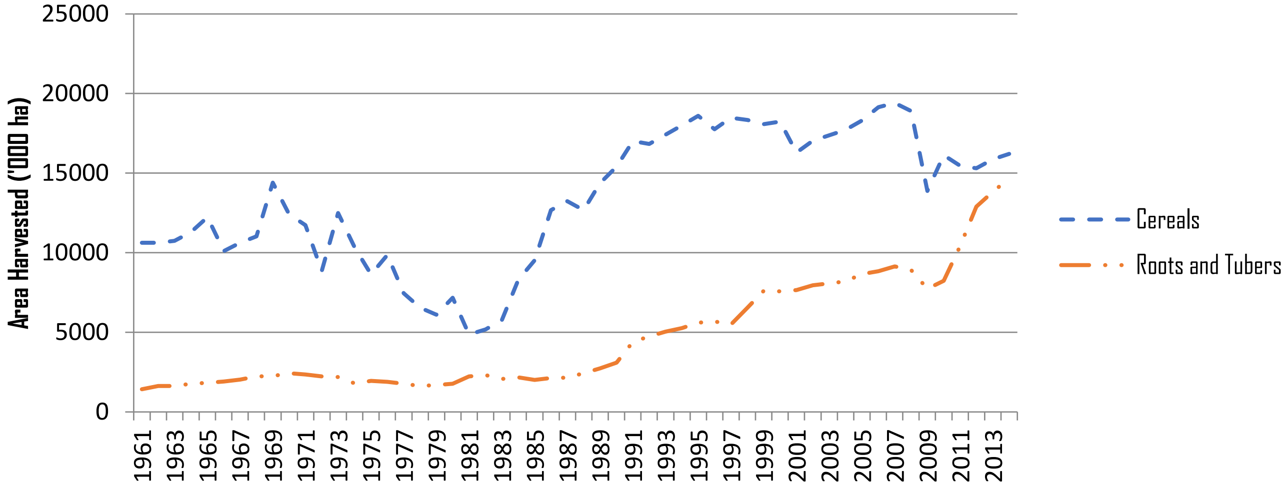
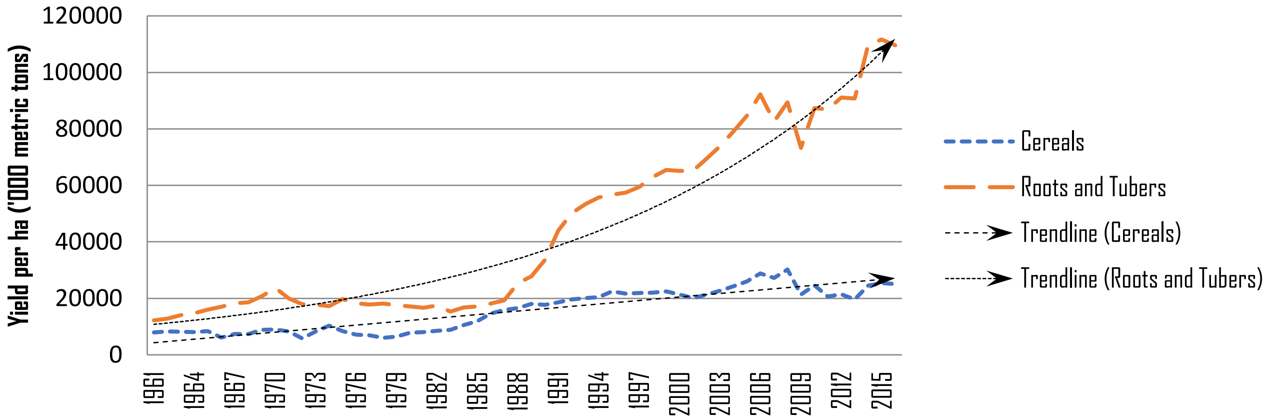
Figure 1: Time Trend of Area Harvested for Cereals, Roots and Tubers in Nigeria



Source: Authors' drawing from FAOSTAT database, 2016 database

Figure 2: Time Trend of Yield/Ha for Cereals, Roots and Tubers in Nigeria



Source: Authors' drawing from FAOSTAT database, 2016 database

Table 1: Selected Crops with Outputs, Prices and Expected Revenues

Crop	Land Area ('000 ha)	Output ('000 metric tons)	Avg. Price per kg (Naira)	Avg. Revenue per ha ('000 Naira)
Yam	3236.16	37328.17	76.07	877.45
Cassava	3481.88	42533.17	65.31	797.79
Cocoyam	520.12	2957.09	80.00	454.83
Cotton	398.56	602.44	230.22	347.99
Melon	469.7	507.34	123.06	132.92
Rice	2432.64	4472.51	72.03	132.43
Maize	4149.33	7676.85	64.65	119.61
Guinea corn	4960.13	7140.96	73.08	105.21
Beans	2859.77	3368.24	83.03	97.79
Groundnut	2785.17	3799.15	69.02	94.15
Soyabeans	291.38	365.06	60.03	75.21
Millet	4364.16	5170.45	58.53	69.34

Source: Nigerian Bureau of Statistics (NBS), 2009

Table 2: List of crops classified as C_1 (by most exported)

Crops (C_1)	Export ('000 metric tons)	% of sample (wave 1)	% of sample (wave 2)
Cassava	42,533.17	10.42	6.48
Sugarcane	1,429.57	0.04	0.04
Cotton	533.31	0.16	0.19
Ginger	167.29	0.08	0.08
Sesame seed (Beni-seed)	127.60	0.36	0.35
Total	44790.94	11.06	7.14

Source: Author's calculation based on the Nigerian LSMS data for 2011 and 2013.

Table 3: List of crops classified as $\mathbf{C_2}$ (by being a tuber or root)

Crop	% of sample (wave 1)	% of sample (wave 2)
Yam	21.51	23.17
Cassava	10.42	6.48
Cocoyam	1.49	1.71
Groundnuts	1.79	1.45
Potatoes	0.58	0.64
Ginger	0.08	0.08
Total	35.87	33.53

Source: Authors' calculation based on the Nigerian LSMS data for 2011 and 2013

Table 4: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Primary output is C1 crop	0.11	0.32	0	1
Primary output is C2 crop	0.35	0.47	0	1
Household Commercialization Index (C3)	48.22	7.36	0	80.40
ln(Total Food Auto-Consumed in HH)	10.75	1.21	1.78	13.94
ln(output)	10.98	1.72	0	15.59
ln(land)	8.89	1.73	0	13.04
ln(labour)	4.26	5.30	0	16.73
ln(inputs)	7.01	4.41	0	14.25
Age of HH Head	50.09	15.10	16	110
Marital Status of HH (Married=1)	0.75	1.71	0	1
Religion of HH Head (Christian=1)	0.53	0.55	0	1
Gender of HH Head	0.89	0.31	0	1
Number of adult males in household	1.36	0.93	0	11
Number of adult females in household	1.54	0.89	0	7
Number of dependent males in household	1.69	1.62	0	16
Number of dependent females in household	1.51	1.47	0	11
Household size	6.11	3.13	1	31
Literate (Can read and write=1)	0.47	0.49	0	1
Years of education of HH Head	3.89	3.24	1	13
Rural	0.89	0.32	0	1
Mean per capita expenditure (MPCE) in naira	448408.6	290725.4	33907.57	2975185

Source: Authors' calculation based on the Nigerian LSMS data for 2011 and 2013.

Table 5: Results of the Stochastic Frontier Analysis model with Greene (2010) correction for sample selection bias

	Cobb-Douglas (Time Varying Decay-TVD)	
	Coefficient	SE
Constant	3.016	43.130
lnLand	0.372***	0.013
lnLabour	0.470***	0.004
lnInput	0.110***	0.005
Sigma^2	1.975	0.039
Gamma	0.163	0.023
Sigma_u^2	0.322	0.048
Sigma_v^2	1.652	0.052
lnSigma^2	0.680***	0.019
ilgtgamma	-1.633***	0.171
Mu	4.387	43.131
Statistics		
No. of obs.	5192	
No. of groups	3045	
Wald chi^2	1359.16***	

Note: *** represents significance at 1% alpha

Source: Authors' calculation based on the Nigerian LSMS data for 2011 and 2013.

Table 6: Cross tabulation of crop choice variables and average technical efficiency

		C_1		Difference between 1 & 0	C_2		Difference between 1 & 0
		1	0		1	0	
TE	t = 1	0.660	0.640	0.020	0.666	0.651	0.015
	t = 2	0.644	0.611	0.033	0.670	0.620	0.04

Source: Authors' calculation based on the Nigerian LSMS data for 2011 and 2013.

Note: The estimates are based on SFA for sub-samples of the data without the Greene (2010) correction, while the results in all other tables are based on SFA with the Greene correction.

Table 7: Productivities of different segments of the population by the characteristics of the household heads (from Wave 1) based on SFA with Greene (2010) correction for sample selection bias

	Male	Female	Age (<20)	Age (20-60)	Age (>60)	Land size (<1ha)	Land size (1-5ha)	Land size (5-10ha)	Land size (>10ha)
Productivity (<25%)	4%	15%	7%	2%	7%	9%	5%	11%	2%
Productivity (25-50%)	24%	35%	19%	9%	12%	19%	20%	19%	40%
Productivity (50-75%)	62%	48%	65%	70%	66%	69%	65%	65%	46%
Productivity (>75%)	10%	2%	9%	19%	15%	8%	10%	5%	12%
Overall Average Productivity	66%	62%	64%	70%	66%	69%	69%	64%	63%

Source: Authors' calculation based on the Nigerian LSMS data for 2011 and 2013

Table 8: Treatment Effects Model Results for the Selection of Crop equation and the impact of Crop Choice on Productivity (Technical Efficiency)

	C_1 – Farmer chose a commonly exported crop		**C_2** – Farmer chose a tuber/root crop	
	Selection	Impact	Selection	Impact
	(1)	(2)	(3)	(4)
Crop Choice		0.0014		0.045*** (0.004)
		(0.005)		
Age of HH Head	0.01	0.0010*	0.019	0.001
	(0.35)	(0.0006)	(0.45)	(0.001)
Age Square of HH Head	-0.022	-0.0000	-0.022	-0.000
	(0.22)	(0.0000)	(0.22)	(0.000)
Education of HH Head	2.02e-05	-0.0136***	2.02e-05	-0.012***
	(1.81e-05)	(0.0028)	(1.01e-05)	(0.003)
HH Size	0.128*	-0.808***	0.129*	0.003***
	(0.008)	(0.280)	(0.007)	(0.001)
Sex of HH Head	0.233***	0.766***	0.235***	0.028***
	(0.054)	(0.316)	(0.054)	(0.007)
Rural	-0.22	0.005	-0.22	0.007
	(0.34)	(0.004)	(0.34)	(0.004)
Female Share	-7.55e-05	-0.002	-7.05e-05	-0.002*
	(0.00)	(0.001)	(0.00)	(0.001)
Married	0.118*	0.000	0.118*	-0.000
	(0.063)	(0.001)	(0.063)	(0.001)
Region1 (NW)	0.167	-0.008*	-0.181	-0.006
	(0.209)	(0.004)	(0.150)	(0.004)
Region2 (NC)	1.074***	0.036***	1.557***	0.019***
	(0.187)	(0.004)	(0.123)	(0.004)
Region3 (SW)	1.737***	0.003	1.738***	-0.011
	(0.212)	(0.007)	(0.161)	(0.007)
Region4 (SE)	1.031***	-0.020***	2.284***	-0.049***
	(0.192)	(0.005)	(0.132)	(0.005)
Region5 (SS)	2.207***	0.003	2.885***	-0.031***
	(0.193)	(0.006)	(0.157)	(0.006)
Free Inputs[#]	0.677***		0.334***	
	(0.023)		(0.033)	
Non-farm income[#]	0.118*		0.11**	
	(0.0638)		(0.062)	
Previous year's seeds[#]	0.420*		0.484***	
	(0.10)		(0.064)	
Constant	-2.384***	0.588***	-2.538***	0.592***
	(0.495)	(0.018)	(0.419)	(0.017)

N	2422	2422	2422	2422
Time Dummies	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; # Exclusion restrictions

Source: Authors' calculation based on the Nigerian LSMS data for 2011 and 2013.

Table 9: Treatment Effects Model Results for the Selection of Crop equation and the impact of Crop Choice on Poverty (log MPCE)

	C_1 – Farmer chose a commonly exported crop		**C_2** – Farmer chose a tuber/root crop	
	Selection (Probit)	Impact	Selection (Probit)	Impact
	(1)	(2)	(3)	(4)
Crop Choice		-0.183**		-0.161***
		(0.066)		(0.022)
Age of HH Head	-0.007	0.008	0.019	-0.001
	(0.019)	(0.007)	(0.45)	(0.003)
Age Square of HH Head	0	0	-0.022	0
	(0)	(0)	(0.22)	(0)
Education of HH Head	-0.036	0.067	2.02e-05	0.090***
	(0.095)	(0.037)	(1.01e-05)	(0.017)
HH Size	0.128*	0.152***	0.129*	0.079***
	(0.008)	(0.008)	(0.007)	(0.004)
Sex of HH Head	0.233***	-0.300**	0.235***	-0.004
	(0.054)	(0.096)	(0.054)	(0.044)
Rural	-0.22	0.011	-0.22	-0.142***
	(0.34)	(0.057)	(0.34)	(0.026)
Female Share	-7.55e-05	-0.079***	-7.05e-05	0.009
	(0.00)	(0.016)	(0.00)	(0.008)
Married	0.118*	-0.085***	0.118*	-0.056***
	(0.063)	(0.017)	(0.063)	(0.008)
Region1 (NW)	0.560*	-0.118*	-0.181	-0.267***
	(0.270)	(0.052)	(0.150)	(0.024)
Region2 (NC)	1.266***	-0.221***	1.557***	0.060*
	(0.257)	(0.056)	(0.123)	(0.027)
Region3 (SW)	1.276***	-0.038	1.738***	0.019
	(0.289)	(0.087)	(0.161)	(0.041)
Region4 (SE)	1.277***	-0.239***	2.284***	-0.159***
	(0.263)	(0.061)	(0.132)	(0.032)
Region5 (SS)	2.471***	-0.087	2.885***	0.140***
	(0.263)	(0.080)	(0.157)	(0.039)
Free Inputs#	0.677***		0.334***	

	(0.023)		(0.033)	
Previous year's seeds#	0.420*		0.484***	
	(0.10)		(0.064)	
Constant	-2.706***	11.084***	-2.538***	12.069***
	(0.619)	(0.235)	(0.419)	(0.109)
N	2422	2422	2422	2422
Time Dummies	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; # Exclusion restrictions

Source: Authors' calculation based on the Nigerian LSMS data for 2011 and 2013

Table 10: Results of Impact of Crop Commercialization with Crop Choice on Productivity

	FE	CRE	FE	CRE	FE	CRE
	(1)	(2)	(3)	(4)	(5)	(6)
C3 – Commercialization	-0.011	0.067				
	(0.057)	(0.037)				
C3*C1 – by export and commercialization			0.014	0.00844		
			(0.05)	(0.34)		
C3*C2 – by tuber/root crop and commercialization					0.035***	0.055***
					(0.004)	(0.004)
Age of HH Head	0.096***	0.008	0.096***	0.008	0.096***	0.008
	(0.027)	(0.007)	(0.027)	(0.007)	(0.027)	(0.007)
Age Square of HH Head	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sex of HH Head	-1.740	-0.300**	-1.740	-0.300**	-1.740	-0.300**
	(1.025)	(0.096)	(1.025)	(0.096)	(1.025)	(0.096)
Education of HH Head	0.096	0.067	0.096	0.067	0.096	0.067
	(0.095)	(0.037)	(0.095)	(0.037)	(0.095)	(0.037)
HH Size	0.747***	0.152***	0.747***	0.152***	0.747***	0.152***
	(0.045)	(0.008)	(0.045)	(0.008)	(0.045)	(0.008)
Rural	0.01	0.019***	0.01	0.019***	0.01	0.019***
	(0.35)	(0.01)	(0.35)	(0.01)	(0.35)	(0.01)
Female Share	-0.022	-0.050	-0.022	-0.050	-0.022	-0.050
	(0.22)	(0.041)	(0.22)	(0.041)	(0.22)	(0.041)
Married	2.02e-05	0.358	2.02e-05	0.358	2.02e-05	0.358
	(1.81e-05)	(0.041)	(1.81e-05)	(0.041)	(1.81e-05)	(0.041)
Region1 (NW)		-0.808***		-0.808***		-0.808***
		(0.280)		(0.280)		(0.280)
Region2 (NC)		0.766***		0.766***		0.766***
		(0.316)		(0.316)		(0.316)
Region3 (SW)		-0.001		-0.001		-0.001
		(0.00)		(0.00)		(0.00)
Region4 (SE)		-0.299		-0.299		-0.299
		(0.270)		(0.270)		(0.270)
Region5 (SS)		-0.087		-0.087		-0.087
		(0.080)		(0.080)		(0.080)
Constant	10.23***	11.095***	10.23***	11.095***	10.23***	11.095***
	(0.326)	(0.229)	(0.326)	(0.229)	(0.326)	(0.229)
N	2422	4844	2422	4844	2422	4844
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1

Source: Authors' calculation based on the Nigerian LSMS data for 2011 and 2013

Table 11: Results of the Impact of Crop Commercialization with Crop Choice on Poverty

	FE	CRE	FE	CRE	FE	CRE
	(1)	(2)	(3)	(4)	(5)	(6)
C3 – Commercialization	-0.142***	-0.056***				
	(0.026)	(0.008)				
C3*C1 – by export and commercialization			0.019*	0.0178***		
			(0.00766)	(0.006)		
C3*C2 – by tuber/root crop and commercialization					-0.095*	-0.161***
					(-0.021)	(0.022)
Age of HH Head	0.096***	-0.001	0.096***	-0.001	0.096***	-0.001
	(0.027)	(0.003)	(0.027)	(0.003)	(0.027)	(0.003)
Age Square of HH Head	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sex of HH Head	-1.740	0.090***	-1.740	0.090***	-1.740	0.090***
	(1.025)	(0.017)	(1.025)	(0.017)	(1.025)	(0.017)
Education of HH Head	0.096	0.079***	0.096	0.079***	0.096	0.079***
	(0.095)	(0.004)	(0.095)	(0.004)	(0.095)	(0.004)
HH Size	0.747***	-0.004	0.747***	-0.004	0.747***	-0.004
	(0.045)	(0.044)	(0.045)	(0.044)	(0.045)	(0.044)
Rural	0.01	-0.142***	0.01	-0.142***	0.01	-0.142***
	(0.35)	(0.026)	(0.35)	(0.026)	(0.35)	(0.026)
Female Share	-0.022	0.009	-0.022	0.009	-0.022	0.009
	(0.22)	(0.008)	(0.22)	(0.008)	(0.22)	(0.008)
Married	2.02e-05	-0.056***	2.02e-05	-0.056***	2.02e-05	-0.056***
	(1.81e-05)	(0.008)	(1.81e-05)	(0.008)	(1.81e-05)	(0.008)
Region1 (NW)		-0.267***		-0.267***		-0.267***
		(0.024)		(0.024)		(0.024)
Region2 (NC)		0.060*		0.060*		0.060*
		(0.027)		(0.027)		(0.027)
Region3 (SW)		0.019		0.019		0.019
		(0.041)		(0.041)		(0.041)
Region4 (SE)		-0.159***		-0.159***		-0.159***
		(0.032)		(0.032)		(0.032)
Region5 (SS)		0.140***		0.140***		0.140***
		(0.039)		(0.039)		(0.039)
Constant	5.198***	11.095***	5.198***	11.095***	5.198***	11.095***
	(1.233)	(0.229)	(1.233)	(0.229)	(1.233)	(0.229)
N	2422	4844	2422	4844	2422	4844
Time Dummies	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors in parentheses and *** p<0.01, ** p<0.05, * p<0.1A

Source: Authors' calculation based on the Nigerian LSMS data for 2011 and 2013

Households' crop choice, $\boldsymbol{C}_{it}$, in Equation (5) can be written as:

$$\boldsymbol{C}_{it}^{*} = \gamma \boldsymbol{Z}_{it} + \varepsilon_{it} \qquad \text{(A1)}$$

The selection into treatment $\boldsymbol{C}_{it}^{*}$ in this model is a function of ε_{it}, which is correlated with ν_{it}, the error term in the outcome equation of $\boldsymbol{Y}_{it}$ above. Thus, $\boldsymbol{C}_{it}^{*}$ is an unobserved latent variable (what is observed in the data is simply the choice, but not the underlying activity). The assumption is made that this is a linear function of the exogenous covariates $\boldsymbol{Z}_{it}$ and a random component ε_{it}. The relationship between the observed $\boldsymbol{C}_{it}$ and the latent $\boldsymbol{C}_{it}^{*}$ can be defined in this way:

$$\boldsymbol{C}_{it} = \begin{cases} 1, & if \quad \boldsymbol{C}_{it}^{*} < 0 \\ 0, & if \quad \boldsymbol{C}_{it}^{*} \geq 0 \end{cases} \qquad \text{(A2)}$$

The problem here is that estimating Equation (A1) directly by OLS would only be consistent if there is no correlation between ν_{it} and ε_{it} (notationally, this correlation is represented by ρ; so ideally, we want $\rho = 0$) (Greene, 2008). But in this case, ρ is not zero, thus a different method would have to be used to estimate the coefficients consistently.

Formally, if we assume that the binary data ($\boldsymbol{C}_{it}$) have been generated by an underlying normal distribution, the expected conditional outcome of productivity and poverty (Y_{it}) could be written in this way:

$$\begin{aligned} E[Y_{it}|\boldsymbol{C}_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}] &= \eta \boldsymbol{X}_{it} + \beta \boldsymbol{C}_{it} + \mu_i + E[v_{it}|\boldsymbol{C}_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}] \\ = \eta \boldsymbol{X}_{it} + \beta \boldsymbol{C}_{it} + \mu_i & \\ &+ \left[\rho_1 \sigma_{v_1} \{\phi(\gamma \boldsymbol{Z}_{it}) / \Phi(\gamma \boldsymbol{Z}_{it})\} | \boldsymbol{C}_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}\right] P(\boldsymbol{C}_{it} = 1|\boldsymbol{X}_{it}) \qquad (A3) \\ &+ \left[\rho_0 \sigma_{v_0} \{-\phi(\gamma \boldsymbol{Z}_{it}) / 1 - \Phi(\gamma \boldsymbol{Z}_{it})\} | \boldsymbol{C}_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}\right][1 - P(\boldsymbol{C}_{it} = 1|\boldsymbol{X}_{it})] \end{aligned}$$

Thus, the expected outcomes for farmers with different crop choices have been disaggregated. The expected outcome for a particular crop choice (the crop choice "1") would be:

$$E[Y_{it}|\boldsymbol{C}_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}] = \eta \boldsymbol{X}_{it} + \beta \boldsymbol{C}_{it} + \mu_i + \left[\rho_1 \sigma_{v_1} \{\phi(\gamma \boldsymbol{Z}_{it}) / \Phi(\gamma \boldsymbol{Z}_{it})\} | \boldsymbol{C}_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}\right]$$
(A4)

And the expected outcome/ for the other crop choice (or the crop choice "0") would be:

$$E[Y_{it}|\boldsymbol{C}_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}] = \eta \boldsymbol{X}_{it} + \mu_i + \left[\rho_0 \sigma_{v_0} \{-\phi(\gamma \boldsymbol{Z}_{it})/1 - \Phi(\gamma \boldsymbol{Z}_{it})\} | \boldsymbol{C}_{it}, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}\right] \quad \text{(A5)}$$

Here, $\rho_1 \sigma_{v_1}$ represents the covariance between ν_i and ε_i for farmers with the crop choice "1", $\rho_0 \sigma_{v_0}$ represents the covariance between ν_{it} and ε_{it} for those with another crop choice (the crop choice "0"), $\phi(\gamma \boldsymbol{Z}_{it})$ is the marginal probability of the standard normal distribution at $\gamma \boldsymbol{Z}_{it}$ and $\Phi(\gamma \boldsymbol{Z}_{it})$ is the cumulative distribution function of the standard normal distribution at $\gamma \boldsymbol{Z}_{it}$. Equations (9) and (10) above include the "Inverse Mills Ratio" to control for the possible sample selection bias. The difference between the expected outcomes of the treated and non-treated becomes:

$$E[Y_{it}|\boldsymbol{C}_{it} = 1, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}] - E[Y_{it}|\boldsymbol{C}_{it} = 0, \boldsymbol{X}_{it}, \boldsymbol{Z}_{it}] = \beta + bias\ from\ selection \quad \text{(A6)}$$

In this case, it is expected that there is a positive bias on the OLS estimates (that it overestimates the impact of the crop choice "1" on productivity and poverty), as ρ is positive. The coefficients are estimated by maximum log likelihood as this provides consistent estimates. The usual log likelihood equations are as follows:

$$lnL_{it} \begin{cases} ln\Phi\left\{\frac{\gamma \boldsymbol{Z}_{it} + (Y_{it} - \eta \boldsymbol{X}_{it} - \beta)\rho/\sigma}{\sqrt{1-\rho^2}}\right\} - \frac{1}{2}\left(\frac{Y_{it} - \eta \boldsymbol{X}_{it} - \beta}{\sigma}\right)^2 - \ln\left(\sqrt{2\pi\sigma}\right), & \boldsymbol{Z}_{it} = 1 \\ ln\Phi\left\{\frac{-\gamma \boldsymbol{Z}_{it} - (Y_{it} - \eta \boldsymbol{X}_{it})\rho/\sigma}{\sqrt{1-\rho^2}}\right\} - \frac{1}{2}\left(\frac{Y_{it} - \eta \boldsymbol{X}_{it}}{\sigma}\right)^2 - \ln\left(\sqrt{2\pi\sigma}\right), & \boldsymbol{Z}_{it} = 0 \end{cases} \quad \text{(A7)}$$

So in reduced form, there are two stages of regression; the first stage is the regression to estimate the probability for a farmer choosing to grow a type of crop, conditional on $\boldsymbol{Z}_{it}$; the inverse mills ratio was computed from the residuals and used in the second stage – an impact regression of the $\boldsymbol{X}_{it}$ and the IMR as an extra regressor to deflate the selection bias on productivity and poverty. The $\boldsymbol{Z}_{it}$ vector of variables used in the first stage would include selection restrictions, which are parameters that influence choice but do not "directly" influence productivity or poverty, and as such would not belong in the main impact equation of interest. Instruments that will satisfy the exclusion restrictions which have been used here are the amount of stored seed from the previous season used in planting the current season, and the amount of free seed received by the farmer and used in planting.

For the continuous crop choice variable (**C_3**) and its interactions, a Fixed Effects (FE) model or a Correlated Random Effects (CRE) model is will be used to address endogeneity due to unobserved time-invariant characteristics. The FE method addresses potential biases by using the variation in commercialization within a household over the two time periods to identify the causal effect of crop commercialization on productivity (Wooldridge, 2002). However, a limitation of the FE model is that we are unable to use the time-invariant variables. This can be an issue when important variables affecting productivity such as gender are time-invariant. On the other hand, The CRE model can address endogeneity due to unobserved time-invariant factors with time-invariant variables (Wooldridge, 2010; Sheahan et al., 2013).