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Technical Efficiency of Sweet Potato Farmers in Okene Local Government Area of Kogi State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author DOO design the study, wrote the proposal, performed the data analyses and wrote the first and final draft of the manuscript. Authors JOO and OJS managed the literature searches and participated in data collection. Authors SJI, UCI, FCA, OSU and SIA participated in data collection and processing. All authors read and approved the final manuscript.

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ABSTRACT

This study analyzed technical efficiency of sweet potato farmers in Okene Local Government Area of Kogi State, Nigeria. A sample of 80 sweet potato farmers was selected using the multistage sampling technique. Structured questionnaire was used for data collection. This implies that sweet potato farmers in the study area are technical inefficient in resource use, and therefore technical efficiency could be increased by 53% through optimal reallocation of existing resources. This result also reveals that level of education, farming experience; household size and credit access are important factors contributing to technical efficiency. Sweet potato farmers with higher education that acquired more farming experience have small household size and have access to credit

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tends to be more efficient. Therefore, policies that will enable the farmers to improve on their education and grant them increased access to credit to be vigorously pursued for increasing the farmers' efficiency and income.

Keywords: Technical efficiency; stochastic frontier; sweet potato; farmers.

1. INTRODUCTION

Sweet potato (*Ipomoea batatas*) is a creeper of the convolvulacea family. It originated from Central America and is widely cultivated as important staple food in most parts of the world. Presently, Nigeria is the largest producer of sweet potato in Africa with annual output of 3.46 million metric tons, and globally the second largest producer after China [1,2]. Sweet potato is grown for both human and livestock consumption, and it is the only crop among the root and tuber crops that has a positive per capita annual rate of increase in production in sub-Saharan Africa [3]. It is the only member of the genus, *Ipomoea* whose roots are edible and one of the world's most important food crops due to its high yield and nutritive value.

Sweet potatoes offer significant potential for increasing food production and income in Nigeria. It has a high yield potential that may be realized within a relatively short growing season and adaptability to a wide ecological range of 0 to 2000 meters above sea level [4]. Sweet potato is consumed without much processing in most parts of the tropics. It is either eaten boiled, roasted or fried. The roots can also be slightly fermented in water for 2-3 days to reduce the sweetness, then sun dried and milled, mixed with either yam or cassava flour for human consumption. The leaves and tender shoots of sweet potato are used as vegetables. The leaf contains, on dry matter basis, about 8% starch, 4% sugar, 27% protein and vitamins, and therefore are very nutritious. It also contains about 56 mg carotene per 100gm dry mater. The leaves are usually eaten boiled or incorporated into soup and stew [5].

Industrially, sweet potato flour can be used to substitute wheat in bread making or marine flour in balanced feeds. Baby foods have been formulated using sweet potato while some bakeries blend 15-30% of sweet potato flour for making bread and 20-30% for pastries. It is also used in the brewing of alcoholic drinks and as sweeteners in non-alcoholic drinks [6]. In spite of these important aspects, less research has been done on sweet potato than on the other root crops.

Cultivation of sweet potato in Kogi State of Nigeria is threatened by low prices of the crop and its products in the face of rising cost of production inputs and sweet potato farmers can hardly increase their production considering the meager returns from their harvest [4].

Consequently, ever-growing demand for sweet potato due to its numerous uses has remained a major challenge. The population is rapidly growing and exerts pressure on the increased demand for sweet potato. The low production of the crop may not only be tied to high cost of resource inputs, and low producer prices [4]. Greater emphasis is inevitable upon sweet potato farmer's efficient utilization of the available resources in an optimal manner. The need to improve the efficiency in sweet potato production for increased output to meet the growing demand has become imperative. No previous study in Okene Local Government Area (LGA) of Kogi State estimated the technical efficiency of sweet potato farmers, resulting in a dearth of information which this study intends to provide. This paper

estimates the technical efficiency of sweet potato farmers in Okene LGA of Kogi State, Nigeria.

Previous studies on efficiency of farmers can be classified broadly into the following three categories; namely, deterministic parametric estimation, non-parametric mathematical programming and the stochastic parametric estimation [7]. The use of non-parametric techniques are limited in efficiency measurement in agriculture despite the fact that non-parametric methodologies can be used in situation where data are more limited and where production technologies are less well understood [8,9].

Econometric modeling of stochastic frontier methodology of [10] associated with the estimation of efficiency has been an important area of research in recent years. Basically the studies are mostly based on Cobb-Douglas function and transcendental logarithmic (translog) functions that could be specified either as production functions or cost functions. The first application of stochastic frontier model to farm level data was by [11]. But technical efficiency of farms was not directly addressed in the work. K Kalirajan [12] estimated a stochastic frontier Cobb-Douglas production function using cross-sectional data and found the variance of farm effects to be a highly significant component in describing the variability of rice yield. FS Bagi [13] used the stochastic frontier Cobb-Douglas production function model to investigate whether there were any significant differences in the mean technical efficiencies of part-time and full-time farmers. Results showed no apparent significance, irrespective of whether the part-time and full-time farmers were engaged in mixed farming or crops-in only.

FS Bagi and CI Haung [14] estimated a translogarithmic stochastic frontier production using maximum likelihood estimation method, and the parameters were estimated and individual technical efficiencies ranged from 0.38 to 0.91. In most of the studies, it was found that the Cobb-Douglas stochastic frontier does not provide an adequate representation for describing the data given the specification of a translog model. The Cobb-Douglas frontier production function was used in this study since studies [18,21,22] noted that as long as interest rests on efficiency measurement and not on the general structure of the production technology.

The analysis of efficiency is generally associated with the possibility of farms producing a certain optimal level of output from a given bundle of resources at least cost. MJ Farrel [15] in [9] distinguishes between three types of efficiency;

- (a) Technical Efficiency, which is the physical ratio of output to the factor input. The greater the ratio, the greater the magnitude of technical efficiency.
- (b) Allocative or Price Efficiency. A farm is allocatively efficient when production occurs at a point where the marginal value product is equal to the marginal factor cost.
- (c) Economic Efficiency; which obtains where both technical and allocative efficiencies have been attained, and is therefore the product of technical and allocative efficiencies.

The achievement of either technical or allocate efficiency is a necessary but not a sufficient condition to ensuring economic efficiency. MJ Farrel [15] therefore suggested a method of measuring technical efficiency of a firm in an industry by estimating the production function of firms which are fully efficient (i.e. a frontier production function).

The study was conducted in Okene Local Government Area (LGA) of Kogi State, Nigeria. Okene LGA is within the derived Savannah zone vegetation belt, marked with two clearly defined seasons, the wet and dry season.

2. MATERIALS AND METHODS

The wet season starts in late March with annual rainfall ranging from 1016mm to 1152mm and the maximum precipitation occurs toward the end of October. The dry season starts from November to early March. The people of Okene LGA are predominantly farmers, cultivating sweet potato, yam, maize, vegetables, cassava, sesame, sorghum and groundnut. They also keep livestock such as goats, sheep and poultry.

The study used multi-stage sampling technique to select representative sample. Five communities were purposively selected from a list of communities in the LGA obtained from the community development office at the LGA headquarters, based on their sweet potato production data with the state Agricultural Development Programme (ADP). Two villages were purposively selected from each sampled community based on the intensity of sweet potato production, making a total of 10 villages. The sampling frame was the list of sweet potato farmers in the sampled villages compiled with the assistance of extension agents. From this sampling frame totaling 105 sweet potato farmers, a sample size of 80 farmers were selected for the study using simple random sampling technique.

Data were collected on the socio-economic characteristics of the farmers, production activities in terms of inputs, outputs and their prices, using questionnaire.

2.1 Data Analysis

The econometric modeling of stochastic production efficiency frontier model independently proposed by [10] and [16] extended by [17] and applied by [9] and [18] was used in the analysis of data.

The frontier production model begins by considering a stochastic production function with a multiplicative disturbance term of the form;

$$Y = f(X_a; \beta)e^E \dots \dots \dots (1)$$

where, Y is the quantity of agricultural output, X_a is the vector of input quantities, β is vector of parameters, e represents exponential, and E is stochastic disturbance term consisting of two independent elements V and U, where

$$E = U+V \dots \dots \dots (2)$$

The symmetric component V, accounts for random variation in output due to factors outside the farmer's control, such as weather, diseases and pests. It is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$. A one-sided component, $U \leq 0$ reflects technical inefficiency relative to the stochastic frontier, $f(X_a; \beta)e^E$. Thus, $U=0$ for a farm output lying on the frontier and $U < 0$ for one whose output is below the frontier as $N(0, \sigma_u^2)$ i.e, the distribution of U is half-normal [19].

The frontier of the farm is given by combining equations (1) and (2) as follows;

$$Y = f(X_a; \beta)e^{(u+v)} \dots\dots\dots(3)$$

Measure of production efficiency for each farm can be calculated as;

$$TE = \exp [E(U/E)] \dots\dots\dots(4)$$

In the efficiency analysis, the (19) single stage model was applied, where U in equation (3) is a non-negative random variable which is the efficiency associated with technical efficiency factors in production of the sample farmers. It is assumed that the efficiency factors are independently distributed and that U arises by the truncation (at zero) of the normal distribution, with mean U and variance δ^2 where U in equation [3] is defined as,

$$U = f(Z_b; \delta^2) \dots\dots\dots(5)$$

Where, Z_b is vector of farmer-specific factors and δ is vector of parameters. The β and δ -coefficients in equation [1] and [5] respectively are unknown parameters to be simultaneously estimated together with the variance parameter which is expressed in the form;

$$I = \delta_u^2 / (\delta_u^2 + \delta_v^2) \dots\dots\dots(6)$$

Where I parameter has a value between zero and one.

2.2 The Empirical Model

The Cobb-Douglas stochastic frontier production function is specified as;

$$\ln Y_{ij} = \beta_0 + \beta_1 \ln X_{1ij} + \beta_2 \ln X_{2ij} + \beta_3 \ln X_{3ij} + \beta_4 \ln X_{4ij} + \beta_5 \ln X_{5ij} + V_{ij} + U_{ij} \dots\dots\dots(7)$$

Where,

- Y = Output of sweet potato farmers (kg).
- X₁ = farm size (Hectares).
- X₂ = labour input (Mandays).
- X₃ = quantity of fertilizer used (kg).
- X₄ = expenses on planting materials and agrochemicals (Naira).
- X₅ = capital inputs measured in naira and these include depreciation charges on machinery and equipment, rent on land, interest charges on borrowed capital and irrigation charges.
- $\beta_0 - \beta_5$ = regression coefficients to be estimated.
- V_{ij} = normal random errors assumed to be independently and identically distributed, having N(0, δ^2).
- U_{ij} = non-negative random variables called technical efficiency associated with the technical efficiency of the farmers involved.

U_{ijs} are the technical inefficiency effects which are assumed to be independent of V_{ijs} such that U_{ij} is the non-negative truncation (at zero) of the normal distribution with mean U_i and Variance δ^2_v where U_i is defined by;

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} = \dots \dots \dots (8)$$

Where,

- U_i = Technical efficiency of the *i*th farmer
- Z_1 = Age of the farmer (years)
- Z_2 = level of education (number of years spent in school)
- Z_3 = farming experience (years)
- Z_4 = household size (number of persons)
- Z_5 = extension contact (number of visits per year)
- Z_6 = sex (dummy variable, 1 for male, 0 for female)
- Z_7 = cooperative membership (dummy variable, 1 for membership, 0 otherwise)
- δ = coefficients and unknown parameters to be estimated.

These variables are assumed to influence technical efficiency of the farmers.

3. RESULTS AND DISCUSSION

Table 1 presents the Maximum Likelihood Estimates (MLE) of the stochastic frontier production function. All the parameter estimates emerged with the desired signs and are all statistically significant. The estimate of the sigma-squared (δ^2) is significantly different from zero at 0.01 level indicating a good fit and the correctness of the specified distributional assumptions of the composite error term. The magnitude of the variance ratio (λ) is 0.428 which is significant at the 0.01 level, suggesting that systematic influences that are unexplained by the production function are the dominant sources of errors. The parameter estimates.

Of the production factors show that the estimated coefficient for farm size (x_1) is positive as expected and significant at 0.01 level. The 0.413 elasticity of farm size implies that a 1% increase in farm size, *ceteris paribus*, would lead to an increase of 0.413 percent in the output of sweet potato and vice versa. Large hectarage of farm land is required to expand production of crops and since land is limited in supply, its shortage results in reduced crop production.

The estimated coefficient for labour input (x_2) is positive as expected and significant at 0.01 level. The 0.391 elasticity of labour implies that a 1% increase in labour use, *ceteris paribus*, would lead to an increase of 0.391 percent in the output of sweet potato and vice versa. Labour is required in the accomplishment of farm operations which are time bound.

The coefficient for quantity of fertilizer used (x_3) was also positive and significant at 0.05 level. The 0.109 elasticity of quantity of fertilizer used implies that a 1% increase in quantity of fertilizer used would lead to an increase of 0.109 percent in farmers' output.

The coefficient of expenses on planting material (x_4) is negative as expected and significant at 0.01 level. The -0.093 elasticity of expenses on planting material implies that a 1% increase in expenses on planting material would lead to a decrease of -0.093 percent in farmers' output.

Table 1. Maximum Likelihood Estimates of the Parameters of the stochastic Production Function

Variable	Parameter	Coefficient	t-ratio
Production factors			
constant	β_0	10.402	5.613**
Farm size (x_1)	β_1	0.413	2.708**
Labour input (x_2)	β_2	0.391	3.083**
Quantity of fertilizer (x_3)	β_3	0.109	2.531*
Expenses on planting			
materials (x_4)	β_4	-0.093	-3.007**
Capital input (x_5)	β_5	0.508	2.511*
Efficiency factors			
constant	δ_0	8.713	4.908**
Age (z_1)	δ_1	-0.039	-1.814
Level of education (z_2)	δ_2	0.247	2.916**
Farming experience (z_3)	δ_3	0.168	3.014**
Household size (z_4)	δ_4	-0.094	-2.544*
Credit access (z_5)	δ_5	0.065	2.551*
Sex (z_6)	δ_6	-0.039	-1.643
Cooperative membership(z_n)	δ_7	0.052	1.813
Diagnostic statistics			
Log likelihood function		-92.106	
LR test of one-sided errors		25.112	
Sigma –squared (δ^2)		0.394	4.663**
Gamma (λ)		0.428	3.417**

** and * imply significance at 0.01 and 0.05 levels respectively
 Source: summarized from computer output

The estimated coefficient for capital input (x_5) is positive and significant at 5% level, implying that high level of investment translates to higher returns. Therefore, the elasticity of capital input the 0.508 implies that a 1% increase in capital input would lead to a 0.508 percent increase in total output of sweet potato. These results are similar to those of [20,21,18,22,9].

The estimated determinants of technically efficiency as shown in Table 1 indicates that level of education (z_2), farming experience (z_3), household size (z_4) and credit access (z_5) are all significant. Level of education is positively related to technical efficiency, which implies that farmers with more years of education exhibited higher level of technical efficiency. This results conforms to the findings of [23,24,21,18,22].

The estimated coefficient of farming experience (z_3) is positive and significant at 1% level, implying that level of technical efficiency of farmers increase with more years of farming experience than would be the case for new entrants in sweet potato farming.

The estimated coefficient for household size (z_4) is negative as expected and statistically significant at the 0.05 level. This suggests that farmers who have more people in their households tend to be less efficient in sweet potato production. Although it is theoretically plausible that more adults in the farmers’ household means more work force and savings in labour available for farm work. But this depends fundamentally on two factors, namely; the number of people in a household who can actually work on the farm and the length of time for which each member is prepared to work on the household farm. Consequently, what

matters is not the size of the household per se, but the composition and quality of those capable of working on the farm.

The estimated coefficient for credit access (z_5) is positive as expected and statistically significant at 5% level. This implies that farmers who have access to credit, tend to be more efficient in sweet potato production. Farmers with access to credit are more disposed to hire labour, purchase material inputs and increase farm sizes. This finding is similar to those of [9,22].

The distribution of the technical efficiency of the sweet potato farmers Table 2 shows that overall technical efficiency indices of the sample farmers is less than 1 (100%) indicating that all the farmers are producing below the maximum efficiency frontier.

Results in Table 2 show that the best farm has a technical efficiency of 0.96 (96%) while the worst farm has a technical efficiency of 0.13 (13%) implying that some farmers are operating far away from the frontier region. The mean technical efficiency is 0.47 which implies that on the average, the sweet potato farmers are able to obtain a little over 47% of potential output from a given mix of production inputs, suggesting a wider scope for the farmers to increase their level of technical efficiency by allocating the existing resources more optimally.

Table 2. Distribution of Technical Efficiency Estimates of Sweet Potato farmers in Okene LGA, Kogi State

Efficiency	Frequency	Percentage
≤ 0.20	3	3.7
0.21 – 0.40	26	32.5
0.41 – 0.60	37	46.3
0.61 – 0.80	10	12.5
0.81 – 1.00	4	5.0
Total	80	100

Mean technical Efficiency 0.47
 Maximum Technical Efficiency 0.96
 Minimum Technical Efficiency 0.13

Source: computed from MLE Results

The results show that it will take an average sweet potato farmer in the survey area (1-0.47/0.96) i.e. 51% cost saving to become the most efficient sweet potato farmer. For the most technically inefficient farmer to achieve the technical efficiency status of its most efficient counterparts, then that farmer could realize a cost saving of (1 – 0.13/0.9) i.e. 86% cost saving to become the most efficient farmer.

4. CONCLUSION AND RECOMMENDATIONS

This study analyzed technical efficiency of sweet potato farmers in Okene LGA of Kogi State, Nigeria. The maximum likelihood estimation results show that farm size, labour, quantity of fertilizer, expenses on planting material and capital inputs are the major factors significantly explaining changes in the output of sweet potato farmers.

The technical efficiency of sweet potato farmers ranges from 0.13-0.96 with a mean of 0.47. This implies that sweet potato farmers in the study area are technical inefficient in resource use and therefore technical efficiency could be increased by 53% through optimal reallocation of existing resources. This result also reveals that level of education, farming experience, household size and credit access are important factors contributing to technical efficiency.

Sweet potato farmers with higher education that acquired more farming experience, have small household size and have access to credit tends to be more efficient. Therefore, policies that will enable the farmers to improve on their education and grant them increased access to credit to be vigorously pursued for increasing the farmers' efficiency and income.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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