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Technical Efficiency and Return to Scale in Yam Production in Tai Local Government Area of Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author PAE designed the study, performed the statistical analysis and interpreted the results of the findings and wrote the first draft of the manuscript. Authors AHU and RE managed the data collection process and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study examined the technical efficiency and return to scale in yam production in Tai Local Government Area of Rivers State, Nigeria. The specific objectives were to profile the socioeconomic characteristics of the yam farmers, determine the technical efficiency of yam production, determine the factors influencing technical inefficiency and return to scale in yam production. Multi-stage sampling technique was used in selecting a sample of 75 yam farmers using structured questionnaire. Descriptive statistics and stochastic frontier analysis were used in achieving the objectives. The results indicated that the average age and farming experience of the farmers were 41 years and 17 years respectively. Also, the mean household size was six persons. The technical efficiency of farmers varied from 10.04% to 99.93% with a mean of 72.46%. Farm size, seed yam, hired labour and fertiliser were the significant factors that influence variation in yam output. Socio-economic variables such as gender, age, family size, marital status and educational level were found to have significant effects on the technical inefficiency among yam producers. The return to

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scale was 0.776 which indicated that the framers operated in stage II of the production process. It was therefore recommended that yam farmers should reduce the use of yam setts as its coefficient shows negative sign to maximized yield.

Keywords: Yam; technical efficiency; return to scale stochastic frontier; Tai LGA.

1. INTRODUCTION

Yams (*Dioscorea* species) are annual bearing monocotyledonous tuber crops grown majorly in the tropics. It comprises of over 600 species, ten of which are edible. Six of these edible tubers are grown in Africa, and only three are cultivated in Nigeria. Some of the species grown in Nigeria are the White yam (*Dioscorea rotundata*), Yellow yam (*Dioscorea cayensis*) Water yam (*Dioscorea alata*) Chinese yam (*Dioscorea polystachya*) and three-leaved yam (*Dioscorea dumetorum*) amongst others [1-25].

Yam originated in South East Asia and was domesticated in West Africa in the 16th century, about 7,000 years ago. Yams are grown on over 5 million hectares in about 47 countries of the world [11-16]. In 2014, 68.2 million tonnes of yams were produced in the world, and 97% of these were from Sub-Saharan Africa and grown on over 6 million hectares of land (Food and Agriculture Organization Database [12].

Nigeria is the largest producer of yams in the world accounting for 66% of the total world output followed by a wide margin by Ghana, Cote d'Ivoire, Benin, Togo, Cameroon and Central African Republic [11]. Nigeria's yam production hit 37.33 million tonnes in 2010 and by 2014 this increased by 21% to 45 million tonnes [12]. In Nigeria, yams are the fifth most harvested crops, following after cassava, maize, guinea corn, and beans/cowpeas. After cassava, yams are the most commonly harvested tuber crops in the country [18].

The stochastic frontier production function can be used to determine the efficiency of inputs used in a production process and also to determine the factors influencing technical inefficiency [4-7]. A stochastic production frontier represents the production technology of a farm as: $\mathrm{Yi} = \mathrm{f}(\mathrm{Xij}\,;\,\beta) + \varepsilon\mathrm{i}$ Where Yi is an output of the ifarms, Xij is a vector of inputs used by farm i, and εi is a "composed" error term. The error term εi is equal to $\mathrm{vi} - \mathrm{ui}$ .The term vi is a two-sided $(-\infty < v\mathrm{i} < \infty)$ normally distributed random error $(\mathrm{v} \sim \mathrm{N}\,[0, \sigma\mathrm{v}2]$ that represents the stochastic effects outside the farmer's control (e.g., weather; natural disasters, and luck), measurement errors, and other statistical noise. The term ui is a one-sided $(\mathrm{ui} \geq 0)$ efficiency component that represents the technical inefficiency of the farm [4]. The technical efficiency of an individual farmer is defined regarding the ratio of the observed output to the corresponding frontier output, given the available technology. The technical efficiency: $(\mathrm{TE}) = \mathrm{Y} / \mathrm{Y}* = \mathrm{f}(\,;\,\beta) + \varepsilon\mathrm{i} \,/\, \mathrm{f}(\mathrm{Xi}\,;\,\beta) + \mathrm{vi} - \mathrm{ui}$ Where, Y = Observed output, $Y*$ =Frontier output. The parameters of the stochastic frontier production function are estimated using the Maximum Likelihood Estimation (MLE) method [8].

Some researchers have empirically investigated factors that determine yam production in Nigeria. For instance, [6] noted that farm size, labour and planting materials have a positive effect on the technical efficiency of yam production in Kogi state. [2] found a positive relationship between net returns (profitability) in yams output and land improvement techniques in Nigeria. [26] found that lack of access to farm inputs, high cost of inputs, poor producer prices, high incidences of pests and diseases and inadequate of storage facilities have negatively affected yam production. Similarly, [14-17] results indicate that the factors of production such as labour, finance and material inputs like fertilizer have influence on yam production. [5], found a robust relationship between farm size, marital status and yam cultivation in Wukari Local Government Area of Taraba State, Nigeria.

The studies by [9-10], suggests that farmers' education, family labour, extension contact and experience of farmers have a positive effect on the farm level technical efficiency and yam output. Similarly, [22], found out that land, seed yam, family labour, education, and fertilizer are the drivers that influence yam production in Nigeria. [24], suggests that education, extension contact and experience of yam farmers positively affect the farm level technical efficiency effects and they also confirmed the fact that higher educational attainment motivates farmers to acquire and utilise innovations more effectively. Their findings were affirmed by [23], who stated that education, works directly to enhance the ability of farmers to adopt more advanced technologies and crop management technique thereby achieving higher rates of return on land which eventually leads to improvement in production methods and higher technical efficiency level. According to [14], who carried out a study on the determinants of yam production and economic efficiency among small-holder farmers in South-Eastern Nigeria, the socioeconomic characteristics of sampled farmers such as farming experience, educational level, access to credit and contact with extension agents, influences the yam farmers' ability to use available technology, a situation that must have contributed to the observed variation and low level efficiency amongst them.

Despite the importance of yam in the economic and socio-cultural aspect of Nigeria as a nation, its production has not been given the needed attention [21] and its productivity has to be low and inconsistent over the years. This is obvious with the fall in output percentage growth rate of yam from 24% in 2010 to 19% in 2014 despite the increase in land area harvested from 2.8 million hectares to 5.4 million hectares in the same period as earlier stated [12]. This study was aimed to access whether or not the current technologies are efficient for the yam farmers in Tai Local Government Area of Rivers State, Nigeria? What are the socioeconomic characteristics of the yam farmers? Are the yam farmers technically efficient? And what are the factors that affect technical inefficiency in the study area? This study, therefore, sought to address these questions in the study area.

The broad objective of this study was to determine the technical efficiency and return to scale in yam production in Tai Local Government Area of Rivers State, Nigeria.

The specific objectives were to: profile the socio-economic characteristics of yam farmers, determine the technical efficiency of yam production, the factors that influence technical inefficiency and the return to scale in yam production in the study area.

2. MATERIALS AND METHODS

The study was carried out in the Tai Local Government Area (LGA) of Rivers State, Nigeria. It has an area of 159 km^2 and a population of 117,797 [19] and a projected population of 142,602 in 2011 [19-18]. The LGA lies between latitudes 4° 43' and 7° 18'N of the equator and longitudes 4.72°and 7.30°E of the Greenwich Meridian. The LGA is within the tropical climate and experiences two distinct seasons, the rainy season and the dry season. Tai LGA has two broad sections: the Tua Tua Kingdom and the Barasi Nonwa Kingdom, both under the overall Tai Kingdom. Most of the people are Ogoni; speaking Tee and Baan languages. Communities include Ban – zogoi, Bara – Ale, Bara – Alue, Barayira, Borobara, Botem, Bunu, Deeyor Kira, Gbam, Gbene-Ue, Horo, Kebara Kira, Korokoro, Kpite, Nonwa Tai (Kebara), Nonwa Uedume, Orkpo, Sime and Ueken [3]. The primary occupations are farming, and fishing to a lesser degree [3]. The major crops grown in the area are yam, cassava and maize Yam is among the staple food in the area and both farmers and consumers eat yams year round.

The population of the study was the entire yam farmers in Tai Local Government Area of Rivers State. Tai Local Government Area is made up of 19 communities. Multi-stage sampling technique was employed in the study. Firstly, a total of five communities were selected using the purposive sampling technique from the LGA, based on the concentration of yam farmers in the area. The communities selected were Bunu, Kebara Kira, Nonwa Tai, Borobara and Gbene-Ue with sampling frame of 74, 75, 77, 75 and 76 respectively complied by the researcher as there was no list of yam farmers in the study area. Secondly, using the proportionate sampling technique, 20% of the sampling frame (377 yam farmers) were selected using random sampling technique giving a sample size of 75 yam farmers that is 15 yam farmers each from the five communities selected. Primary data for the study was collected by the use of a structured questionnaire which was administered to the yam farmers alongside scheduled interview.

Descriptive statistics (frequency counts, mean, standard deviation and percentages) and the stochastic frontier production function was used to achieve the objectives. The stochastic frontier production function for yam production adopted in this study as specified by the Cobb-Douglas functional form comprising of four independent variables is defined as;

$$\text{Log } Y = \beta_0 + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 + (V_i - U_i) \quad (1)$$

Where;

Log = Natural logarithm
Y = Value of yam produced in kg
X_1 = Farm size in hectare
X_2 = Seed yam in kg
X_3 = Labour in man day
X_4 = Fertilizer in kg

β_0, β_1, β_2, β_3 and β_4 = Regression coefficients

V_i = Random variables assumed to be independent of U_i, Normally distributed with zero mean and constant variance. Represents the stochastic effects outside the farmer's control (e.g., weather; natural disasters, and luck), measurement errors, and other statistical noise.

U_i = Non –negative random variables assumed to be independent of V_i .Represents the technical inefficiency of the farm.

The technical inefficiency component μ_i was modelled regarding the factors which are assumed to affect the efficiency of production of the yam farmers. These factors are related to the socio-economic variables of the farmers' and are assumed to influence the technical inefficiency of the farmers [8]. As specified by [4]. The farmers' specific technical inefficiency is defined by the function:

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 \quad (2)$$

Where;

Z_1 = Gender (dummy)
Z_2 = Age (year)
Z_3 = Marital Status (dummy)
Z_4 = Family Size (number of persons)
Z_5 = Farming Experience (years)
Z_6 = Educational Level (number of schooling years)
μ_i = Technical inefficiency
δ_i = Inefficiency Coefficients

The diagnostic parameters estimated in the stochastic production function included the sigma squared σ^2, gamma γ and the maximum-likelihood ratio test. Sigma squared (σ^2) which is the summation of U_i and V_i variances was determined. It indicates the goodness of fit of the model used.

$$\sigma^2 = \sigma^2_v + \sigma^2_u \quad (3)$$

Where:

σ^2_v = variance of the error term due to noise

σ^2_u = variance of the error term resulting from technical inefficiency

Gamma (γ) was also determined. It gives the proportion of the deviation of yam output from the production frontier caused by technical inefficiency which equals to σ^2_u / σ^2

If the value of γ is equal to zero, the difference between actual farmer yield and the efficient yield is entirely due to statistical noise. On the other hand, a value of one would indicate the difference attributed to the farmers' less than efficient use of technology i.e. technical inefficiency [4]

So that, $0 \leq \gamma \leq 1$

The Maximum Likelihood Estimate method using the computer FRONTIER 4.1 was used in estimating the parameters of the stochastic frontier production function [4-8] and the maximum-likelihood ratio test was used for testing of the significant presence of technical inefficiency effects in the yam farmer's production.

3. RESULTS AND DISCUSSION

3.1 Socio-economic Characteristics of the Yam Farmers

The Socio-economic characteristics of the farmers interviewed are summarized and presented in Table 1.

The results in Table 1 show the gender distribution of the yam farmers. The result reveals that 75% of the farmers studied were males while females constituted the remaining 25%. This means that male were more actively engaged in yam production than their female counterparts in the study area. This finding is in agreement with the findings of [9] who reported that yam production was dominated by males but stated that despite this dominance, the importance of women in agricultural related activities could not be overemphasized. The results also show that the average age of the farmers was 41 years. The result indicated that the yam farmers were in their active and productive age. This however disagrees with the findings of [6], who reported a mean age of 53

Table 1. Summary statistics of socio-economics characteristics of yam farmers in Tai LGA

Variables	Yam farmers	Mean	Percentage
Gender: Male	56		75
Female	19		25
Age (years)		41	
Marital Status: Single	12		16
Married	50		67
Divorced	4		5
Widow/Widower	9		12
Household Size (persons)		6	
Farming experience (years)		17	
Years of Schooling (years)		7	
Farm size (hectare)		0.9	

Source: Field Survey, 2017

years for yam farmers in Kogi State, Nigeria. Table 1 further shows that 67% of the farmers studied were married, 16% were single while the remaining others were either divorced or widowed. This is in line with the study by [25] who specified that farming is a necessary condition for married persons to lift their households out of poverty and ensure a hunger-free home. The average household size was 6 persons in the study area. This implies that there was a reasonable supply of family labour for farm operations in the study area. [8], reported that yam production is labour intensive and as such, family size is a necessary variable for large areas of land to be cultivated on a relatively short period.

The mean years of schooling was 7 years and this implied that majority of the farmers in the study area had primary education. [14] who reported that education is a key driver to innovation adoption in agricultural production. The average farming experience in yam production was 17 years. This result implies that the yam farmers had high experience in yam production in the study area. The average farm size was 0.9 hectares in the study area. This indicates that majority of the farmers were small-scale farmers which is in line with the findings of [5] who reported that majority of farmers in developing nations like Nigeria are in rural areas which are characterized by small scale farmers and heavy land fragmentation.

3.2 Results of Ordinary Least Squares and Maximum Likelihood Estimates of Yam Production in the Study Area

The results obtained from the Stochastic Production Function as shown by the Ordinary Least Squares (OLS) and the Maximum Likelihood Estimate (MLE) for yam production in Tai LGA is presented in Table 2. The results show that the coefficients estimated for the MLE were statistically significant at 1% levels. As the stochastic frontier production function assumes Cobb-Douglas production function, the coefficient values of the variables can be used as the direct elasticity of the function and represent proportional changes in yam yield as a result of a proportional change in inputs used in the production process.

It can be seen from Table 2 that inputs such as: Farm size (ha), Fertilizer (kg) and Labour (man-days) had a significant positive impact on yam yield. The elasticity of fertilizer (2.512) was highest. This implies that for yam farmers, 1 percent increase in fertilizer usage will lead to 2.512 percent increase in yam yield in the study area. These findings was made more pertinent by [14] who opined that the significance of fertilizer stems from the fact that it is a major land augmenting input that increases crop yield per hectare by improving the fertility and productivity of the soil.

The positive coefficients of farm size (0.217) and labour (0.548) indicated that 1 percent increase in the amount of these inputs would lead to the increase in yam yield by 0.217 percent and 0.548 percent, respectively. This result confirms *a priori* expectation. Conversely, yam seeds had negative effects on yam yield.

The amount of yam seeds utilized by the farmers had an elasticity of about -3.442. This implies that 1 percent increase in the number of yam setts employed will lead to a fall in yam yield by 3.442 percent. This defiles *a priori* expectation and was significant at 1 percent level. This may stem from the fact that higher seed rate could cause overcrowding and may lead to a competition of available nutrients which consequently leads to lower yield thus, hinders production at the frontier. The sigma squared was statistically different from zero at 1% level thus giving credibility to the goodness of fit of the model as well as the correctness of the specific distributional assumption of the composite error term (V – U). The gamma estimated was 0.999 and was statistically significant at 1% level. This implies that 99.9% of the variations in yam output among the farmers were due to difference in their levels of technical efficiencies.

3.3 Technical Inefficiency

The signs of the coefficients of the inefficiency parameters are expedient in explaining the observed level of technical inefficiency of the farmers. A negative coefficient indicates that the variable has the effect of reducing Technical inefficiency, while the positive coefficient has the effect of increasing the Technical inefficiency. Table 2 also reveals that age and household size contributed negatively to farmers' Technical inefficiency. This means that they lead to a decline in Technical inefficiency. This result confirms *a priori* expectation. The more the number of persons in a farm family, the cheaper the source for labour supply because it supplements hired labour. This agreed with the findings of [22], who reported that the farm enterprise would be is seen as a personal family business therefore giving rise to higher labour quality, supervision and farm operations are carried out more effectively hence making the production process more efficient. Also, the age of the farm household head decreased Technical inefficiency. This may stem from the fact that as the age of the farmer increases, the number of years he spends in producing yam also increases. With this increase in farm experience, his managerial abilities in optimum resource combinations and ability to prevent and withstand future risks and uncertainties in production also increase thereby decreasing Technical inefficiency. This postulate is supported by the findings of [6], who found age to be significant in decreasing Technical inefficiency.

The level of education had a significant and negative effect on Technical inefficiency. The result implies that farmers with more years of schooling tend to be more efficient, thus reducing Technical inefficiency in yam production, presumably due to their enhanced ability to acquire technical knowledge, which enables them move closer to the frontier output. Also, these farmers respond readily to the use of improved technology in agriculture. This is in line with the findings of [8] who stated that education has the potential of moving yam farmers output to the frontier.

Also, the marital status of the yam farmers in the study area had a significant and negative effect

Table 2. Stochastic estimation of the production function

Variables	Parameter	OLS estimate	ML estimate
Production function			
Constant	β_0	8.71 (1.895)*	11.140 (12.193)***
Farm size (ha) X_1	β_1	0.101 (0.291)	0.217 (3.228)***
Yam sett (kg) X_2	β_2	-1.979 (-0.830)	-3.442 (-7.422)***
Labour (man-day) X_3	β_3	0.142 (0.239)	0.548 (11.065)***
Fertilizer (kg) X_4	β_4	2.512 (1.061)	3.340 (7.333)***
Inefficiency Parameters			
Constant	δ_0		1.945 (1.752)*
Gender (Z_1)	δ_1		1.145 (1.871)**
Age (Z_2)	δ_2		-0.118 (-2.105)**
Marital status (Z_3)	δ_3		-1.637 (-3.225)**
Family size (Z_4)	δ_4		-0.334 (-2.533)**
Farming experience (Z_5)	δ_5		0.095 (2.014)
Educational Level (Z_6)	δ_6		-0.998 (-0.151)**
Diagnostic Parameters			
Sigma squared	σ^2		1.130 (6.267)***
Gamma	γ		0.999 (755888.04)***
Log likelihood	λ		37.832
Mean efficiency			0.72

Source: Computed from field data, 2017

*Figures in parenthesis are t-ratio; *** = Significant at 1%, ** = Significant at 5% and * = 10 % Significant.*

on Technical inefficiency and thus decreases Technical inefficiency in yam production. Farmers who were married were more technically efficient in yam production than farmers whose marital status stated otherwise (single, widowed or divorced). This may be due to the reason that married farmers tend to have a larger household size than the unmarried ones and thus this serves as a source of labour for farm operations. Hence, their efficiency in yam production. This collaborates the finding reported by [25] who specified that farming is a necessary condition for married persons to lift their households out of poverty and ensure a hunger-free home.

Gender had positive effect on Technical inefficiency, statistically significant at 5 percent level. The positive coefficient of gender implies that male head households are relatively technically efficient than their female counterparts. Majority of the females in the study area were uneducated i.e. had no formal education and were not encouraged to produce yams because it was termed a 'mans' job while the women concentrated on cultivating smaller staple crops like maize, fluted pumpkin, cocoyam, okra amongst others. [20] also had similar results as regards the gender variable and it was recommended that to improve women farmers' productivity, women need to better support to increase access to factors of production such as land, credit, inputs, information and technology.

3.4 Frequency Distribution of Technical Efficiency

The result of the Technical efficiency distribution of the yam farmers in the study area is presented in Table 3. Based on the estimation of the production frontier function, the frequency distribution of the Technical efficiency of yam farmers in Tai LGA is presented in Table 3. The technical efficiency of the yam farmers ranges from 10.04 percent to 99.93 percent with a mean efficiency of 72.46 percent; suggesting that there was significant variation in technical efficiency among yam farmers in the study area and an indication of inefficiency in resource use. Hence, there exists a significant variation between the efficiency of the best technically efficient farmer and that of the average farmer.

This is in line with the findings of [22] where it was opined that this type of wide variation in farmer-specific efficiency levels is a common phenomenon in developing countries such as Nigeria. Majority of the yam farmers had technical efficiency above 90 percent.

Table 3. Range of technical efficiency among the yam farmers

Range of technical efficiency (%)	Frequency	Percentage (%)
Below 50	16	21.3
50.00- 59.99	5	6.7
60-69.99	10	13.3
70-79.99	1	1.3
80-89.99	1	1.3
90-99.99	42	56.0
Summary		
Minimum 10.04%		
Maximum 99.93%		
Mean 72.46%		

Source: Field Data, 2017

3.5 Returns to Scale

The result of the Returns to Scale of yam production in the study area is presented in Table 4.

Table 4. Elasticity and returns to scale

Factor	Elasticity
Land	0.101
Fertilizer	2.51
Yam setts	-1.979
Labour	0.142
Return to Scale	0.776

Source: Field Survey, 2017

Table 4 shows the elasticity and returns to scale of yam production in the study area. The returns to scale indicate what would happen to output if all the inputs are increased at the same time. The result of this study shows that one unit increase in the quantities of the inputs would cause output to increase but at a decreasing rate. The returns to scale calculated as the sum of the estimated output elasticity was 0.776, and suggests decreasing returns to scale. The yam farmers in the study area are at a rational stage of production -stage 2.

4. CONCLUSION

Efficiency is an important factor of productivity growth as well as stability of production. The results of the study revealed that technical efficiency in yam production in Tai Local

Government Area of Rivers State range from 10.04 percent to 99.93 percent with a mean efficiency of 72.45 percent. This means that there are substantial opportunities to increase productivity and income through more efficient utilization of productive resources. Factors that were significant and related to technical inefficiency were gender, age, household size and marital status. The yam farmer also operated in the rational stage of production where resources are optimally utilized as seen from the result of the return to scale. Based on the findings of the study, the following recommendations were made. The negative and significant impact of yam seed on yam yield show that this resource is over-utilized or inefficiently used hence may hinder production at the frontier. Farmers in the study area should reduce the seed rate utilized to avoid overcrowding and competition for plant nutrients and thereby increase output.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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