ASSESSMENT OF TECHNICAL AND RESOURCE-USE EFFICIENCY OF YAM PRODUCTION IN UKUM LOCAL GOVERNMENT AREA OF BENUE STATE, NIGERIA

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ABSTRACT

This study analyzed the technical and resource-use efficiency of yam production in Ukum Local Government Area of Benue State using Stochastic Frontier Model. Primary data were collected for one year period using structured questionnaire. The result of the summary statistics revealed an average farm size of 3.28 ha/ farmer which was an indication that they were small-scale farmers. The maximum likelihood estimates showed that planting materials, herbicides, capital inputs and fertilizers were the major determinants of the technical efficiency of the farmers in the area. The estimated coefficient of the inefficiency function revealed that sex, level of involvement in farming, membership of cooperative, extension contact and fertilizer usage reduced the technical inefficiency of the farmers. The technical efficiency indices revealed that none of the farmers operated at maximum efficiency frontier level with a mean technical efficiency of 0.638, which implied that the farmers were able to obtain about 64% of yam output from a given mix of production inputs. The result of the resource-use efficiency showed that the farmers were inefficient in the use of their resources. Based on the results, it is therefore recommended that government should organize training programmes to educate the farmers on the technical knowhow of yam production so as to improve their technical efficiency frontier level. In addition, extension agents should be engaged in training the farmers on how they can optimized the use of resources to increase their efficiency level and reduce input wastage.

KEY WORDS: Efficiency, stochastic frontier and production

INTRODUCTION

Agriculture is the mainstay of the Nigerian economy providing employment for over 60% of the population. The effect of rapid urbanization and population growth in recent years on the livelihood of the rural and urban dwellers cannot be over-emphasized. This has led to widening gap in the demand-supply responses to crop and livestock production and consumption in the country. To bridge this gap, there is need for increased food production to meet the need of the urban teeming population. Yam has been identified as a tuber crop that could be produced to ensure food security in the nation (Ojo, 2013). Nigeria is the largest yam (*Dioscorea spp.*) producer in the world, contributing to two-thirds of global yam production each year (Nigerian Bureau of Statistics (NBS), 2012). Yam is the fifth most widely harvested crop in the country following cassava, maize, guinea corn/sorghum, and beans/cowpeas. In yam zone of West Africa, comprising Cameroon, Nigeria, Benin, Togo, Ghana and Cote d' Ivoire, yam production is more than 90% of the total world production which is estimated at about 20 – 25million tons per year (Izekor and Olumese, 2010). As an annual tuber crop, it is an important source of carbohydrate in the diet of an average Nigerian. It can be eaten boiled, pounded, fried, as porridge or processed to make yam flour (*elubo).* It contains a higher value in protein (2.4%) and substantial amount of vitamins (Thiamine, Riboflavin and Ascorbic acid) and some other minerals like calcium, phosphorus and iron than any other common tuber crop. Aside these, it is a rich source of industrial starch and plays vital roles in traditional culture, rituals and religion as well as local commerce of the African people . In addition, it contributes more than 200 dietary calories per capita daily for more than 150 million people in west Africa while servicing as an important source of income to Nigerian people (Babaleye, 2003; Izekor and Olumese, 2010). With the roles of yam in food security, findings have shown that yam production in Nigeria is grossly inadequate and cannot meet ever increasing demand for it under present level of input use (Akoroda and Hahn, 1995). To meet this increase in demand for yam and surpass it, there is need for increase in yam farmers' efficiency and productivity. Efficiency of agricultural production is an important issue in developing countries and this measure of producer's performance is often useful for policy purposes. Besides, the concept of efficiency provides a theoretical basis for such a measure (Jatti *et al.,* 2010). Hence, there is the need to allocate given resources and the technologies at the farmers disposal to maximize profit and attain the greatest efficiency level. This paper therefore seeks to determine how efficient these farmers are in the use of all production resources. This is with the view to provide relevant recommendations for policy formulation.

Conceptual Framework

Farrell (1957) distinguishes between technical and allocative efficiency through the use of a frontier production and cost function respectively. He defined technical efficiency as the ability of a firm to produce a given level of output with a minimum quantity of inputs under certain technology and allocative efficiency as ability of a firm to choose optimal input levels for a given factor prices. In Farrell's Framework, economic efficiency (EE) is an overall performance measure and is equal to the product of TE and AE (that is EE = TE x AE).

However, over the years, Farrell's methodology has been applied widely, while undergoing many refinements and improvements. Such improvement is the development of stochastic frontier model that enables one to measure firm level efficiency using maximum likelihood estimate. The Stochastic frontier model incorporates a composed error structure with a two sided symmetry and one sided component. The one-sided component reflects inefficiency while two sided component capture random effects outside the control of production unit including measurement errors and other statistical noise typical of empirical relationship.

In this study, Battese and Coelli (1995) model was used which builds hypothesized efficiency determinants into the inefficiency error component so that one can identify focal points for action to bring efficiency to higher levels.

The general form of the model is expressed as:

$$Q_1 = \beta_0 + \beta_1 X_1 + \left(V_I - U_I\right) \quad (1)$$

Where

Q_i is the production (or the logarithm of the production) of the ith firm;

Xi is a vector of (transformations of the) input quantities of the ith firm;

β is a vector of unknown parameters;

The Vi are random variables which are assumed to be iid $\left(N, \delta^2 v\right)$ and independent of the Ui which are non-negative random variables which are assumed to account for technical inefficiency in production and are often assumed to be iid $\left(0, \delta^2 u\right)$.

It is further assumed that the average level of technical inefficiency, measured by the mode of the truncated normal distribution (i.e. U_i) is a function of factors believed to affect technical inefficiency as shown below:

$$U_i = \delta_0 + \delta_1 Z_1 \quad (2)$$

Where

Z_1 is a column vector of hypothesized efficiency determinants and δ_0 and δ_1 are unknown parameters to be estimated. It is clear that if U_i does not exist in equation (1) or $U_1 = \delta^2{}_0 = 0$, the stochastic frontier production function reduces to a traditional production function. In that case, the observed units are equally efficient and residual output is solely explained by unsystematic influence. The distributional parameters, U_i and δu_2 are hence inefficiency indicators, the former indicators, the former indicating the average level of technical inefficiency and the latter the dispersion of the inefficiency level across observational units.

Given functional and distributional assumptions, the values of unknown coefficients in equations (1) and (2), i.e β_0, β_1, δ_0, δu_2 and δv_2 can be obtained jointly using the maximum likelihood estimation method (MLE). An estimated value of technical efficiency for each observation can then be calculated as

$TE_I =$ exp(-Ui).

The unobservable value of V may be obtained from its conditional expectation given the observation value of (Vi – Ui) (Yao and Liu, 1998).

METHODOLOGY

Study area: Ukum Local Government Area (LGA) is located in Benue State, Nigeria. Benue State was created in 1976, has a landmass of 30, 955km^2 as well as an estimated population of 4,219,244. It is made up of 413,159 farm families (National Population Commission., 2006). Most of the people in the State are farmers while inhabitants of the riverine areas engage in fishing as their primary or secondary occupations. Benue State experiences two distinct seasons, the wet and the dry seasons. The rainy season lasts from April to October with annual rainfall between 150mm-180mm and the dry season begins in November and ends in March. The State lies within the lower river Benue in the Middle belt region of Nigeria with geographic coordinates of longitude $7^\circ\ 47'$ and $10^\circ 0'$ East. Latitudes $6^\circ 25'$ and $8^\circ\ 8'$ North and shares boundaries with five other States namely; Nassarawa to the north, Taraba to the east, Cross-river to the south, Enugu to the south-west and Kogi to the west. The State also shares a common boundary with the Republic of Cameroun on the South-eastern part of the country (Ministry of Information and Culture, 2004). Benue State is acclaimed the nation’s “food basket” because of its rich and diverse agriculture produce which include yams, beans, cassava, potatoes, maize, soybeans, sorghum, millet, and coco-yam. It also boasts of the longest stretches of river systems in the country with great potential for a viable fishing industry, dry season farming through irrigation and for an inland water way through navigation (Ministry of Information and Culture, 2004).

Sampling technique: A multi-stage sampling technique was used for this study. In the first stage, one out of the twenty-three Local Government Areas (LGAs) was randomly selected from the State while in the second stage, six towns/villages were randomly selected from each LGA. In the third stage, nineteen yam household farmers were randomly selected from the town/villages making a total of one hundred and fourteen respondents.

Data gathering and survey instrument: This study involved the collection of primary data using structured questionnaire to elicit relevant information from the respondents for a year period. The information included data on the determinant of the technical efficiency of yam farming house holds.

Analytical techniques: Transformation of the study data was achieved using Stochastic frontier model**.** A production frontier is defined in terms of the maximum output that can be achieved from a set of inputs given the technology available to the farmer. The general form of the model as used by Ojo (2013) is expressed as:

$$Q_1 = \beta_0 + \beta_1 X_1 + (V_I - U_I) \qquad (3)$$

Where,

Q_i is the production (the logarithm of the production) of the *ith* firm;

X_i is a vector of (transformations of the) input quantities of the *ith* firm;

β is a vector of unknown parameters;

V_i are random variables

U_i are non-negative random variables

An estimated value of technical efficiency for each observation was calculated as:

$$TE_I = \exp(-U_i). \qquad (4)$$

Specifically, for the purpose of this study, Cobb-Douglas frontier model was assumed to describe the production function of the farmers on which data were obtained. The model in which the determinants of inefficiency were incorporated was estimated simultaneously with The Cobb-Douglas stochastic frontier model. The model estimated can be represented as:

$$\ln Y_i = \beta_0 + \sum \beta_j LnX_{ij} + (V_i - U_i) \qquad (5)$$

Where

ln = Natural logarithm;

i = ith sampled smallholder farm;

Y_{ij} = Vector of Output of yam (tonnes) which was aggregated using grain equivalent table

X_{ij}s = Vector of inputs.

The X_{ij}s are specified as:

X_1 = Farm size (Ha)

X_2 = Labour (Man-day)

X_3 = Planting materials (Kg)

X_4 = Herbicides and Pesticides (₦)

X_5 = Fertilizer (Kg)

X_6 = Capital Input (₦)

β_j = Input coefficients for the resources used in production;

U_i = Farmer specific characteristics related to production efficiency;

Vi = Statistical disturbance term

The explicit form of the fitted Cobb-Douglas functional form can be written thus:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + V_1 - U_1 \quad (6)$$

Where Y, X_1, X_2, X_3, X_4, $X_5$and X_6 are as defined earlier. The V_i's are assumed to be independent and identically distributed (iid) normal random errors having zero mean and unknown variance. U_i's are non-negative random variables called technical efficiency of production of the respondent farmers which are assumed to be independent of the Vi's such that U_i's are the non-negative truncation (at zero) of the normal distribution with mean μ and variance σ^2

$$\mu = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + \delta_8 Z_{8i} + \delta_9 Z_{9i} + \delta_{10} Z_{10i} + \delta_{11} Z_{11i} + \delta_{12} Z_{12i} + \delta_{13} Z_{13i} + \delta_{14} Z_{14i} \quad (7)$$

Where:

Z_1 = Farmer's sex (1, if male; 0, if female)

Z_2 = Years of experience

Z_3 = Level of involvement in farming (0, if part-time; 1, if full-time)

Z_4 = Household size (number of people available for farm work)

Z_5 = Education (years)

Z_6 = Membership of cooperative society (1 if respondent is a member; 0 otherwise)

Z_7 = Age (years)

Z_8 = Centrality (farm in central municipalities = 1, else = 0)

Z_9 = Extension contact (1, if there is extension contact; 0 if not)

Z_{10} = Credit usage (1, if credit is taken for farming; 0, if not)

Z_{11} = Farm size (Ha)

Z_{12} = Fertilizer usage (1, if Yes; and 0 if No)

Z_{13} = Farm distance from home (Km)

Z_{14} = Farmer's residence during farming (0, if village; 1, if farmstead).

δs= unknown scalar parameters to be estimated

μ = Technical efficiency

Efficiency of resource-use was determined by analyzing the ratio of Marginal Value Product (MVP) to Marginal Factor Costs (MFC) of inputs with the ratio was calculated to decide on the efficiency of resource use. Following Rahman and Lawal (2003) and Omoyajowo (2009), the efficiency of resource-use (r) was estimated as:

$$r = \frac{MVP}{MFC}$$

The value of MVP was estimated as:

$$MVP = MPP * P_y$$

$$= \beta \frac{\overline{Y}}{\overline{X}_i} * P_y$$

While the value of MFC was estimated as the unit price of the inputs, *i.e*,

$MFC = P_{xi}$

The different component measures of the efficiency of resource use can then be defined as follows:

r = Efficiency ratio

β = Regression coefficient

P_y = Unit price of output

P_y = Unit price of input

$\overline{Y_i}$ = Mean value of yam output

$\overline{X_i}$ = Mean value of X_i

When r = 1 (efficient use of resources); r > 1 (under utilization of resources); r < 1 (over utilization of resources).

RESULTS AND DISCUSSION

Assessment of the determinants of technical efficiency among yam farmers

The summary statistics of the production operation of yam farmers in the study area are presented in Table 1. They include the sample mean and the standard deviation for each of the variables. The large size of the standard deviation confirmed that most of the farming households operated different scales of operation. Analysis of the inputs also revealed an average farm size of 3.28 ha/ farmer which revealed that they were small-scale farmers. The average labour in man-day was 104.42 which implied that the farmers dependent on family and hired labour or either of them, for their farming operations. The average planting materials, herbicides, fertilizers, and capital inputs were 354.2kg, ₦9241.67, 90.80kg and ₦23458.77, respectively which further confirmed that the farmers operated on small-scale. However, for Nigeria to be self-sufficient in yam production, machinery must be put in place to expand the scale of operation of the farmers.

Table 1: Summary statistics of the variables in Stochastic Frontier Model

Variables	Mean	Standard deviation	Minimun	Maximum
Farm Size(ha)	3.28	2.14	1.0	8.0
Labour (Man-days)	104.42	43.75	87.0	125.0
Planting Material(kg)	354.20	330.98	31.5	1001.5
Herbicides	9241.67	7853.16	800.0	22500.0
Fertilizer (kg)	90.80	38.33	50.0	200.0
Capital Inputs	23458.80	10361.43	3000.0	48800.0

Source: Field Survey, 2014

The maximum likelihood estimation (MLE) method was used to fit the Cobb-douglas stochastic production function to the study data. Specifically, MLE was used in estimating the determinants of technical efficiency of yam production in the study area as presented in Table 2. It was also used in determining the effect of farmer specific characteristics on technical inefficiency of production. The parameters were estimated simultaneously using Frontier 4.1c developed by Coelli (1996). The result showed that the coefficients of planting materials (X_3) and herbicides (X_4) were found to be statistically significant at $P < 0.01$ while the coefficient for capital inputs X_6 and fertilizer (X_5) were statistically significant at $P < 0.05$ and $P < 0.10$, respectively. Further, the coefficient of herbicides and capital inputs showed the expected positive sign which implied that an increase in any of these variables will lead to an increase in the output of yam in the area. However, the negative coefficients of planting material and fertilizer tend to confirm that the excessive use of these variables could cause a decrease in the output of yam. This result is at variance with that of Nsikak-Abasi (2013) who reported that land, family labour, hired labour, planting materials and stakes were the major efficiency determinants of yam farmers in rural Nigeria.

The estimated coefficient of the inefficiency function provides some explanations for the relative efficiency levels recorded by individual farms. Since the dependent variable of the inefficiency function represent the level of inefficiency, a positive sign of an estimated parameter implies that the associated variable has a negative effect on efficiency a negative sign indicates the reverse. Hence, farmer's sex ($p < 0.01$), level of involvement in farming ($p < 0.10$), membership of cooperative societies ($p < 0.01$), ,extension contact ($p < 0.05$) and fertilizer usage ($p < 0.01$) which had negative coefficients implied that increased in these factors led to increase in the farmers' technical efficiency. This is in line with Oladeebo (2007) who reported that age and number of contact with extension agents were significant determinants of efficiency of swamp rice farmers in the study area.

Table 2: **Maximum likelihood estimates of the Cobb-Douglas frontier function for small scale yam farmers in Benue State**

Variables	Parameters	Coefficient	Standard error	t-ratio
Constant	β_0	*-1.235*	1.478	-0.836
Farm size (X_1)	β_1	0.153	0.173	0.884
Labour(X_2)	β_2	0.027	0.287	0.093
Planting Material (X_3)	β_3	-56.241	0.707	-79.590***
Agrochemical (X_4)	β_4	57.868	0.712	81.273***
Fertilizer (X_5)	β_5	-0.126	0.072	-1.746*
Capital (X_6)	β_6	0.496	0.237	2.094**
Inefficiency model				
Constant	δ_0	7.858	2.678	2.934***
Farmers sex (Z_1)	δ_1	-1.359	0.374	-3.639***
Years of Experience (Z_2)	δ_2	-0.331	0.313	-1.056
Involvement in farming(Z_3)	δ_3	-0.034	0.019	-1.769*
Household size (Z_4)	δ_4	0.576	0.273	2.112**
Education (Z_5)	δ_5	0.124	0.049	2.547**
Cooperative Membership (Z_6)	δ_6	-0.055	0.030	-1.813*
Age (Z_7)	δ_7	-0.107	0.211	-0.505
Centrality (Z_8)	δ_8	0.000	0.014	-0.002
Extension contact (Z_9)	δ_9	-1.354	0.527	-2.569**
Credit usage (Z_{10})	δ_{10}	0.026	0.292	0.087
Farm size (Z_{11})	δ_{11}	3.293	0.758	4.342***
Fertilizer usage (Z_{12})	δ_{12}	-0.359	0.098	-3.671***
Farm distance from home (Z_{13})	δ_{13}	0.315	0.173	1.819*
Farmer's residence during farming (Z_{14})	δ_{14}	2.008	0.429	4.686***
Diagnostic statistics				
Sigma Square	δ^2	0.352	0.058	6.104***
Gamma	γ	0.785	0.066	11.887***
Log likelihood Function		-61.62		
LR Test		76.42		

Source: Computer Output from Frontier Analysis. *** Significant at 1% level, ** Significant at 5% level and * Significant at 10% level

The result of Table 2 further revealed that the positive coefficients of household size ($p < 0.05$), education ($p < 0.05$), farm size ($p < 0.01$), farm distance from home ($p < 0.10$) and farmer's residence during the farming period ($p < 0.01$) showed that farmers level of technical efficiency decreased with increase in any of these variables. That is, if the members of farmers household did not participate in farming, it must have increased the number of hired labour and cost of production during the production season, and also, the more the educational attainment the more the tendency of the farmers to opt out in search of white collar job in urban areas. In addition, if the distance from home to the farm was very far and there was no farmstead in the farm could have led to the inefficiency of the farmers during the production season. This is at variance with the findings of Oladeebo and Fajuyigbe (2007) who reported that age and years of education of farmers had positive significant influence on the level of technical efficiency of rice farmers in the State.

Technical Efficiency Indices of the farmers: The technical efficiency indices were derived from the MLE results of the Stochastic frontier production function. The result of the technical efficiency indices (Table 3) revealed that none of the farmers operated at maximum efficiency frontier level. The modal efficiency class index was between 0.51-0.60 of 18.4% while the lowest modal efficiency class was between 0.11-0.20. No farmer operated within the efficiency class range of 0.31-0.40. In essence, only 79.8% of the farmers operated at 0.51-1.00 technical efficiency level. Moreover, an average yam farmer in the area would enjoy input saving of 32.83% [(1-0.63/0.95)*100] if he attains the technical efficient level of the most efficient farmer in the study area. The most inefficient farmer would experience an efficiency gain of 89.89% [(1-0.096/0.950)*100] if he is to attain the efficiency level of the most efficient farmer. The overall result of the technical efficiency analysis thus reveals that most of the farmers were moderately technically efficient, with a mean technical efficiency of 0.6381 (63.81%), implying that on the average, farmers in the study area were able to obtain about 64% of yam output from a given mix of production inputs. Alternatively put, an average yam output among the sample fell by 36% below the maximum possible level due to inefficiency factors. This is corroborated by Shehu *et al* (2010) who reported a mean efficiency index of 0.95 and an observed variation of 0.67 to 0.99 in the technical efficiency of yam farmers in Benue State, Nigeria.

Table 3: Distribution of technical efficiency levels of yam farmers in the study area

Efficiency Class Index	Frequency	Percentage
0.00-0.10	9	7.9
0.11-0.20	4	3.5
0.21-0.30	8	7.0
0.31-0.40	0	0.0
0.41-0.50	2	1.8
0.51-0.60	21	18.4
0.61-0.70	17	14.9
0.71-.80	18	15.8
0.81-0.90	16	14.0
0.91-1.00	19	16.7
Total	114	100.0
Mean	0.6382	
Minimum Value	0.0958	
Maximum Value	0.9501	

Source: Computed from MLE Result

Resource use efficiency in yam production: The result of the estimated efficiency ratio (r) from the ordinary least squares regression estimation (Table 4) show that herbicides and planting materials were under-utilized while fertilizer input was over-utilized by the yam farmers in the study area (Table 5). This implies that the production resources were not efficiently utilized by the yam farmers in the sample.

Table 4: Multiple regression result of yam production in the study area

Variable	Coefficient	Standard error	t-values
Constant	-0.406	3.950	0.918
Farm size	-0.104	0.194	$0.593^{N.S}$
Herbicides	0.549	0.155	0.001***
Fertilizer	-0.451	0.217	0.040**
Labour (manday)	0.566	0.542	$0.298^{N.S}$
Planting materials	0.564	0.083	0.000***

Source: Computer analysis based on field survey, 2014

Table 5: Resource-use efficiency of yam farmers in the study area

Inputs	MPP	MVP	MFC	MVP/MFC	Efficiency index
Herbicide (Litre)	129.719	20755.02	900	23.06	Under-utilization of resource
Fertilizer (kg)	-852.06	-136329.56	160	-852.06	Over-utilization of resources
Planting material	6.49591	1039.35	200	5.20	Under- utilization

Source: Field survey, 2014

CONCLUSION AND RECOMMENDATIONS

The study examined the technical and resource-use efficiency of yam farmers in Ukum Local Government Area of Benue State. The result of the summary statistics revealed an average farm size of 2.14 ha/ farmer which was an indication that they were small-scale farmers. The technical efficiency indices revealed that none of the farmers operated at maximum efficiency frontier level while the mean technical efficiency recorded by the farmers (i.e. 0.6381) implies that farmers in the study area were able to attain about 64% efficiency in yam production from the given mix of production inputs. It was however found that farmers were not efficient in the use of fertilizer which was over utilized herbicides and planting materials which were (under-utilized). Based on the results, it is therefore recommended that government should organize training programmes to educate the farmers on the technical knowhow of yam production so as to improve their level of technical efficiency. Further, extension agents should be engaged in training the farmers on how to enhance the use of production resources so as to increase their efficiency level and prevent input wastage.

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