Return to scale and determinants of farm level technical inefficiency among small scale yam based farmers in Niger state, Nigeria: implications for food security

[1]Ojo, M. A., U. S. Mohammed[1], A. O. Ojo[2], and R. S. Olaleye[1]

[1] Department of Agricultural Economics and Extension Technology,
Federal University of Technology, Minna, Niger State, Nigeria

[2] Department of Agricultural Economics and Extension Technology,
Federal University of Technology, Akure, Ondo State, Nigeria

Corresponding author e-mail: akinmikky@yahoo.co.uk

Abstract: The study examined the implication of resource productivity and farm level technical inefficiency in yam production on food security in Niger state, Nigeria. Data used for the study were obtained using structured questionnaire administered to 100 randomly selected yam based farmers from Edati and Munyan Local Government Areas of the state. Stochastic frontier production function was used to represent the production frontier of the small scale yam based farms.

The result showed the return to scale of 1.686 indicating an increasing return to scale and that small scale yam production in the area was in stage I of the production function. The study also showed that the levels of technical efficiency ranged from 31.72% to 95.10% with mean of 75.64% which suggests that average yam output falls 24.46% short of the maximum possible level. From the results obtained, although farmers were generally relatively efficient, they still have room to increase the efficiency in their farming activities as about 24 percent efficiency gap from optimum (100%) remains yet to be attained by all farmers. Therefore, in the short run there is room for increase in technical efficiencies on yam based farms in the study area. The result further showed that, farmers' educational level, years of farming experience and access to extension service significantly influenced the farmers' efficiency positively. It is recommended that relevant policies that would enhance the technical skill of the farmers and access to extension services should be evolved by the stakeholders.

Keywords: Yam production, return to scale, technical inefficiency, stochastic frontier production function

INTRODUCTION

The Agricultural sector has always been an important component of Nigerian economy. The sector is almost entirely dominated by small scale resource poor farmers living in the rural areas, with farm holdings of 1-2 hectares, which are usually scattered over a wide area. According to Olayide *et al* (1981), about 75% of Nigeria's land is under arable cultivation with land-human ratio of 58 persons per square kilometre in south western Nigeria. This shows that the average sizes of farmlands are very small. The production practices of small-scale farmers are synonymous with their production characteristics such as subsistence level of production, low hectare due to tenurial rights, poor access to credit and other production inputs as well as poor managerial ability and enterprise combination based on ecological considerations, available resources, taste and preferences of farm families.

Yam is widely consumed especially in West Africa. As a food crop, the place of yam in the diet of the people in West Africa and in Nigeria in particular cannot be overemphasized. Babaleye, (2003) observes that yam contributes more than 200 dietary calories per capita daily for more than 150 million people in West Africa while serving as an important source of income to the people. Yam is a preferred food and a food security crop in some sub-Saharan African countries (IITA, 1998). Babaleye (2003) reported that in many yam producing areas in Nigeria, yam is food and food is yam. Unlike cassava, sweet potato and aroids, one can store yam tubers for periods of up to 4 or even 6 months at ambient temperatures. This characteristic contributes to the sustaining of food supply, especially in the difficult period at the start of the wet season. Olawoye (1994) opined that food security existed when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Root and tuber crops especially yam- FAO, (1987) emphasized that tuber crop e.g. yam has some inherent characteristics, which make it attractive, especially to smallholder farmers in Nigeria. First, it is rich in carbohydrates especially starch and consequently has a multiplicity of end uses. Secondly, it is available all the year round making it preferable to other more seasonal crops such as grains, peas and beans, and other crops for food security. According to Akoroda and Hahn (1995), the production of yam in Nigeria is grossly inadequate and cannot meet the ever-increasing demand for it under present level of input use. In order to meet this level of demand and even surpass it, there is need to assess the level of inefficiency and its determinants in yam production. This study in the light of this intends to measure the magnitude of gain that could be obtained to improve farmers' performance by examining the return to scale and determinants of technical inefficiency of yam production in Niger State, Nigeria. Therefore, a stochastic frontier modelling is developed to simultaneously estimate resource productivity and determinants of technical inefficiency in yam production

The 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 (TE) as the ability of a firm to produce a given level output with a minimum quantity of inputs under certain technology and allocative efficiency (AE) 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 typically 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:

$$Q_1 = \beta_0 + \beta_1 X_1 + (V_I - U_I) \quad \text{........} \quad (1)$$

Where

Q_i is the production (on the logarithm of the production) of the i^{th} firm;

X_i is a vector of (transformations of the) input quantities of the i^{th} firm;

β is a vector of unknown parameters;

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

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

$$U_i = \delta_0 + \delta_1 Z_1 \quad \text{......} \quad (2)$$

Where

Z_I 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 $U_1 = \delta_0^2 = 0$, 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 influences. The distributional parameters, U_i and δU^2 are hence inefficiency 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 method (MLE). An estimated value of technical efficiency for each observation can then be calculated as

$TE_I =$ exp ($-U_i$).

The unobservable value of V may be obtained from its conditional expectation given the observation value of ($V_i - U_i$) (Yao and Liu, 1998).

METHODOLOGY

Study Area- The study was conducted in Niger State of Nigeria. The state is located within latitudes 8^o – 10^o north and longitudes 3^o – 8^o east of the prime meridian with land area of 76,363 square kilometers and a population of 4,082,558 people (Wikipedia, 2008). The state is agrarian and well suited for production of arable crops such as cowpea, yam, cassava and maize because of favourable climatic conditions. The annual rainfall is between 1100mm – 1600mm with average monthly temperature ranging from 23^{o}C and 37^{o}C (NSADP, 1994). The vegetation consists mainly of short grasses, shrubs and scattered trees.

Sampling Techniques- The data mainly from primary sources were collected from two Local Government Areas (LGAs) which were purposively selected because of prevalence of the crop in the area using multistage sampling technique. The LGAs are Edati and Munyan LGAs. The second stage involved a simple random selection of 50 farmers from each of the two LGAs, thus, making 100 respondents. The data were collected with the use of structured questionnaire designed in line with the objectives of the study.

Empirical Models- The stochastic frontier production function is expressed as follows:

$$LnY_i = \beta_0 + \sum \beta_j LnX_{ij} + V_i - U_i$$

Where

Ln = Natural logarithm;

I = i[th] sampled smallholder farm;

Y = Value of farm output from farm I;

Xs = input variables in the model, and

X_1 = Farm Size (in hectares);

X_2 = Labour (in man-day);

X_3 = Fertiliser (kg);

X_4 = Herbicide (litres);

X_5 = Quantity of Seed (kg)

β_3 = Input coefficients for the resources used in production;

U_i = Farmer specific characteristics related to production efficiency;

Vi = Statistically disturbance term.

The explicit form of the Cobb-Douglas functional form is written thus:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + V_1 - U_1$$

Where Y_1, X_1, X_2, X_3, X_4 and X_5 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 inefficiency 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) at the normal distribution with mean μ and variance σ^2

$$\mu = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i}$$

Z_1, Z_2, Z_3, Z_4 and Z_5 are the age, household size, level of education, years of farming experience and access to extension agents (number of contact) of the i[th] farmers respectively and the βs and δs are known scalar parameters to be estimated.

The variables like age, household size, level of education, years of farming experience and access to extension agents were included in the model for the technical inefficiency effects to include positive effects of farmers' characteristics on the efficiency of production.

The technical efficiency of the farmers is expressed as:

$TE_i = \exp(-Ui)$

Return to Scale: This is the measure of farm's success in producing maximum output from a given set of inputs. The elasticity of production (*Ep*) and return to scale (RTS) was estimated using the formula

$$\sum^{k} Epx_i = RTS$$

RESULTS AND DISCUSSION

Production Analysis: The summary statistics of the variables for the frontier estimation is presented in Table1. They include the sample mean and the standard deviation for each of the variables. The mean of 3.29 tons of yam per annum was obtained from the data analysis with a standard deviation of 1.97.

Analysis of the inputs also revealed an average farm size of 1.93ha per farmer an indication that the study covered small scale family managed farm units. The average labour of 74.42 man- day showed that yam farmers relied heavily on human labour to do most of the farming operations. The analysis of other input variables showed the mean values of 228.69kg, 6.90litres and 224.98kg for fertiliser, agrochemical and seed yam respectively. All these findings exemplify the nature of subsistence farming which dominates agricultural production in Nigeria.

Variables representing the demographic characteristics of the sampled farmers employed in the analysis of the determinant of technical inefficiency include age of the farmers, household size, educational level of the farmers, years of experience and number of extension contacts. The average age of the farmers, household size, year of schooling, years of experience and number of extension contact were 42.92, 4.16, 5.27, 15.70 and 2.29 respectively, meaning that the farmers were relatively young and with no formal education.

Table 1. Summary Statistics of the Variables in Stochastic Frontier Model

Variables	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Output (tons)	0.48	9.96	3.29	1.97
Farm Size (ha)	0.50	5.20	1.93	0.10
Labour (Man-days)	25.00	102.00	74.42	1.66
Fertiliser (kg)	2.00	650.00	228.69	20.67
Agrochemical (Litres)	2.00	14.00	6.90	0.29
Seed yam(kg)	45.00	650.00	224.98	9.26
Age (years)	25.00	65.00	42.92	9.42
Household Size	0.00	11.00	4.16	2.20
Education Level (years)	0.00	13.00	5.27	3.90
Years of Experience	2.00	47.00	15.70	9.45
Number of Extension Contact	0.00	4.00	2.29	0.67

Source: Field Survey, 2008

The stochastic frontier production function estimates of small scale yam based farmers in Niger State are presented in Table 2. The Table showed that the coefficients of labour, herbicide and agrochemical had the expected positive signs which indicated that a unit increase in these inputs will lead to increase in the gross output of yam. These variables were statistically significant at 1% and 5% levels of probability. The coefficients of land and fertiliser are negative. The estimated elasticities of mean output with respect to labour, agrochemical and seed yam inputs were 0.371, 0.977, and 0.365 respectively. This means that for 1% increase in man-day of labour, the output will increase by 0.371%. One percent increase in the amount of agrochemical applied and seed yam planted also increased yam output by 0.977% and 0.365% respectively. However, a 1% increase in land and fertiliser used decreased yam output by 0.01% and 0.017% respectively.

Determinants of Technical Inefficiency

Table 2 shows the result for the regression analysis of the determinants of technical inefficiency in small scale yam based production in Niger State. The estimated coefficients of the inefficiency function provide some explanations for the relative efficiency levels among individuals' farms. Since the dependent variable of the inefficiency function represents the mode of inefficiency, a positive sign of an estimated parameter implies that the associated variable has a negative effect on efficiency and a negative sign indicates the reverse. The negative coefficients for education, farming experience and extension contacts imply that educated farmers, the farmers with high farming experience and extension contacts in small scale yam production were more technically efficient meaning that as the level of education, years of farming experience and access to extension services increased in the study area, the technical inefficiency of the farmers decreases. Also, negative coefficient for age and household size implied that the farmers' level of technical inefficiency increased with increased in age and household size.

The sigma square is 0.4954 and statistically significant at 1 percent. This indicates a good fit and the correctness of the specified distributed assumption of the composite error term. The gamma (γ) ratio of 0.9394 which is significant at 1% level implied that about 93.94 percent variation in the output of yam-based farmers was due to differences in their technical efficiencies

Table 2: Maximum Likelihood Estimates of Parameters of the Cobb-Douglas Frontier Function for Small Scale Yam based Farmers in Niger State.

Variables	**Parameters**	**Coefficients**	**t-ratio**
General Model			
Constant	β_0	6.089	9.161***
Farm Size (ha) (X_1)	β_1	-0.010	$-0.190^{N.S}$
Labour (Man-days) (X_2)	β_2	0.371	3.069***
Fertiliser (kg) (X_3)	β_3	-0.017	-0.921^{NS}
Agrochemical (Litres) (X_4)	β_4	0.977	7.285***
Seed yam (Kg) (X_5)	β_5	0.365	2.018**
Inefficiency Functions			
Constant	δ_0	-0.730	$-0.314^{N.S}$
Age (years)	δ_1	0.010	$0.458^{N.S}$
Household Size	δ_2	0.021	$0.356^{N.S}$
Education Level (years)	δ_3	-0.007	-9.403***
Farming Experience (years)	δ_4	-0.013	-13.432**
Extension Contact	δ_5	-0.495	-4.032***
Diagnosis Statistics			
Sigma-square δ^2		0.4954	8.320***
Gamma γ		0.9394	11.767***
Log likelihood function		-23.67	
LR Test		87.53	

Source: Computed from MLE Results

* = Significant at 10% level; ** = Significant at 5% level; *** = Significant at 1% level.

NS = Not significant

Elasticity of production inputs and returns to scale: The input elasticities of production are shown in Table 3. The summation of the elasticities of 1.686 obtained indicated an increasing return to scale and that small scale yam production in the area was in stage I of the production function.

Table 3: Estimated elasticity of factor inputs and return to scale

Variables	Coefficients (Elasticity of production)
Farm Size (X1)	-0.010
Labour (X2)	0.371
Fertiliser (X3)	-0.017
Agrochemical (X4)	0.977
Seed yam(X5)	0.365
Return to Scale	**1.686**

Source: Field survey, 2008

Test of Hypotheses and Diagnostic Statistics

The result of the generalized likelihood ratio which is defined by the chi square distribution is presented in Table 4. The null hypothesis in the Table is Ho: $\gamma = 0$, which specifies that the inefficiency effects in the stochastic frontier production are not stochastic. The null hypothesis is rejected. This implies that the traditional response function (OLS) is not an adequate representation of the data.

Table 4: Generalized likelihood ratio test of hypothesis for parameters of the stochastic production frontier for small scale yam production in Niger State.

Null Hypothesis	Log likelihood	No. of Restrictions	χ^2 Statistics	Critical value	Decision
Ho: $\gamma = 0$	-23.67	7	87.53	14.07	Rejected

Source: Computed from MLE Results

Technical Efficiency Estimates of the Farmers

The technical efficiency indices were derived from the MLE results of the stochastic production function, using computer programme FRONTIER 4.1. The indices in Table 5 showed that the technical efficiency of the sampled farmers was less than one (less than 100%), implying that all the yam farmers in the study area were producing below the maximum efficiency frontier. Some farmers demonstrated a range of technical efficiency of 0.9510 (95.10%) while the worst farmer had a technical efficiency of 0.3172 (31.72%). The mean technical efficiency is 0.7564 (75.64%), implying that on the average, farmers in the study area were able to obtain a little over 75percent of potential yam output from a given mix of production inputs. From the results obtained, although farmers were generally relatively efficient, they still have room to increase the efficiency in their farming activities as about 24.36 percent efficiency gap from optimum (100%) was yet to be attained by all farmers.

Table 5: Distribution of Technical Efficiency Indices among Yam Farmers in the Study Area

Efficiency Class Index	Frequency	Percentage
0.00 - 0.10	0.00	0.00
0.11 – 0.20	0.00	0.00
0.21 – 0.30	0.00	0.00
0.31 – 0.40	2.00	2.00
0.41 – 0.50	7.00	7.00
0.51 – 0.60	11.00	11.00
0.61 – 0.70	7.00	7.00
0.71 – 0.80	22.00	22.00
0.81 – 0.90	41.00	41.00
0.91 – 1.00	10.00	10.00
Total	100.00	100.00
Mean	0.7564	
Maximum value	0.9510	
Minimum value	0.3172	

Source: Computed from MLE Results

SUMMARY AND CONLUSION

This empirical study is on return to scale and determinants of farm level technical inefficiency among small scale yam based farmers in Niger state, Nigeria: Implications for food security. A Cobb-Douglas production frontier was estimated by maximum likelihood estimation method to obtain ML estimates and inefficiency determinants. The MLE results revealed that TE of small scale yam farmers varied due to the presence of technical inefficiency effects in yam production. Labour, agrochemical and seed yam were found to be the significant production factors which accounted for changes in the output of yam in the study area. The distribution of the technical efficiency indices revealed that most of the farmers were technically efficient with mean TE index of 0.7564 (about 73% of the farmers had technical efficiency above 70%). The results of the inefficiency model showed that the years of education, farming experience and number of extension contacts significantly increased the farmers' technical efficiency.

This study showed that small scale yam based farmers were not fully technically efficient and therefore there is allowance of efficiency improvement by addressing some important policy variables that could negatively and positively influence farmers' levels of technical efficiency in the area.

POLICY IMPLICATION AND RECOMMENDATIONS

The implication of the study therefore, is that the level of efficiency among small-scale yam producers in Nigeria could be increased by 24.36 percent through better utilisation of available resources, given the current state of technology.

In view of current global effort in achieving the Millennium Development Goals (MDGs), Nigerian Government as part of this effort should embark on a food policy measure that will strategically ensure that yam farmers follow appropriate farm practices/recommendations in the course of technology adoption. In view of this, a more realistic package that will increase the ratio of the number of farmer to extension contact should be pursued and encouraged as a vital step towards sustainable agricultural production in the country. It was shown that education (years of schooling) had a positive correlation with technical efficiency and therefore farmers should be encouraged to improve their levels of education by registering in Adult/Continuing Education Centres in the area.

REFERENCES

Akoroda, M.O. and Hahn, S.K. (1995): 'Yams in Nigeria: status and trends.' *African Journal of Roots and Tuber Crops 1(1), pp. 38-41*

Babaleye, T. (2003): 'West Africa; Improving yam production technology', ANB- BIA supplement Issue/Edition Nr 463.

Battese, G.E. and Coelli, T.J. (1995): 'A model for technical inefficiency effects in a stochastic frontier production for panel data.' *Empirical Economics*, 20: 325-332.

Farell, M. J. (1957): 'The measurement of productive efficiency.' *Journal of the Royal Statistical Society*, 120, Part (III): 253-290.

Food and Agriculture Organisation (FAO) (1987): 'Formulation Reports: Roots and Tubers Expansion Programme.' FAO, Rome, Italy.

Food and Agriculture Organization, (1998): 'Women and sustainable food security.' www.fao.orgwaicent/fao/nfo/sustdev/fsde 001.htm

IITA (1998): Annual Report, 1997, International Institute for Tropical Agriculture. Ibadan

Niger State Agricultural Development Programme (NSADP), (1994): Impact study final report. Agricultural Development Programme Planning Unit, Minna Pp.24

Olayide, S. O., Olayemi, J. K. and Eweka, J. A. (1981): Perspectives in Benin-Owena

River Basin Development by Centre for Agricultural and Rural Development Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria. pp. 25-50.

Olawoye J. E. (1994): 'Gender priorities and issues in agricultural extension services.' A

Paper presented at the National Conference of Agricultural Extension Society of Nigeria, ARMTI, Ilorin pp. 3-6

Yao, S. and Z. Liu (1998): 'Determinant of grain production and technical efficiency in *China' Journal of Agricultural Economics*. 49(2), pp. 171-184.

Wikipedia, (2008). Wikipedia, (2008). 'Geography of Niger State, Nigeria.' Canback Global Income Distribution Database. [Online through Wikipedia] Retrieved June10, 2008 from http://en.wikipedia.org/wiki/Niger_State