Productivity and Production Efficiency Among Small Scale Irrigated Sugarcane Farmers in Niger State, Nigeria: A Stochastic Translog Frontier Function Approach.

Ojo M.A.[1], Mohammed U. S.[1], Ojo A.O.[2], Baba K.M[1] and Anjorin S,T[3]
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
3. Department of Crop Science, University of Abuja, Nigeria
Corresponding author e-mail: akinmikky@yahoo.co.uk

ABSTRACT

The study examined productivity and production efficiency among small scale irrigated sugarcane farmers in Niger State, Nigeria using a stochastic translog frontier function. Data for the study were obtained using structured questionnaires administered to 100 randomly selected sugarcane farmers from Paiko and Gurara Local Government Areas of the State. Stochastic translog frontier production function was used to represent the production frontier of the small scale irrigated sugarcane farms. The results showed a return to scale of 3.51 indicating an increasing return to scale and that small scale irrigated sugarcane production in the area was in stage I of the production region. The study also showed that the levels of technical efficiency ranged from 82.58% to 99.24% with mean of 95.39% which suggests that average irrigated sugarcane output falls 5% 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 5 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 irrigated sugarcane 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: Sugarcane production, productivity and production efficiency, translog frontier function

Introduction

Sugarcane is the major raw material used for sugar manufacturing in Nigeria. It accounts for about 61% of the total world sugar production (Wayagari *et al.*, 2003). Two types of sugarcane are grown in Nigeria- industrial and softcane (chewing) sugarcane. The industrial cane is the hard or tough type generally processed into sugar by the sugar estates. The soft cane, also called chewing cane, is mainly chewed raw for its sweet juice. Some of it is also processed into different crude sugar products. Local farmers grow softcane all over Nigeria.

Soft cane production accounts for about 60% of total sugarcane production in many years in Nigeria (Wayagari, 1999). The exact total land area currently under cane cultivation and the total production in Nigeria is not known, but it is estimated at between 25,000 – 35,000 hectares, out of which soft cane covers 18,000 hectares. Average yield of soft cane on farmers' plots varies between 45 - 75 tonnes per hectare depending on management, varieties and inputs used.

Globally the major use of the crop is in the manufacture of sugar. Sugar is used universally as a sweetener, blender and as a preservative. Major industrial users of the product include the pharmaceutical industries, the food and beverages industries, bakeries, soft drinks bottling plants as well as biscuit and other confectionery manufacturers. Domestically, it is used in large amounts as a table sweetener. Although a number of other by-products, e.g. bagasses, molasses, etc. are produced when sugarcane is processed, its major product and the one for which it is commercially cultivated is sugar. Nevertheless, cane production for chewing purpose is also of major commercial interest in Nigeria.

However, the unfolding performance of irrigated sugarcane can be attributed to the fact that bulk of the country's farm, over 90% is dependent on subsistence agriculture (small holder farmers) with rudimentary farm system, low capitalization and low yield per hectare.

However, irrigated sugarcane farms just like the other crop farms in Nigeria are the small-scale types which are characterized by very low productivity. The problem of declining crop productivity in Nigeria is important. In view of this, production efficiency of small holder farms has important implications for development strategies adopted in most developing countries where the primary sector is still dominant. An improvement in the understanding of the levels of production efficiency and its relationship with a host of farm level factors can greatly aid policy makers in creating efficacy of present and past reforms.

The objective of this paper is to contribute towards better understanding of small scale farmers' production efficiency in Nigeria with a view to predicting allocative efficiencies of irrigated sugarcane in Niger State, Nigeria, using stochastic frontier production function.

Conceptual Framework

Production efficiency is usually analyzed by its two components – technical and allocative efficiency. In a production context, technical efficiency relates to the degree to which a farmer produces the maximum feasible output from a given bundle of inputs (an output oriented measure), or uses the minimum feasible level of inputs to produce a given level of output (an input oriented measure). Allocative efficiency, on the other hand, relates to the degree to which a farmer utilizes inputs in optimal proportions, given the observed input prices (Coelli *et al*., 2002). The popular approach to measuring efficiency, the technical efficiency component, is the use of frontier production function (e.g. Battese and Coelli, 1995; Battese, 1992). However, Yotopolous and others argue that a production function approach to measuring efficiency may not be appropriate when farmers face different prices and have different factor endowments (Ali and Flinn, 1989). This led to the application of stochastic profit function models to estimate farm specific efficiency directly (e.g., Ali and Flinn, 1989; Sanzidur, 2003 and Ogundari, 2006).

Coelli (1996) as well as Battese and Coelli (1995) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics. The advantage of Battesse and Coelli (1995) model is that it allows estimation of the farm specific efficiency scores and the factors explaining efficiency differentials among farmers in a single stage estimation procedure.

In this study, Battese and Coelli's (1995) model 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, was used.

The general form of the model is expressed as:

$$Q_i = \beta_0 + \beta_i X_i + (V_i - U_i) \qquad (1)$$

Where:

Q_i is the production (or 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;

The Vi are random variables which are assumed to be iid *(N,δ^2v)* 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 *(0,δ^2u)*.

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:

$$U_i = \delta_0 + \delta_i Z_i \qquad (2)$$

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 Ui does not exist in equation (1) or $U_i = \delta_0^2$, 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, *Ui 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 (ME). An estimated value of technical efficiency for each observation can then be calculated as

$$TE_I = \exp(\text{-Ui}). \quad (3)$$

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: 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 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 ranges from 23^oC and 37^oC (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 include Paikoro and Gurara LGAs. The second stage involved a simple random selection of five villages from each LGA. This is followed by random selection of 50 farmers from each of the two LGAs, thus, making 100 respondents. The data were collected using structured questionnaire designed in line with objectives of the study. Information was collected on the total output of sugarcane in tons. The input data include: land area under cultivation (ha), labour (man-days), quantity of fertilizer (kg), planting materials (tons), Agrochemical (litres), and cost of farm tools (Depreciation). Data were also collected on the household socio- economic variables such as years of schooling, farming experience, age, household size and number of extension contact.

Model Specification: The nature of efficiency measure in this study is technical efficiency; hence, the stochastic translog frontier production function is defined as:

$$\ln Y_i = \beta_0 + \sum_{k=1}^{6} \beta_k \ln X_{ki} + \tfrac{1}{2}\sum_{k=1}^{6}\sum_{l=1}^{6} \beta_{kl} \ln X_{ki} \ln X_{lj} + v_i - u_i \quad (4)$$

Where

ln represents the natural logarithm; the subscript i-the sample farmer; Yi represents the farm output for farmer i; Xs represents the input variables [land size (ha), Labour (man-day), fertilizer (kg), agrochemical (litres), planting material (tons) and cost of farm tools]. In the model; β_k represents the input coefficients for the resources used in production;

Equation 4 can be explicitly written as:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \tfrac{1}{2}\beta_{11}[\ln X_1]^2$$
$$+ \tfrac{1}{2}\beta_{22}[\ln X_2]^2 + \tfrac{1}{2}\beta_{33}[\ln X_3]^2 + \tfrac{1}{2}\beta_{44}[\ln X_4]^2 + \tfrac{1}{2}\beta_{55}[\ln X_5]^2 + \tfrac{1}{2}\beta_{66}[\ln X_6]^2 + \beta_{12} \ln X_1 \ln X_2$$
$$+ \beta_{13} \ln X_1 \ln X_3 + \beta_{14} \ln X \ln_1 X_4 + \beta_{15} \ln X_1 \ln X_5 + \beta_{16} \ln X_1 \ln X_6 + \beta_{23} \ln X_2 \ln X_3 + \qquad (5)$$
$$\beta_{24} \ln X_2 \ln X_4 + \beta_{25} \ln X_2 \ln X_5 + \beta_{26} \ln X_2 \ln X_6 + \beta_{34} \ln X_3 \ln X_4 + \beta_{35} \ln X_3 \ln X_5 +$$
$$\beta_{36} \ln X_3 \ln X_6 + \beta_{45} \ln X_4 \ln X_5 + \beta_{46} \ln X_4 \ln X_6 + \beta_{56} \ln X_5 \ln X_6 + V_i - U_i$$

Where Y, X_1, X_2, X_3, X_4 X_5 and X_6 are as defined earlier. The Vi's are assumed to be independent and identically distributed (iid) normal random errors having zero mean and unknown variance. Ui'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 Ui's are the non-negative truncation (at zero) of the normal distribution with mean μ and variance δ^2

The inefficiency model can be explicitly defined for this study as:

$$U_i = \delta_0 + \sum_{n=1}^{5} \delta_n Z_{ni} \qquad (6)$$

Equation (6) can be written as:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} \qquad (7)$$

Where U_i is as defined above, Z_{1i} is farmer's age; Z_{2i} is the farmer's years of schooling; Z_{3i} is the years of experience; Z_{4i} is the household size and Z_{5i} is the number of contact with extension agent.

Productivity Analysis: This is measured in terms of return to scale (RTS) which is obtained from summation of inputs elasticities. Hence, given the specification of the translog stochastic frontier model above, the output elasticity (ε_p) with respect to the inputs is computed using the expressions in the equation below:

$$\varepsilon_p = \frac{\partial \ln Y_i}{\partial \ln X_{ki}} = \beta_i + \sum \beta_{kl} \ln X_{ki} \qquad (8)$$

Log Likelihood Ratio Test: For this study, two different models were estimated. Model1 is the traditional response function in which the inefficiency effects are not present. It is a special case of the stochastic frontier production function model in which the total variation of output from the frontier output due to technical inefficiency is zero, that is, $\gamma = 0$. Model 2 is the general model where there is no restriction and thus $\gamma \neq 0$. The two models were compared for the presence of technical inefficiency effects using the generalized likelihood ratio test which is defined by the test statistic, chi-square ($\chi 2$).

$$\chi^2 = -2\{\ln[L(H_0) - L(H_a)]\} \quad (9)$$

Where, χ^2 has a mixed chi-square distribution with the degree of freedom equal to the number of parameters excluded in the unrestricted model. H_0 is the null hypothesis that $\gamma = 0$. It is given as the value of the likelihood function for the frontier model and H_a is the alternative hypothesis that $\gamma \neq 0$ for the general frontier model.

RESULTS AND DISCUSSION

Production Analysis: The summary statistics of the variables for the frontier estimation is presented in Table1. They include the units, sample mean value, standard deviation, minimum and maximum values for each of the variables used in the analysis. The average sugarcane produced per annum was approximately 6.57tons/ha. Similarly, the average, fertilizer, agrochemical and planting materials of approximately 179.80 kg/ha, 3.75 litres/ha and 0.86tons/ha were obtained from the analysis.

Table1: Summary statistics of the variables in stochastic frontier model

Variables	Minimum	Maximum	Mean	Standard Deviation
Output (tons)	3.00	20.00	6.84	2.23
Farm Size (ha)	0.50	2.50	1.04	0.41
Labour (Man-days)	25.12	942.88	88.16	117.29
Fertilizer (kg)	100.00	350.00	187.00	58.44
Agrochemical (Litres)	2.00	8.00	3.90	1.37
Planting material (tons)	0.15	2.00	0.90	0.42
Cost of farm tools	766.66	2333.33	1512.67	345.72
Age (years)	19.00	71.00	38.79	10.91
Education level (years)	0.00	15.00	7.60	5.08
Years of Experience	1.00	38.00	11.76	6.96
Household Size	1.00	12.00	5.15	2.93
Number of Extension Contact	0.00	6.00	1.86	1.23

Source: Field Survey, 2008

However, the average labour utilisation of 84.62 man-days was recorded for the study among the farmers. This is expected, given the tedious operations in irrigated sugarcane production.

Variables representing the demographic characteristics of the sampled farmers employed in the analysis of the determinant of technical inefficiency include age of the farmers, educational level of the farmers, years of experience, household size, 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 38.79, 7.60, 11.76, 5.15 and 2.86 respectively, meaning that the farmers were relatively young and less educated.

Table 1 shows that estimated elasticities of mean output with respect to land, labour, fertilizer, agrochemical and planting materials inputs are -17.82, 0.85, 18.45, -1.15 and 6.53 respectively. This means that one percent increase in labour, fertilizer and planting materials increased irrigated sugarcane production by 0.85%, 18.45% and 6.53% respectively. Also, one percent increase in area cultivated to irrigated sugarcane and agrochemical decreased irrigated sugarcane output by 17.82% and 1.15% respectively.

Determinants of Technical Inefficiency

Table 2 shows the result for the regression analysis of the determinants of technical efficiency 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 long farming experience and frequent extension contacts in small scale irrigated sugarcane 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 decreased. Also, positive coefficient for age implied that the farmers' level of technical inefficiency increased with increased in age.

The sigma square is 0.2521 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 0.6286 which is significant at 1% level implied that about 62.86 percent variation in the output of irrigated sugarcane farmers was due to differences in their technical efficiencies

Table2: Maximum Likelihood Estimates of Parameters of the Translog Frontier Function for Small Scale Irrigated Sugarcane Farmers in Niger State.

Variables	Parameters	Restricted Model	General Model (Preferred Model)
General Model			
Constant	ß$_0$	-34.607(-1.065)	-35.005(-28.862)***
$\ln X_1$	ß$_1$	-18.332(-2.679)***	-17.827(-17.642)***
$\ln X_2$	ß$_2$	1.227(0.7171)	0.846(0.883)
$\ln X_3$	ß$_3$	15.837(1.736)*	18.453(4.950)***
$\ln X_4$	ß$_4$	-0.264(-0.811)	-1.167(-0.824)
$\ln X_5$	ß$_5$	6.997(1.810)*	6.526(6.142)***
$\ln X_6$	ß$_6$	-2.047(-0.426)	-3.355(-1.543)
$[0.5\ln X_1]^2$	ß$_{11}$	-1.845(-1.726)*	-1.902(-3.294)***
$[0.5\ln X_2]^2$	ß$_{22}$	-0.083(-1.256)	-7.646(-1.481)
$[0.5\ln X_3]^2$	ß$_{33}$	-1.764(-1.027)	-1.889(-2.641)***
$[0.5\ln X_4]^2$	ß$_{44}$	-0.574(-2.412)**	-0.691(-2.555)**
$[0.5\ln X_5]^2$	ß$_{55}$	0.115(2.535)***	1.041(4.774)***
$[0.5\ln X_6]^2$	ß$_{66}$	0.765(1.383)	1.153(1.889)*
$\ln X_1 \ln X_2$	ß$_{12}$	0.319(1.305)	0.416(1.959)*
$\ln X_1 \ln X_3$	ß$_{13}$	3.977(2.684)***	3.903(6.284)***
$\ln X_1 \ln X_4$	ß$_{14}$	-0.013(0.026)	0.015(0.041)
$\ln X_1 \ln X_5$	ß$_{15}$	-1.002(-3.046)***	-0.892(-4.468)***
$\ln X_1 \ln X_6$	ß$_{16}$	0.185(0.264)	0.135(0.267)
$\ln X_2 \ln X_3$	ß$_{23}$	-0.099(-0.423)	-0.840(-0.526)
$\ln X_2 \ln X_4$	ß$_{24}$	0.121(1.138)	0.100(1.017)
$\ln X_2 \ln X_5$	ß$_{25}$	-0.911(0.683)	-0.183(-1.516)
$\ln X_2 \ln X_6$	ß$_{26}$	-0.064(0.489)	-0.026(-0.233)
$\ln X_3 \ln X_4$	ß$_{34}$	-0.725(-1.552)	-0.538(1.698)
$\ln X_3 \ln X_5$	ß$_{35}$	-1.209(1.689)*	-1.188(-2.837)***
$\ln X_3 \ln X_6$	ß$_{36}$	0.760(-1.094)	-1.087(-1.950)*
$\ln X_4 \ln X_5$	ß$_{45}$	0.288(1.175)	0.251(1.317)
$\ln X_4 \ln X_6$	ß$_{46}$	0.659(1.992)*	0.679(3.199)***
$\ln X_5 \ln X_6$	ß$_{56}$	-0.065(-0.189)	0.280(0.084)
Inefficiency Functions			
Constant	δ_0		-0.335(-0.735)
Age (years)	δ_1		0.024(0.810)
Household Size	δ_2		-0.085(0.714)
Education Level (years)	δ_3		-0.551(-3.024)***
Farming Experience (years)	δ_4		-0.012(-2.510)**
Extension Contact	δ_5		-0.547(2.601)***
Diagnosis Statistics			
Sigma-square δ^2	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.3357	0.2521(2.655)***
Gamma γ	$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$		0.6286(3.506)***
Log likelihood function		44.81	41.34
LR Test			69.37

Source: Computed from MLE Results

**** = Significant at 1% level of probability,** = Significant at 10% level of probability, * = Significant at 1% level of probability, Numbers in parenthesis = t-ratios*

Productivity Analysis

The return to scale (RTS) analysis which serves as a measure of total resource productivity is given in Table 3. The RTS parameter (3.51) is obtained from the summation of the coefficients of the estimated inputs (elasticites) which indicates increasing return to scale and that irrigated sugarcane production in the study area was in the stage I of the production surface.

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

Variables	Coefficients (Elasticity of production)
Farm Size (X_1)	-17.82
Labour (X_2)	0.85
Fertilizer (X_3)	18.45
Agrochemical (X_4)	-1.15
Seed yam(X_5)	6.53
Farm tools	-3.35
Return to Scale	**3.51**

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 translog production frontier for small scale irrigated sugarcane production in Niger State.

Null Hypothesis	Log likelihood	No. of Restrictions	χ^2 Statistics	Critical value	Decision
Ho: $\gamma = 0$	41.34	7	69.37	14.07	Rejected

Source: Computed from MLE Results

Table5: Distribution of Technical Efficiency Indices among Irrigated Sugarcane Production in the Study Area

Efficiency Class Index	Frequency	Percentage
Below 0.80	0.00	0.00
0.81 – 0.90	14.00	14.00
0.91 – 1.00	86.00	86.00
Total	100.00	100.00
Mean	0.9539	
Maximum value	0.9924	
Minimum value	0.8258	

Source: Computed from MLE Results

Technical Efficiency Estimates of the Farmers

Table 5 shows the predicted technical efficiencies for the sampled farmers. The minimum estimated technical efficiency is 0.8258, the maximum is 0.9924 while the mean is 0.9539 with a standard deviation of 4.1792. The implication of these statistics is that, in the short run, there is scope for increasing irrigated sugarcane production by 4.6108 percent by adopting techniques used by the best practice irrigated sugarcane farmers. This further suggests that, on average, approximately 4 percent of irrigated sugarcane yield was lost because of inefficiency.

SUMMARY AND CONLUSION

This empirical study is on productivity and production efficiency among small scale irrigated sugarcane farmers in Niger State, Nigeria. A stochastic translog 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 irrigated sugarcane farmers varied due to the presence of technical inefficiency effects in irrigated sugarcane production. Farm size, fertilizer and planting material were significant production factors which accounted for changes in the output of irrigated sugarcane production in the study area.

Average TE of approximately 95 percent obtained shows that about 5 percent variation of observed irrigated sugarcane yield from the frontier output can be attributed to difference in farmer's technical efficiency. This can be traced to none optimal use of inputs and inefficiency effects observed among the production units. Household size, years of schooling, years of farming experience and extension contact decreased the technical inefficiency of the farmers with years of schooling, years of farming experience and extension contact been significantly different from zero.

POLICY IMPLICATION AND RECOMMENDATIONS

The implication of the study therefore, is that the level of efficiency among small-scale irrigated sugarcane producers in Niger State could be increased by 5 percent through better utilisation of available resources, given the current State of technology.

On the basis of the findings, it is suggested that efforts to increase number of contact between farmers and extension workers in the area. This could be a vital step towards sustainable increase in agricultural production. It was shown that education (years of schooling) had a positive correlation with technical efficiency. Therefore farmers should be encouraged to improve their levels of education by registering in Adult/Continuing Education Centres in the area

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