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Technical Efficiency in Food Crop Production in Oyo State, Nigeria

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ABSTRACT This study used a stochastic frontier production (Maximum Likelihood Estimation, MLE) methodology to estimate the technical efficiency of 100 farmers in Oyo State, Nigeria. Efficiency analysis is an issue of interest given that the overall productivity of an economic system is directly related to the efficiency of production of the components within the system. The empirical results show that the mean level of technical efficiency is 70 percent. The estimated technical efficiencies of the farmers ranged between 18 percent and 93 percent indicating that with the present technology there is still room for a 30 percent increase in food production. Age of farmers, farming experience and level of education were factors that significantly influence the level of technical efficiency. Technical inefficiency of farmers increases with age while it decreases with years of experience and level of education.

INTRODUCTION

In Nigeria, food consumption accounts for a high proportion of total households' expenditure. According to C.B.N, (1995), it accounted for about 50% of total household's expenditure in 1994 with an increment to 72% in 1995. The ability of Nigeria agriculture to perform its role in development has been declining thus creating wide gap between the demand for and supply of food. Most studies show that aggregate food production in Nigeria has been growing at about 2.5 percent per annum in recent years but the annual rate of population growth has been as high as 2.9 percent (Olayemi, 1998). The reality is that Nigeria has not been able to attain self-sufficiency in food production, despite increasing land area been put into food production annually. One way peasant farmers can achieve sustainable agricultural development is to raise the productivity of their farm by improving efficiency within the limits of the existing resource base and available technology. Efficient use of various inputs is an important part of sustainability (Harwood, 1987) which implies either fewer inputs to produce the same level of output or higher output at the same level of inputs. An increase in efficiency in food crop production could lead to an improvement in the welfare of farmers and consequently a reduction in their poverty level and food insecurity.

This study seeks to estimate farmer's technical efficiency in food crop production in Oyo State, Nigeria. The study went further; to investigate the influence some basic variables have on technical inefficiency of production of peasant farmers. Farrel (1957) developed the concept to technical efficiency based on the input output relationship. He suggested a method of measuring technical efficiency by estimating the production function of firms which are fully efficient. A farm is said to be technically inefficient when actual or observed output from a given input mix is less than the maximum possible.

MATERIALS AND METHOD

Theoretical/Conceptual Framework

Efficiency measurement and the procedure of maximum likelihood estimation are the basic theoretical constructs on which this study is conceptualized. In economic analysis, much is concerned with the technical and economic efficiencies or resource transformation and allocation (Coelli, 1994). Production efficiency is concerned with the relative performance of the process used in transforming inputs into output. The concept of efficiency goes back to the pioneering work of Farrel (1957) who distinguishes between three types of efficiencies:

- technical efficiency (TE)
- allocative or price efficiency (AE), and
- economic efficiency (EE)

Technical efficiency in production is the physical ratio of product output to the factor input, the greater the ratio, the greater the magnitude of technical efficiency.

Allocative efficiency is concerned with

choosing optimal sets of inputs. A firm is allocatively efficient when production occurs at a point where the marginal value product is equal to the marginal factor cost.

Economic efficiency is a situation where there are both technical and allocative efficiencies. The simultaneous achievement of both efficient condition according to Heady (1952) occurs when price relationship are employed to denote maximum profits for the firm or when choice indicators are employed to denote the maximization of other economic objectives. So, economic efficiency refers to the choice of the best combination for a particular level of output which is determined by both input and output prices.

Farrel's measure of efficiency depends on the existence of the efficient production function with which observed performance of a firm can be compared. A production function based on the "best" practical results would have to be used as a reference for measuring individual performance. However, due to the problem of complication, Farrel considered it better to compare performance with the "best" obtained than to set up some unrealizable ideal. He then obtained from scattered diagrams of several firms an isoquant showing the least exacting standard of efficiency assumption of convexity to the origin and non-positive slope at any point.

The stochastic efficiency frontier models independently proposed by Meeusen and Vanden Broeck (1977) and extended by Jondrow *et al* (1982) was used in analyzing the data. It allows for the estimation of individual firm efficiency level with both time variations and cross-sectional data. The stochastic efficiency frontier production function is defined by:

$$Yi = F\ (Xi, \beta)\ \exp\ (Vi - Ui)\quad i = 1,2 \ldots N \qquad (1)$$

Where :-

Yi	=	Output of i th firm
Xi	=	corresponding (M x Z) vector of inputs
β	=	vector of unknown parameter to be estimated.
Vi	=	Symmetric error component that accounts for random effects and exogenous shock.
Ui< O	=	a one - sided error component that measures technical inefficiency.

Estimation of inefficiency effect, - U from statistical noise, V is accomplished by estimating the mean of conditional distribution of U given V expressed as:

$$\frac{U}{e} = \mu i + \sigma^* \left(f^* \frac{(-\mu i)}{\sigma^*}\left[1 - F\ \frac{(\mu i)}{\sigma^*}\right]\right) \quad (2)$$

where :-

$$\sigma^* = \frac{(\sigma^2 v\ \ \sigma^2 u)}{\sigma^2}^{1/2} \qquad \mu = \frac{(-\sigma^2 u\ eui)}{\sigma^2}$$

f = standard density function, and

F = standard distribution function

This is done by means of maximum likelihood estimation (MLE), which involves the estimation of population parameters such that the probability density for obtaining the actual sample observation that have been obtained from the population is greater than the probability density obtainable with any other assumed values (estimations) of the population parameter (Olayemi 1998; Draper et al., 1966). The MLE method provides estimators that are asymptotically consistent and efficient. The parameters of the stochastic frontier function model are estimated by the method of maximum likelihood, using the computer program FRONTIER version 4.1 (Coelli, 1994).

METHODOLOGY

Study Area, Sampling and Data Collection: This study was conducted in Oyo State of Nigeria. Oyo is one of the 36 states in Nigeria and it lies in the Western part of the country. The state with two ecological zones (rainforest to the South and derived savannah to the North) is well suited for food crop production. Food crops grown in the area include Yam, Maize, Cassava, Cowpea, Sorghum, Plantain and Rice. Oyo State Agricultural Development Programme (OYSADEP) has grouped the state into four zones namely Ibadan/ Ibarapa, Ogbomosho, Saki and Oyo zones.

Saki zone (where the study was conducted) presents a good picture (given the name "food basket") of the state having enjoyed the services of the Agricultural Development Project for close to two decades now. The zone has agriculture as its major traditional occupation with trade and crafts as the secondary occupation. The zone formally called Oyo North has Tede as the zonal headquarters. It has twenty five major villages headed by a block extension officer under the ADP administration.

Mixed cropping is the major farming practice in the area with a combination of various food crops in the mixture. Livestock keeping is also predominantly practiced by the farmers especially the female members of the household. Majority of the farmer in the area are small-scale farmers with average farm size of about four acres. Also both family and hired labour are common, though with most children going to school, the importance of family labour is fast declining. A two-stage sampling technique was employed in selecting the samples needed for the study. First, the villages in the zone were divided into four strata based on economic and socio-cultural considerations and one village was randomly selected from each stratum.

The second stage involved a random selection of 25 farmers from each of the villages in the selected strata. In all, a total of 100 small holder farmers were interviewed with the aid of structured questionnaires.

The range of data collected covered those on household's farm activities. These include material input (input purchase cost and quantity), family and hired labour use, total value of output consumed, retained and sold, socio-economic variables such as age, gender, marital status, farming experience, family size, level of education, source(s) of credit. tenural arrangement, farm size (acre on food crops) on enterprise basis and off – farm general activities. The primary data collected were supplemented with secondary data obtained from Oyo State Agricultural Development Project (OYSADEP), Farmers' Union and Co-operative bodies.

The secondary data covered information on the prices of inputs and output, labour wage rates and interest on agricultural loans.

Empirical Models

The stochastic frontier production function is expressed as follows:

$\mathrm{Ln}\, Yi = \beta o \times \mathrm{Ln}\, \Sigma^3 \beta j \times ji \;\; \Sigma^3\Sigma^3 \;\beta jk \times ji \times ki \times vi - ui$ .... (3)

Where Ln = natural logarithm;

i = i th sample smallholder farmer;

Y = value of farm output for farmer ß ;

Xs = input variables in the model, and

X1 = total area of land (in acres);

X2 = total labour in mandays (family + hired);

X3 = cost of capital;

βs = input coefficient for the resources used in production ;

js = input variables in the first - order term of the trans log model;

ks = input variables in the second – order term of the trans log model;

The explicit form of the model is written thus:

$\mathrm{Ln}\, Yi = \beta o + \mathrm{Ln}\, \beta 1\, X_1 + \mathrm{Ln}\, \beta_2\, X_2 + \mathrm{Ln}\, \beta_3\, X_3 + \mathrm{Ln}\, \beta_4\, X_1^2$

$+ \mathrm{Ln}\, \beta_5\, X2^2 + \mathrm{Ln}\, \beta_6\, X3^2 + \mathrm{Ln}\, \beta_7\, X_1\, X_2 +$

$\mathrm{Ln}\, \beta_8\, X_1\, X_3 + \mathrm{Ln}\beta_9\, X_2\, X_3 + Vi - Ui$ .... (4)

Where Y, β, X_1, X_2, X_3 are as defined earlier the Vi's are assumed to be independent and identically distributed normal random errors having zero mean and unknown variance. Ui's are non-negative random variables called technical inefficiency effects which are associated with technical inefficiency of production of the respondent farmers which are assumed to be independent of the Vis such that Uis are the non negative truncation (at zero) of the normal distribution with mean, μ and variance, σ^2.

$\mu\, i = \sigma_o + \sigma_1\, Z_1 i + \sigma_2\, Z_2 i + \sigma_3\, Z_3 i$...............(5)

where:

Z_1 Z_2 and Z_3 are the age, farming experience and level of education of the ith farmers respectively, and the βs and σ_s are unknown scalar parameters to be estimated.

The variables age, farming experience and level of education are included in the model for the technical inefficiency effects to indicate positive effects of farmers characteristics on the efficiency of production.

The technical efficiency of the ith farmer is expressed as

$\mathrm{Te}\, i = \exp\, (-\,Ui)$ .... (6)

RESULTS AND DISCUSSION

The model specified is estimated by the maximum likelihood approach, using a computer programme FRONTIER 4.1 developed by Coelli (1994). The estimates are presented in Table 1 .

The estimated coefficient for land is positive, which conform to *a priori* expectations, indicating that the level of technical inefficiency of the small holder croppers tend to increase for the larger farms. Labour appears to be the most important factor of production with an elasticity of 0.302, showing the labour- intensive nature of farming in the study area. Also the elasticity is positive as expected and statistically significant at 5 percent level suggesting that a 1 percent increase in labour will induce an increase of 0.3 percent in the farm gross margin and vice versa. These results agree with previous work by Amaza et al. (2000). The coefficient of capital (i.e seeds, agro-chemicals etc.) is positive and statistically significant at 1 percent level in conformity with *a*

Table 1: Maximum likelihood estimates of trans log production frontier and inefficiency function for small-holder crop farmers in Oyo State, Nigeria.

Variable	*Parameter*	*Coefficient*	*Standard error*
Constant	β_0	3.240	1.105*
Land	β_1	0.061	0.243
Labour	β_2	0.302	1.840**
Capital	β_3	0.292	0.063***
Land x Land	β_4	0.176	2.502**
Labour x Labour	β_5	0.148	1.951*
Capital x Capital	β_6	0.022	0.017***
Land x Labour	β_7	0.481	2.406**
Land x Capital	β_8	0.363	0.210
Labour x Capital	β_9	0.194	1.251
Inefficiency Function			
Constant	σ_0	4.011	2.310***
Age	σ_1	0.137	0.018
Experience	σ_2	- 0.182	0.092
Education	σ_3	- 0.088	0.087***
Diagnostic statistics			
Sigma -Square	σ^2	0.812	0.488***
Gamma	γ	0.804	0.122***
Ln (Likelihood)		-	5.810

*** Significant at the 0.01 level; ** at the 0.05 level ; * at the 0.10 level.
Source: Computed MLE results.

priori expectation. The estimated coefficients of the inefficiency function provide some explanations for the relative efficiency levels among individual 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 positive coefficient for age variable implies that the older farmers are more technically inefficient than the younger ones. Older farmers tend to be more conservative and less receptive to modern and newly introduced agricultural technology. The negative coefficient for farming experience indicate that farmers with greater experience are less inefficient. Also negative coefficient for education implies that the farmers level of technical inefficiency declines with more education. These results are in conformity with previous works by Parikh et al. (1995).

The sigma square (0.812) is large 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 variance ratio (ã) is estimated to be as high as 80.40 percent suggesting that the systematic influences that are unexplained by the production function are the dominant sources of random error, that is the existence of technical inefficiency among the sampled farmers account for about 80 percent of the variation in the output level of the crops grown. This confirms that in the specified model, there is the presence of a one-sided error component and that a classical regression model of the production function based on the OLS (Ordinary Least Square) estimate would be an inadequate representation of the data. The results of the diagnostic statistics therefore confirm the relevance of the stochastic parameters of the production frontier and maximum likelihood estimation.

Technical efficiency estimates of the farmers

The technical efficiency indices are derived from the MLE results of the stochastic production function, using computer programme FRONTIER 4.1. The indices in table 2 show that the technical efficiency of the sampled farmers is less than 1 (less than 100%) implying that all the farmers in the study area are producing below the maximum efficiency frontier.

Some farmers demonstrated a range of technical efficiency. The best farmers (two of them) have technical efficiency of 0.93 (93%) while the worst farmer has a technical efficiency of 0.18 (18%). The mean technical efficiency is 0.7103 (71%) implying that on the average, farmers in the study area were able to obtain a little over 70 percent of potential

Table 2: Distribution of technical efficiency indices among farmers in the study area

Efficiency class index	*Frequency*	*Percentage*
0.00 - 0.10	0	0
0.11 - 0.20	1	1
0.21 - 0.30	0	0
0.31 - 0.40	2	2
0.41 - 0.50	6	6
0.51 - 0.60	16	16
0.61 - 0.70	17	17
0.71 - 0.80	30	30
0.81 - 0.90	21	21
0.91 - 1.00	7	7
Total	100	100

Mean = 0.7103
Maximum value = 0.93
Minimum value = 0.18
Source: Computed from MLE results.

output from a given mix of production inputs. The distribution also revealed that only 3% of the farmers have technical efficiency less than 41%. From this estimation, maximum technical efficiency is not yet achieved probably because most of the farmers produce food with the use of inefficient tools, unimproved seed varieties etc. Level of experience, age and low level of formal education are the major factors that culminate to influence the magnitude of the farmers technical efficiency.

CONCLUSION

The study centered on estimation of technical efficiency of farmers using stochastic parametric estimation methods. A translog production frontier was estimated by Maximum Likelihood Estimation method to obtain ML estimates and inefficiency determinants. The distribution of the technical efficiency indices revealed the state of technology used by the sampled farmers as inferior, although farmers on the average, have moderately high level of technical efficiency, given the resources at their disposal (about 75% of the farmers have technical efficiency above 60%). Also the farmers' level of technical efficiency has been shown to be significantly influenced by age, farming experience and level of education.

The policy implication of this study is that the mean technical efficiency of 0.70 could be increased by 30 percent through better use of available resources.

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