Farmers Resource – Use and Technical Efficiency in Cowpea Production in Nigeria

B.T. Omonona [1], O.A. Egbetokun [2] and A.T. Akanbi [1]
[1]Department of Agricultural Economics,
University of Ibadan, Ibadan, Oyo State, Nigeria
[2]Institute of Agricultural Research and Training, Obafemi Awolowo University,
Moor Plantation, P.M.B 5029, Ibadan, Oyo State, Nigeria
(Email: greatjoge@yahoo.com)

Abstract: In Nigeria, the use of stochastic frontier to estimate farm level efficiency effects is still at the rudimentary level and is beginning to build up. Few studies have been undertaken but there is dearth need for more empirical studies on this important issue. This paper presents the analysis of technical efficiency of cowpea production in Osun state southwest Nigeria, using the stochastic production frontier, budgetary and resource-use efficiency analyses. The marginal value products of all the resources used are less than their prices (MVP<MFC), indicating underutilization of resources. The enterprise economic efficiency is 1.17. This means that for every N1 spent by the farmer on cowpea production, 17 kobo was realized as profit. The farmers' average technical efficiency is 87%, which suggest an appreciable use of inputs in productivity. Analysis efficiency using stochastic production frontier shows that farm size, seed, hired labour, family labour, fertilizer and pesticides are significant at 1% and some socio-economic variables using tobit regression model is found to be significantly different from zero at 1% for cooperative membership and farming experience. It is recommended that farmers should be encouraged to join cooperative society and extension services agents should intensify their efforts in training and mobilizing farmers for improved production of cowpea. Also, farmers should cut down the use of resources (quantity) for optimum production and economic benefit.

I. INTRODUCTION

The crucial role of efficiency in increasing agricultural output has been widely recognized by researchers and policy makers alike. The Nigerian government in 2003 made a policy on exportation of food crops. Therefore, it is necessary to study the efficiency of farmers sequel to the export promotion policy on one of the major food crops produced in Nigeria.

An underlying premise behind this work, in line other works, is that if farmers were not making efficient use of existing technology, then efforts designed to improve efficiency would be more cost effective than introducing new technologies as a means of increasing agricultural output. (Belbase and Grabowski, 1985). The efficiency of a farm/firm refers to its success in producing as large amount of output as possible given a set of inputs. To determine the efficiency of a particular firm, there need for efficiency measurement through the production factor inputs and processes. This (efficiency measurement) has received considerable attention from both theoretical and applied economists. From a theoretical point of view, there has been a spirited exchange about their relative importance of the various components of firm efficiency (Leibenstein 1996 and 1978, Comanor and Leibenstein 1969). From an applied perspective, measuring efficiency is important because this is the first step in a process that might lead to substantial resource savings these resource savings have important implications for both policy formulations and firm management (Bravo-Ureta and Rieger 1991).

M.J Farrell originated the current interest in efficiency measurements. Farrell (1957) proposed an approach that distinguishes between technical and allocative efficiency. Technical efficiency refers to the ability of producing a given level of output with a minimum quantity of inputs under a given technology. Allocative efficiency refers to the choice of the optimal input proportions given relative prices. Economic or total efficiency is the product of technical and allocative efficiency. Farrell's model, which is known as a deterministic nonparametric frontier (Forsund, *et al* 1980), attributes any deviation from the frontier to inefficiency and imposes no functional form on the data. Several extensions of Farrell deterministic model have been made by economists such as Aigner and Chu (1968), Afriat (1972), Richmond (1974), Schmidt (1980) and Greene (1980) among others.

A deficiency characterizing all deterministic frontier models is their sensitivity to extreme observations. A more recent approach for measuring efficiency, which seeks to ameliorate the extreme observation problem, is the stochastic frontier model developed by Aigner, *et al* (1977) and by Meeusen and van deu Broeck (1977). Other model such as Data Envelope Analysis (DEA) is a nonparametric data-based methodology that provides measures of optimal profit ratio and best practice efficiency. It identifies the best firms on the efficient productivity frontier (efficient firm) and firms that are interior to that frontier (inefficient firms). Many outputs and inputs can be analyzed simultaneously for a number of observations (Zaibet and Dharmapala 1999). However, the model is not used in this study because cowpea is planted solely in the state.

The stochastic frontier model assumes an error term with two additive components- a symmetric component that accounts for pure random factors, and a one-sided component which captures the effects of inefficiency relative to the stochastic frontier.

In general, a firm is technically efficient if its observed production outlay (y^o, X^o) exactly satisfies the Cobb-Douglas production equation given as $y^o = f(X^o)$, where f is the production frontier, y^o is the output and X^o is a vector of input for the firm. The firm is technically inefficient if $y^o < f(X^o)$ that is, the firm operates inside the production frontier.

The firm is allocatively efficient if the ratio of the marginal products $MP_{(x)}$ between all input equal to the ratio of the input prices MPi/MPi = Pi/Pi

Scale efficiency is achieved if the firm produces at a marginal cost that is the same as the price of the output. Allocative and scale efficiency is the conditions for profit maximization and is labeled price efficiency.

This paper contributes to the efficiency literature in developing country agriculture by quantifying the level of technical efficiency for a sample of cowpea farmers in Osun State, Southwestern Nigeria. The objectives are to determine the profitability, measure the resource use efficiency of cowpea production and to analyze the effect of socio-economic variables on the efficiency level of the farmers.

II. ANALYTICAL FRAMEWORK

In the analysis of the data for cowpea producing farmers, budgetary and resource-use efficiency analyses were used. Also, stochastic production frontier was employed using the variant of the stochastic production analysis adopted by Coelli and Battese (1996), Bravo Ureta and Rieger (1991) and Dawson *et al* (1991).

It is assumed that the farm frontier production function can be written as:

$$Q = f(X_i; \beta) \quad (1)$$

Where Q is the quantity of cowpea output, X_i is a vector of input quantities, and β is a vector parameter.

The empirical model of the stochastic production function frontier applied in the analysis of efficiency of the production system of the cowpea production is specified as:

$$\ln Y_{ij} = \ln \beta_o + \beta_1 \ln X_{1ij} + \beta_2 \ln X_{2ij} + \beta_3 X_{3ij} + \beta_4 X_{4ij} + \beta_5 X_{5ij} + \beta_6 X_{6ij} + \in \quad (2)$$

Where

- Y = total output (kg)
- X_1 = Farm size (ha)
- X_2 = quantity of seed (kg)
- X_3 = amount spent on hired labour (₦)
- X_4 = family labour (maydays)
- X_5 = fertilizer (kg)
- X_6 = pesticides (litres)

Subscript i and j refer to the i^{th} cowpea produce and the jth input respectively and $\in = V_{ij} - U_{ij}$ is the composed error term (Aiger *et al (*1977), Meeiisen and Van deu Broeck 1977). The two components v and u are assumed to be independent of each other, where v is the symmetric (two-sided) component, normally distributed random error ($V \sim N(0,\sigma^2_v)$ which capture variations in output due to factors outside the control of the farmer like fluctuations in input/ prices and u is the one-sided efficiency component with a half-normal distribution ($U \sim |N(0,\sigma^2_u|$) which is non –negative random variable called technical inefficiency effect associated with the technical efficiency of cowpea production and it capture the variation in output due to family size, age, educational status, cooperative membership, farmers experience(yrs) and other socio-economic characteristics. U_{ij} equal zero for any output lying on the frontier while $U_{ij} > 0$ for any output lying below the frontier. Hence,

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

However, the output variable in the stochastic frontier production function is output in kg, the measures of technical efficiencies obtained will, of course, be measures of the overall technical efficiencies of the cowpea farmers. It is assumed that the inefficiency effects are independently distributed and U_{ij} arises by truncation (at zero) of the normal distribution with mean U_{ij} and variance.

The linear tobit regression model was used to analyze the effect of certain socio-economic factors on the technical efficiency of the farmer. The model was used because the dependent variable technical efficiency scores are censored having values ranging between 0 and 1 (Llewenlyn and Williams (1996). The model specification is given as:

$$TE = f(X_1, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, e_t) \quad (4)$$

Where TE is the technical efficiency index for farmer i

X_1 = Farm size (ha)
X_7 = Age of the farmers (yrs)
X_8 = Gender grouping; male=1, otherwise=0
X_9 = Extension awareness/visitation; awareness=1, otherwise=0
X_{10} = Level of education; Dummy variable; if educated= 1, otherwise =0
X_{11} = Cooperative membership; membership =1, otherwise =0
X_{12} = Farmers' farming experience (yrs)
e_t = The error term

III. BUDGETARY ANALYSIS

It is used to determine the profitability of cowpea production and also to analyze the cost and return to the farmers. The budgetary analysis is given as:

$$GM = TR - TVC$$

$$\pi = \text{GM} - \text{TVC}$$

Where

π = Profit (₦)
TR = Total revenue (₦)
TVC = Total variable cost (₦)
GM = Gross margin (₦)
TFC = Total fixed cost (₦)
$\frac{\pi}{TC}$ = Efficiency level

IV. RESOURCE USE EFFICIENCY

In order to ascertain whether resources were efficiently utilized, the marginal value product (MVP) of land, seed, family labour, hired labour, fertilizer and pesticide were computed and then compared with their input prices. Since these variables are expressed in physical quantities in the function estimated, the MVP of such are compared with their unit prices to determine the degree of efficiency in their use.

$$MVP_{xi} = \frac{\partial_y}{\partial_{xi}} \bullet P_y \qquad (5)$$

Where

$\frac{\partial_y}{\partial_{xi}}$ = Marginal Physical Production (MPP)

P_y = Farmgate price

V. DATA AND EMPERICAL PROCEDURES

The data used in this paper come from a random sample of 120 cowpea farmers in Osun State, southwest Nigeria, for the 2004/2005 agricultural growing seasons. The sample comprised of a random sample of six farm-villages with an average of 20 cowpea farmers within each sample village. The data were collected using structured questionnaires tailored to obtain information on input – output production activities of each farm-firm.

The Cobb-Douglas functional form was used to estimate the technical efficiency in the stochastic production frontier. The specific model estimated is the following:

$$\ln Y = \ln \beta_o + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \in \qquad (6)$$

Where *Y,βs* and X_i ($_i$ = 1,2,3........6) and are as defined earlier (eq. 2)

The Tobit regression model was used in the analysis for the socio-economic attribute(s), which affects the technical efficiency in the stochastic production frontier. The Tobit model is given as the following:

$$TE = f(X_1, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, e_t) \qquad (7)$$

Where *TE*, X_i ($_i$ = 1,7,8........12) and e_t are as stated in the previous section (eq. 5).

Descriptive statistics for the variables used in the analysis are given in *Table 3*.

VI. EMPIRICAL RESULTS

Tobit regression model estimates of equation 5 are presented in *Table 3*. Maximum likelihood estimates of the stochastic production frontier are represented in *Table 1*.

All parameter estimates were statistically insignificant at the 1% significance level except for cooperative membership and years of farming experience. The coefficient of cooperative membership has the higher value (elasticity). This suggests that productivity would be higher when farmers belong to cooperative societies. This agrees with the findings of Onyenwaku and Fabiyi (1991). The farming experience gathered over the years of practices was found to significantly enhance the level of cowpea production. Age of farmers have a negative relationship with the technical efficiency. However, the important factor is the number of years the farmer has being cultivating cowpea regardless of other crops. This implies that a unit increase in farming experiences leads to a better assessment of the important and complexities of good farming decision-making including efficient use of input.

The stochastic production regression analysis (*Table 2*) revealed that 10 percent increase in farmland area cultivated given the set of inputs-seed, hired labour, family labour, fertilizer and pesticide will correspond to an increase in output of cowpea with 6.593, 0.54, 0.84, 1.8, 1.1, and 0.37 percent respectively. This shows that the output of cowpea is inelastic to the inputs used in the area. Furthermore, the scale co-efficient is 1.12 signifying increasing returns to scale of cowpea production. Based on this, the null hypothesis of constant returns to scale can be rejected. The farmland area cultivated contributed the highest value, 94%, to the overall technical efficiency in cowpea production (*Table 3*). However, the age of the farmers has 93% input to the efficiency but reduces to an average of 90%, as the farmer grows old. 53% of the male cowpea farmers were technically efficient out of the total 87% of the gender contribution to production efficiency. Awareness on the latest technology in cowpea production through extension services was 56% out of 90% efficiency level in the mode of production. The level of education is 56% educated farmer contributing 90% efficiency in the production of cowpea. Farmers, belonging to a cooperative society were 46% efficient and non-cooperative

Table 1: Maximum Likelihood Parameter Estimates of Stochastic Production Frontier

Variable	Parameter Estimate	Standard Error	T-Statistics
Intercept	0.8952	0.0232	38.55
Farm size	0.0282	0.0246	1.44
Age	-0.0004402	0.000366	-1.20
Sex	0.012	0.0075	1.60
Extension awareness	0.00624	0.009313	0.67
Education	0.008405	0.010263	0.795
Cooperative membership	0.0219***	0.007449	2.94
Farming experience	0.00167***	0.0005529	3.02
Log likelihood function 211.35 Chi-square 41.12, N= 120			

*** Statistically significant at 1%

Table 2: Stochastic Production Frontier for Determinants of Cowpea Output of Farmers in Osun State

Variable	Ml Production Frontier Estimates	Standard Error
Intercept	4.4126	0.0000251
Farm size	0.6593***	0.0000178
Seed	0.0540***	0.0000199
Hired labour	0.0843***	0.00000140
Family labour	0.1801***	0.00000633
Fertilizer	0.1087***	0.00000673
Pesticide	0.0367***	0.00000417
Log likelihood 48.7948 Wald Chi-square 8.056e +10, N= 120		

***Statistically significant at 1%.

members were just 20% efficient. Farmers' experience in cowpea production amounts to 86% efficiency level of the overall technical efficiency of cowpea production. Average technical efficiency in the study area is estimated as 87%. The enterprise economic efficiency is 1.17 (*Table 4*). This means that for every ₦1 spent by the farmer on cowpea production, 17 kobo was realized as profit.

The result of the resource-use efficiency is given in *Table 5*. The current farm gate price of cowpea is ₦ 60.00/kg. Given the levels of technology and prices of both inputs and outputs, the marginal value productivity is the yardstick for judging the efficiency of resource use. A given resource is optimally allocated when there is no divergence between its MVP and its unit price. Thus, the marginal productivities of individual resource provides a framework for

Table 3: Average Technical Efficiency (TE) Indices and Socio-Economic Characteristics for Cowpea Farmers

Variable	N	Percentage (%)	Technical Efficiency (TE)	Mean TE
Size (ha)				
≤0.10	25	20.8	0.93	
>0.10≤0.30	50	41.7	0.98	0.94
>0.30≤0.50	30	25.0	0.93	
>0.50	15	12.5	0.92	
Age (years)				
≤40	20	16.7	0.94	
>40≤50	34	28.3	0.94	0.93
>50≤60	35	29.2	0.91	
>60	31	25.8	0.92	
Gender				
0	18	15.0	0.82	0.87
1	102	85.0	0.92	
Extention				
0	98	81.6	0.75	0.90
1	22	18.4	0.96	
Education				
0	29	24.2	0.85	0.90
1	91	75.8	0.95	
Cooperative				
0	75	62.5	0.40	0.66
1	45	37.5	0.93	
Experience (Years)				
≤10	67	55.8	0.92	
>10≤20	24	20.0	0.73	0.86
>20≤30	17	14.2	0.83	
>30	12	10.0	0.98	

Source: Field Survey, 2005.
Mean Technical Efficiency =0.87

policy decision on resource adjustment and the difference between the MVP and unit cost indicates the scope of resource adjustment to attain economic optimum.

The marginal value products of all the resources are less than their prices (MVP < MFC), *Table 5*. This implies that these resources are underutilized therefore there is resource use inefficiency. However, to curtail this in further production, there is need to cut down the level of resource use until the marginal value product and the marginal factor cost of each resource are at equilibrium in order to attain optimal allocation of the resources in cowpea production (i.e. MVP=MFC).

Table 4: Distribution of Budgetary Analysis

Items	Amount (₦)	
Total revenue		62,258.30
Hired labour	11,288.66	
Cost of seed	1,123.42	
Cost of pesticide	4,029.21	
Cost of fertilizer	2,279.40	
Total variable cost		18,720.79
Gross margin		43,537.51
Total fixed cost	10,000.00	
Profit		33,537.51
Efficiency level (π/C)		1.17

Source: Field Survey, 2005.

Table 5: Marginal value product and unit cost of each resource

Resource	MPP	Unit price of input (₦)	MVP	MFC (₦)
Land	0.6593	10,000	39.6	10,000
Seed	0.5402	100	32.4	100
Hired Labour	0.0843	150	5.06	150
Family labour	0.1801	150	10.81	150
Fertilizer	0.1087	900	6.52	900
Pesticide	0.0368	800	2.22	800

Source: Field Survey, 2005

VII. CONCLUDING REMARKS

This study estimates stochastic frontier production for cowpea farmers in Osun State, southwest Nigeria. This analysis shows that farm size (land), cooperative membership and farming experience are the major contributing factors to the efficient production of cowpea in the state. Other variables such as seed (kg), hired labour (naira), family labour (maydays), fertilizer (kg), and pesticides (litres) were also found to exact positive effect on the production of cowpea.

The result of the study suggests that if farmers should join cooperative society and the plot of the land used for cowpea should increase with adequate farming experience, these would enhance the productivity level of the farmers.

REFERENCES

Afriat, S.N. (1972). Efficiency Estimation of Production Functions, *International Economic Review*. 13: 568-598.

Aigner, D.J. and S. Chu (1968). On Estimating the Industry Production Function, *American Economic Review*. 58: 826-839.

Aigner, D.J., C.A.K Lovell, and P. Schmidt (1977). Formulation and Estimation of Stochastic Frontier Production Function Models, *Journal of Econometrics*. 6: 21-31.

Belbase, K., and R. Grabowski (1985). Technical Efficiency in Nepalese Agriculture, *Journal of Development Areas*. 19: 515-525.

Bravo-Ureta, B.E and Laszlo Rieger (1991). Dairy Farm Efficiency Measurement Using Stochastic Frontiers and Neoclassical Duality, *American Agricultural Economics Association*. 5: 421-427.

Coelli, T.J. and G.E. Battese (1996). Identification of Factors which Influence the Technical Inefficiency of Indian Farmers, Australian Journal of Agricultural Economics. 40: 103-128.

Comanor, W.S. and H. Leibenstein (1969). Allocative Efficiency, X-Efficiency and the Measurement of Welfare Losses, *Economica*. 36: 304-309.

Dawson, J., P. Lingrad, and C.H. Woodford (1991). Generalized Measured of Farm Specific Technical Efficiency, American Journal of Agricultural Economics. 73: 1098-1104.

Farrell, M.J. (1957). The Measurement of Production Efficiency, *Journal of Royal Statistics Society, Series A*. 120: 253-281.

Forsund, F.R., C.A.K. Lovell, and P. Schmidt (1980). A Survey of Frontier Production Functions and of their Relationship to Efficiency Measurement, *Journal of Econometrics*. 13: 5-25.

Greene, W.H. (1980). Maximum Likelihood Estimation of Econometric Frontier Functions, *Journal of Econometrics*. 13: 27-56.

Leibenstein, H. (1996). Allocative Efficiency vs. X-Efficiency, *American Economy Review*. 56: 392-415.

Leibenstein, H. (1978). X-Inefficiency Xist-Reply to a Xorcist, *American Economic Review*. 68: 203-211.

Liewenlyn R.V. and J. R. Williams (1996). Non- Parametric Analysis of Technical, Pure Technical and Scale Efficiencies for Food Crop Production in East Javal, Indonesia, *Journal of Agricultural Economics*. 15: 113-126

Meeusen, W. and J. Van den Broeck (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error, *International Economic Review*. 18: 435-444.

Onyenwaku C.E. and Y.L. Fabiyi (1991). A Comparative Analysis of Cooperative and Non-Cooperative Farmers in Food Production in Imo State, *Ife Journal of Agriculture*. 13: 90-96.

Richmond, J. (1974). Estimating the Efficiency of Production, *International Economic Review*. 15: 515-21.

Schmidt, P. (1980). Frontier Production Functions, *Econometric Reviews*. 4: 289-328.

Zaibet, L. and P.S. Dharmapala (1999). Efficiency of government supported horticulture: The case of Oman, *Agricultural Systems*. 62: 159-168.