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Stochastic Frontier Analysis of Technical Efficiency in Dry Season Leaf Vegetable Production among Smallholders in Ekiti State, Nigeria

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Abstract: This study was conducted to analyze the potential for improving production efficiencies of farmers and to identify factors that influence such efficiencies in dry season leaf vegetable production in Ekiti State, Nigeria. A cross sectional data were collected with the aid of a structured questionnaire. Data were analyzed using a stochastic frontier production function model. The study revealed that about 54.40% of the farmers were 70% and above efficient. The return to scale of 1.112 was obtained indicating that the studied farmers were operating in stage 1 of the production surface (increasing return to scale). Household size, level of education, credit accessibility and extension visits were all found to contribute positively to technical efficiency while age, farming experience and off farm income reduces technical efficiency. The result further show that there exist opportunity to increase technical efficiency and productivity at the present level of inputs.

Key words: Fadama farming, technical efficiency, smallholders and stochastic frontier, vegetable production

INTRODUCTION

Leaf vegetables no doubt offer populations with limited access to meat and fish rich sources of protein and some vital micro nutrients needed for healthy living. Consequently, leaf vegetables are now seen word wide as an ally in the fight against hidden hunger (Spore, 2005). However, most leaf vegetables grown in Nigeria are annual crops which complete their life cycle at the onset of dry season. This often result in the scarcity of the commodity during the dry season with the resultant decrease in protein and certain vital micro nutrients content of the general diet specially the poor who are in majority.

Nigeria, a tropical country with most of her land areas lying in low or middle elevation without frost problem possess a favourable climatic condition for all year round leaf vegetable production, Meanwhile, the observed trend among the smallholders is that, majority of them do rest during the dry season because they are unable to carry out full scale farming activities. Hence, the dry season is a period usually characterized by low income especially among the small holders accompany by hunger and malnutrition which sometimes lead to the death of your children since food prices are too high (Akinyele, 1998).

Adebooye and Opabode (2004) stated that leaf vegetables are sold at high prices during the dry season in most southwestern State in Nigeria. The implication of this is that leaf vegetable production can provide all year round income generating employment opportunities for the farmers with little capital investment. Lenka (1991) opined that a much better returns can be obtained through vegetable cultivation than other crops such as rice on land with less water usage. In general leaf vegetable cultivation can play a vital role in all year round supply of balance diet, improved farm economy, conservation of natural resources and improved farm income (Sahu, 2004). Having been made aware of the enormous benefits inherent in dry season leaf vegetable cultivation couple with introduction of various fadama farming programmes (a world bank grant sponsored agricultural development programme fashioned to help the production of vegetable and maize during the off season), more farmers are now participating in dry season leaf vegetable production in Ekiti State.

In order to enhance the productive capacity of this smallholder, knowledge of the availability of aggregated farm level resources and differences in their productivities is essential. Therefore, the study of their present level of efficiency and the analysis of factors influencing their level of efficiency is necessary. This will indicate the possibilities of increasing their productivity level by highlighting the direction of resource use adjustment and allocation because increased production and productivity

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are direct consequences of efficiency of input combination given the available technology (Ogundari and Ojo, 2005).

Efficiency measurement is very important in that, it is a first step in the process that might lead to substantial resource savings. These resource savings have important implications for both policy formulation and farm management. Also, during financial stress, efficiency gains are particularly important because efficient farms are more likely to generate higher incomes and thus stand a better chance of surviving and prospering (Bravo-Ureta and Rieger, 1991).

Equally in any economy where technologies are lacking efficiency studies show the possibility of raising productivity without increasing the resource base or developing new technology. Therefore, the principal objective of this study is to empirical analyze and identify factors that influence the technical efficiency or otherwise of dry season leaf vegetable producers in Ekiti-State.

MATERIALS AND METHODS

The study area: The study was conducted in Ekiti State of Nigeria, which lies within the tropical zone in the rain forest and savannah region in the Southwestern part of the country. It is located between longitudes 4^0 45' and 5^0 45' E of Greenwich meridian and latitudes 7^0 15' and 8^0 5' north of equator (Carim, 2002). The state enjoys a typical tropical climate with two distinct seasons, the raining season which lasts roughly from April to October and dry season which prevails for the remaining months. Ekiti is basically an agrarian state. Majority of the inhabitants are essentially small holder farmers who depend largely on agriculture for their livelihood.

Sampling technique: A multistage sampling technique was used in selecting the respondents. Based on *a priori* information, 4 Local Government Areas (LGA)s with highest density of dry season vegetable farmers were purposively selected. The second stage was the random sampling of 5 villages from each LGA while the third stage consisted of the selection of five respondents within each village via simple random sampling technique. In all a total of one hundred dry season leaf vegetable producers were selected for interview.

Data collection: Data were collected using a pre-tested structured questionnaire on farmer's outputs, production input variables (farm size, labour used, fertilizer and cost of irrigation) and socio-economic characteristics of the farmers (age, education, farming experience, household size, credit availability, farm size, off farm income and extension visits).

Theoretical/analytical framework: Following the pioneering work of Farrell (1957) in frontier and efficiency measurement. Where he employed a deterministic measurement approach in which he estimated a cost frontier by using linear programming, various modifications and improvements have been made. It was Aigner and Chu (1968) that translated Farrel's frontier into a production function. Later Aigner *et al.* (1977), Meeuseen and Van den Broeck (1977) and Battese and Corra (1977) in their independent works suggested stochastic frontier also known as composed error model. The main strengths of this model/approach are that it deals with stochastic noise and permits statistical test of hypotheses pertaining to production structure and degree of inefficiency. The stochastic frontier production function generally assumes the presence of technical inefficiency of production and may be expressed as:

$$Q_i = f(X_i; \beta) \exp(V_i - U_i) \quad (1)$$

where, Q_i is scalar output of ith farm, X_i is a vector of input and β is a vector of parameters to be estimated, exp is the exponential function, V_i is a disturbance assumed to be independent and symmetrically distributed ($-\infty \le V_i \le$) and it captures the effects of random shocks outside the farmers control (such as unfavourable external effects, luck, unpredictable variation in equipment performance, bad weather etc.). U_i is factors which are under farmer's control. It is assumed to be independently and symmetrically distributed and half normal (Aigner *et al.*, 1977). Other various specifications of the model were proposed by Green (1980), Stevenson (1980) and Lee (1983) while Jondrow *et al.* (1982) incorporate producer-specific efficiency effect to the model.

Technical Efficiency (TE) of an individual farm/firm is defined as the ratio of the observed output (y) to the corresponding frontier output (y^*) conditional on the levels of inputs used by the firm. Thus, the TE of firm/farm i in the context of the stochastic frontier production function Eq. 1 is given by:

$$\begin{aligned} TE &= y_i / y^*_i \\ &= f(X_i; \beta) \exp(V_i - U_i) / f(X_i; \beta) \exp(V_i) \quad (2) \\ &= \exp(-U_i) \end{aligned}$$

Following Jondrow *et al.* (1982), the density function of U and V can be written, respectively as follows:

$$f(U) = 1\sqrt{(2\pi)}(1/\sigma_u) \exp(-u^2/2\sigma_u^2);\ u \ge 0 \quad (3)$$

$$f(V) = 1\sqrt{(2\pi)}(1/\sigma_v)\exp(-v^2/2\sigma_v^2);\ -\infty \le v \le \infty \quad (4)$$

Then the density function of y which is the joint density of (V- U) is given as:

$$f(y) = 1/\{\sigma\sqrt{(\pi/2}\}\exp(-\omega^2/2\sigma^2)\ [1 - F\{(\omega/\sigma)(\gamma/1-\gamma)\}];-\infty \le v \le \infty \quad (5)$$

where, F(.) is the cumulative distribution of the standard normal random variable and

$$\omega = v - u$$
$$\sigma^2 = \sigma^2_u + \sigma^2_v$$
$$\gamma = \sigma_u/\sigma^2 \quad (6)$$

where, γ lies between (0 ;1), with values close to 1 indicating that the random component of the inefficiency effects makes a significant contribution to the analysis of the production system.

The likelihood function of the sample is then written as:

$$L(y;\theta) = \pi[1/\sigma\sqrt{(\pi/2)}\exp(\omega^2/2\sigma^2)\ 1-F\{(\omega/\sigma)(\gamma/1-\gamma)\}] \quad (7)$$

where, θ is the parameter to be estimated and is equal to the production parameters $\sigma^2$and γ.

Measurement of U for individual observation is derived from the conditional distribution of U given V-U (Jondrow *et al.*, 1982; Kalirajan and Flinn, 1983). Given the normal distribution for V and halve-normal distribution for U, the conditional mean of U given U-V is

$$E(U/V-U) = \int u\, f(u/v-u)\, du \quad (8)$$

where, f (u/v-u) = f (u; v-u)/f(v-u). The density function of u, given (v-u) using Eq. 3 and 4 is equivalent to:

$$f(u;v-u) = 1\sqrt{\ }2\pi\sigma/\sigma_u\ \sigma_v\exp[-\sigma_u^2\ /2\sigma_u^2\ \sigma_v^2\ (u+\sigma_u^2\ /\sigma^2)^2]1/1-F(.) \quad (9)$$

where, F(.) is the standard normal distribution function, now

$$E(u;v-u) = (-\sigma_u\ \sigma_v/\sigma)[f(.)/(1-F(.))\ -(v-u)/\sigma\sqrt{\ }\gamma/(1-y)] \quad (10)$$

where, f(.) and F(.) are the values of the standard normal and cumulative normal density functions, respectively.

Estimate of E(u;v-u) are obtain by evaluating Eq. 9 as ML estimates of γ, σ_u and σ_v. Technical efficiency for each farmer is then calculated as:

$$TE = \exp(u;v-u) \quad (11)$$

EMPIRICAL MODEL

Following Battese and Coelli (1983) technical efficiencies and their determinants were estimated using a one step Maximum Likelihood Estimate (MLE) procedure. This is done by incorporating the model for technical efficiency effects in the translog production function which is specified by relating yield as a function of farm size labour used fertilizer used and cost of irrigation as follows:

$$\text{In } Y = \beta_o + \sum_{i=1}^{n}\beta_1 \text{ In}X_1 + 1/2\sum_{i=1}^{n}\sum_{i=1}^{n}\beta_{ij}\text{ In}X_1\text{ In}X_j + V - U \quad (12)$$

Where,

n = 1, 2, 3 and 4; u≥0.
Y = Is the observed yield of i-th farm in kg.
X_1 = Leaf vegetable farm size (ha).
X_2 = Labour used (man days).
X_3 = Fertilizer cost (naira).
X_4 = Cost of irrigation (naira).
β = Is a (k×1) vector of unknown parameters to be estimated.
U = Farm specific character related to efficiency.
V = Statistical disturbance term.

The socioeconomic factors hypothesized as determinants of TE that was incorporated to Eq. 12 is stated as follows:

$$\mu_i = \delta_j Z_{ij}$$

Where,

Z_1 = Age of farmers (years).
Z_2 = Household size (number).
Z_3 = Level of education (year spend in school).
Z_4 = Farming experience (years of active farming).
Z_5 = Off farm income (naira/month).
Z_6 = Extension visits (number).
Z_7 = Credit received (amount in naira).
δ_i = Is a (m×1) vector of unknown parameter to be estimated.

RESULTS AND DISCUSSION

The MLE of the parameters of stochastic frontier production function and the inefficiency model were simultaneously obtained using the program FRONTIER version 4.1c (Coelli, 1996). This program is preferred because apart from being able to predict the variance of parameter in terms of σ^2 s and γ it equally avoid the statistical biases inherent in 2 stage estimation method (Batesse and Coelli, 1995).

Table 1 shows the summary of the production variables. From the table, it could be seen that the farm involved are relatively small with average size of 0.24 ha. Average fertilizer used for the planting season was 46.70 kg while the farmers recorded an average of 96.40 man-days for labour used. Irrigation cost stood at an average of ₦1, 218.21, for the studied farmers, while an average vegetable output of 2329.92 kg was recorded by the farmers.

The result of the estimated translog production frontier and technical efficiencies were presented in Table 2. The table shows that all the estimated coefficients of the parameters of the production function were positive and significant at 5% level. This means that the output increased as each of the independent variable increases and all the independent variables were significantly different from zero indicating that they are all important factors in dry season vegetable production. Also the Return to Scale (RTS) of 1.112 implies that the production at this level is in stage 1 (increasing return to scale) of the function. This implies that resources allocation and production were inefficient at the present level. Equally, the presence of technical inefficiency effects were confirm by a statistical test of the inefficiency hypothesis using the generalized likelihood ratio test and the significant of gamma (γ) estimate. The generalized likelihood ratio test which is defined by the chi square (χ^2) distribution shows that the computed chi square at 5% level with 4 degree of freedom [χ^2(5%, 4)] is 9.49, therefore, the null hypothesis of no inefficiency ($\gamma = 0$) in dry season vegetable production was strongly rejected. The estimated gamma parameter value of 0.615 which is significant at 5% level indicate that gamma is significantly different from one meaning that the frontier is stochastic and about 61.5% of the variation in the output among the sampled farmers was due to differences in their technical efficiencies.

For technical inefficiencies effects, the coefficient of household size variable showed a negative relationship with the predicted inefficiency and was significant at 5% level. This implies that technical inefficiency tend to reduce as household size increases. The finding suggest

Table 1: Summary statistics for the production function variable

	Output (y) Kg	Farm size ha	Labour man days	Fertilizer kg	Cost of irrigation ₦
Minimum	1359.12	0.14	61.22	25.00	2,450.00
Maximum	3009.48	0.31	124.50	75.00	5,425.00
Average	2329.92	0.24	96.40	46.70	4,200.00
S.D.	275.68	0.88	33.74	20.67	118.20

Source: Field survey, 2007

Table 2: MLE estimate of translog frontier production function

Variable	Parameter	Coefficient	t-value
Frontier Production function			
Constant	β_0	4.017	4.93*
Ln farm size	β_1	0.341	3.79*
Ln fertilizer	β_2	0.282	2.60*
Ln labour	β_3	0.273	2.99*
Ln cost of irrigation	β_4	0.216	3.29*
Technical inefficiency function			
Constant	δ_0	9.169	2.67*
Age	δ_1	0.184	0.72
Household size	δ_2	-0.346	3.17*
Level of education	δ_3	-0.259	-0.55
Farming experience	δ_4	0.341	1.13
Off farm income	δ_5	0.196	2.72*
Credit accessibility	δ_6	-0.059	2.98*
Extension visit	δ_7	-0.203	3.62*
Variance parameters			
Sigma square	σ^2	0.154	4.25*
Gamma	γ	0.615	6.51*
Log likelihood	llf	-37.852	

Source: Data analysis, 2007. *Significant at 5%

that household labour may form the bulk of labour used in dry season leaf vegetable production in the studied area, probably because the bulk of operations involved after clearing and ridging of the farms are done either early in the morning or in the evening when household members are readily available and thus provided the needed labour. Although, the coefficient of education variable equally showed a negative relationship with the predicted technical inefficiency effect, it was not significant meaning that, while it could be ascertain that as expected, increase in year of schooling reduces technical inefficiency, it is not an important determinant of technical efficiency in this case. Extension visit variable coefficient also showed a significant negative relationship with the predicted inefficiencies at 5% level. This implies that farmers that received more extension visits tend to be less inefficient. This conform with earlier findings in literatures that extension services improved efficiency, as better management and information utilization should lead to greater benefits to farmers (Obwona, 2006). The coefficient of credit accessibility variable also showed a significant negative relationship with the predicted inefficiency as expected. This is in line with earlier findings in literature that credit facility (financial and non-financial) improve farmers' efficiency (Obwona, 2006).

The positive coefficient of off farm income variable which was significant at 5% level indicates that any

Table 3: Distribution of farmers specific technical efficiencies

Efficiency	No. of farmers	Percentage
30-39.99	4	3.20
40-49.99	8	6.40
50-59.99	18	14.40
60-69.99	27	21.60
70-79.99	35	28.00
80-89.99	22	17.60
90-100	11	8.80
Total	125	100.00
Mean	65	
S.D.	21.60	
Min	35.12	
Max	97.80	

Source: Data analysis, 2007

increase in off farm income level increases inefficiency. This may be because dry season vegetable production is generally viewed as a means of augmenting farm income in the study area and also because off farm income is mainly from wage earnings, thus implying that less time is allocated to the vegetable farm work with increase in off farm income hence the significant positive relationship with the predicted inefficient level.

The coefficients of age and farming experience variables equally showed positive relation with the predicted inefficiency level as against expectation. Although, they were not significant but this suggest that older and more experienced farmers tend to be less efficient in dry season leaf vegetable production perhaps this set of farmers still prefers to rest during the dry season and prepare for the major food crops especially yam that is largely cultivated in the area. Also it could be that older farmers has less need for extra income and as such shows little or no enthusiasm in dry season farming.

Table 3 summarized the TE distribution of the studied farmers. There was great variation in the in the level of efficiency among the farmers, ranging from a very low 35.12-97.80% with a mean efficiency level of 68.60%. However, 54.40% of the farmers had TE of 70% and above.

CONCLUSION

This study estimates the levels of and determinants of farm level specific technical efficiency in dry season leaf vegetable production using the stochastic frontier production function model. The result shows that, there is the existence of abundant opportunity to improve the production efficiency of the crop with the present levels of inputs by simply improving farmers' level of efficiency.

The study further revealed that the observed farm level technical efficiency depends on a number of socio-economic factors, the following factors was identified as significantly contributing towards improving farmers efficiency; household size, extension visits and accessibility to credit, while age, farming experience and off farm income reduces efficiency but only off farm income has a significant effect. This revelation is very important in that these are the factors to be considered by policy makers or those saddled with responsibility of designing programmes towards dry season farming improvements in the studied area if positive results are desired.

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