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Estimation of Farm Level Technical Efficiency in Smallscale Swamp Rice Production in Cross River State of Nigeria: A Stochastic Frontier Approach

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Abstract: The productivity of rice farmers can be raised either by adoption of improved production technologies or improvement in efficiency or both. But with the low rate of adoption of improved rice technologies by farmers in Nigeria, improvement in efficiency becomes the best option in productivity enhancement in the short run. As a result of the near absence of empirical information on farm-level technical efficiency in small scale swamp rice production in the country generally and Cross River State in particular, a Stochastic Frontier function that incorporated inefficiency factors was estimated using a Maximum Likelihood technique to provide estimates of technical efficiency and its determinants using data obtained from 112 small scale swamp rice farmers in Cross River State. The results indicate that, the rice farmers were not fully technically efficient. The mean efficiency obtained was 77 percent indicating that there was a 23 percent allowance for improving efficiency. The result also shows that, farmers' educational level, membership of cooperative/farmer association and access to credit significantly influenced the farmers' efficiency positively. The implications are that policies that would encourage educated persons to form and join cooperatives and provide them with easy access to formal credit should be made and implemented in State.

Key words: Determinants · frontier · rice · small scale · swamp · technical efficiency

INTRODUCTION

One important food crop that has attained a staple food status in Nigeria and also become a major source of calories for the urban poor is rice [3]. The per capita consumption of this commodity has been increasing at an average of 7.3 percent annually due to increasing population, changing consumers' preferences from traditional staples (yams, garri, cocoyam etc.) and urbanization among others [3]. Domestic productions of this commodity have been inadequate and unable to bridge the increasing demand-supply gap. Government's efforts of making the country self sufficient in rice production have not yielded the required results and thus the resort to importation of the commodity with so much of the hard earned foreign exchange. It is Government's goal of achieving self sufficiency in rice production to a large extent will depend on the level of farmers' productivity which can be determined by their rates of adoption of improved technologies and efficiency of resource use. However, with the low rates of adoption of rice technologies by farmers as a result of resource poverty among other reasons, efficiency improvement becomes an important and significant factor in increasing productivity [4]. Farrel [9] had decomposed efficiency into technical, allocative and economic.

Rice is cultivated in upland and swamp ecosystems in the country. Upland rice production accounts for about 30-35 percent of total rice area in the country with yield of between 0.8-2.0 tonnes/kg, while swamp production system accounts for about 25 percent in Nigeria with yields as high as 2 to 8 tonnes/hectare. The latter also accounts for about 43-45 percent of national rice production [17]. In Cross River State, swamp rice production is predominant, followed by upland. Swamp rice farmers in particular and small scale farmers in general in Nigeria have been reported to be inefficient in resource use [14, 15]. In these studies, the efficiencies of the individual

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farmers were not determined due primarily to their use of the Ordinary Least Squares (OLS) technique, [2]. It was also not possible for them to quantify some factors (farm/farmers) that have influenced on farmers levels of efficiency using this technique. The Stochastic Frontier Analysis (SFA) developed independently, by Aigner *et al.* and Meeusen and van den Broeck [1, 13] and modified by Jondrow *et al.* [11] have been used in determining farm level efficiency using cross-sectional data. In this method, the production frontier is accounted for by technical inefficiency, measurement error, statistical noise and other non-systematic influences, unlike the OLS that attributes all the deviations to inefficiency [18]. The analytical method also makes it easy to ascertain policy variables that can be used to address resource use inefficiency of farmers.

The empirical studies that have made use of this model in determining efficiency in crop production in Nigeria is increasing, but they are relatively fewer studies on rice production in the country. In addition, no studies have been documented for swamp rice in Cross River State. The objective of this study is to provide empirical information on farm level technical efficiency and its determinants in small-scale swamp rice production in Cross River State (an important swamp rice growing State in the South-South zone of Nigeria) using the Stochastic Frontier Analytical approach with a view to deriving policy implications for proper policy recommendations.

MATERIAL AND METHODS

Description of study area, sampling technique, sources of data and method of collection B: The study was conducted in Cross River State, an important rice producing State in Nigeria. The State lies within latitude 40°41^1 South and 60°30^I North and between longitude 8°and 9°00^I East of the Equator. The vegetation of the State spans from the mangrove swamp and rainforest in the South to a derived savannah in the north. The State comprises of 18 Local Government Areas out of which 5 (Obubra, Obudu, Ogoja, Yakurr and Bekwarra) are known for rice cultivation.

A multistage random sampling technique was adopted in selecting fifty six (56) farming households in 10 communities in two Local Government Areas (Obubra and Obudu) in the State. A cost itinerary method was used in data collection. The farmers were visited on fortnightly basis to collect information on inputs used in production as well as output of harvested paddy. Information on some socio-economic characteristics of the farmers was obtained on the first visit with the use of questionnaires. Data collection lasted from July 2004 to January 2005.

Analytical techniques: The data obtained were analysed using both descriptive and inferential statistics. Means, standard deviations, percentages and frequencies were used in analyzing the socio-economic characteristics of the farmers, input and output variables and the distributions of efficiency levels.

A stochastic frontier production function that incorporated inefficiency factors was estimated using Maximum Likelihood Estimation (MLE) technique to obtain farm specific technical efficiencies as well as their determinants.

A generalized likelihood ratio test was carried out to ascertain whether the rice farmers were fully technically efficient.

Model specification: The stochastic frontier production function was specified as:

$$Q = f\,(X_i\,;\alpha) + \varepsilon_i \qquad (1)$$

Where,

Q = Output of paddy in ith farm

X_i = Vector of inputs used by ith farm

α = Vector of unknown parameters

ε_i = V-U = Composite error term

Where

V = Random variable assumed to be independently and identically distributed N (O, δ_v^2) and independent of U_i.

U_1 = Random variable that accounts for technical inefficiency and assumed to be independently distributed as truncation of the normal distribution with mean μ_i and variance $\alpha^2 = \alpha u^2(|N(\mu_i,\ \alpha_U^2)|)^2$,

$$\mu_i = A\ \delta \qquad (2)$$

Where:

A = I x e vector of farm/farmers characteristics that may cause inefficiency.

δ = e x I vector of unknown parameters to be estimated. (11).

The farm level stochastic production frontier that represents the maximum output possible (Q^*) can then be expressed as:

$$Q^* = f(X_1 : \alpha) \exp(v_i) \quad (3)$$

Where, Q^* is the frontier output. Using equation 3 to rewrite equation 1, we will have:

$$Q = Q^* \exp(-U) \quad (4)$$

Therefore, technical efficiency of an individual farmer can be obtained as:

$$TE = \frac{Q}{Q^*} + \exp(-U) \quad (5)$$

That is the difference between observed output (Q) and frontier output (Q^*) is embedded in U_i. When U = 0, then production is on the frontier (ie $Q = Q^*$) and the farmer in therefore technically efficient. But if $U>0$, the farmer is inefficient, since production will lie below the frontier [10]. The Maximum Likelihood Estimates (MLEs) of the parameters of the model and the technical efficiency predicted were obtained using the computer programme Frontier 4.1 by [6].

The variance parameters α_u^2 and α_v^2 are expressed as

$$\delta^2 = \delta_v^2 + \alpha_u^2 \quad (6)$$

$$\gamma = \delta_u^2 / \delta_v^2 \quad (7)$$

Where:
γ ranges from 0 to 1.
When γ = 1, it indicates that all deviations are due to technical inefficiency [6].

A Cobb-Douglas function was fitted to the stochastic frontier production function and estimated. This functional form has been consistently used in related efficiency studies [18]. A more flexible form like the translog function can as well be used. However, functional forms have limited effect on empirical efficiency measurement [5]. The specified production function was;

$$Ln\ Q = Ln\alpha_0 X_1 + \alpha_1 LnX_1 + \alpha_2 Ln\ X_2 + \alpha_3 Ln\ X_3 + \alpha_4 Ln\ X_4 + \alpha_5 LnX_5 + \varepsilon_i \quad (8)$$

Where:
- Q = Output of harvested paddy in kg.
- X_i = Farm size in hectares
- X_2 = Labour in man-days
- X_3 = Capital input in naira
- X_4 = Fertilizer applied in kg
- X_5 = Quantity of seed in kg
- Ln = Natural logarithm
- α_0-α_5 = Parameters to be estimated
- ε_1 = Composite error term, defined as V-U in equation (1).

Some farm/farmers characteristics were incorporated into the frontier model with the belief that they have a direct influence on efficiency [4]. The computer programme Frontier 4.1 developed by Coelli [6] was used in the estimation.

The efficiency function was specified as;

$$T.E = \tilde{O}_0 + \tilde{O}_1 Z_1 + \tilde{O}_2 Z_2 + \tilde{O}_3 Z_3 + \tilde{O}_4 Z_4 + \tilde{O}_5 Z_5 + \tilde{O}_6 Z_6 + \tilde{O}_7 Z_7 + \tilde{O}_8 Z_8 + \tilde{O}_9 Z_9 + e \quad (9)$$

Where;
- T.E = Technical efficiency
- Z_1 = Year of Schooling (Education)
- Z_2 = Age of farmers in years
- Z_3 = Farm size in hectares
- Z_4 = Farming experience in years
- Z_5 = Household size (numbers)
- Z_6 = Membership of cooperative/farmers organization
  - 1 = Member
  - 0 = Non-member
- Z_7 = Extension contact (dummy)
  - 1 = Contact
  - 0 = Non Contact
- Z_8 = Credit access (dummy)
  - 1 = Access
  - 0 = No access
- Z_9 = Sex (dummy)
  - 1 = Male
  - 0 = Female

RESULTS AND DISCUSSION

Summary statistics of output and input variables in swamp rice production in cross river state, nigeria: The summary of the production function variables is presented in Table 1. The result indicates that, the

Table 1: Summary statistics of output and input variables in swamp rice production in cross river State, Nigeria

Variable	Unit	Mean	Standard error
Output (Y)	Kg	1110.70	776.63
Labour (X_1)	Man-days	99.14	34.21
Capital (X_2)	₦	849.99	570.35
Farmsize (X_3)	Ha	0.42	0.14
Fertilizer (X_4)	Kg	45.00	21.37
Seed (X_5)	Kg	21.53	12.55

Source: Derived from field survey data, 2004/2005

Table 2: Maximum likelihood estimates of the stochastic production frontier function in swamp rice production in cross river state

Variable	Coefficient
Constant	6.95 (-1.8)
Labour(X_1)	0.75 (3.04) ***
Capital (X_2)	0.15 -1.3
Farm size (X_3)	0.06 (2.96) ***
Fertilizer (X_4)	0.09 -1.89
Seed X_5	0.52 (2.54)**
Sum of elasticities	1.57
Diagnostic Statistics	
Gamma (γ)	0.77 (2.14)**
Sigma-square (δ^2)	0.52 (2.54)**
Log likelihood function	-55.69
LR test	21.66

Note ***: significant at the 1%, ** significant at 5%
t-values are in parentheses.
Source: Output of Frontier 4.1 by Coelli [6].

mean output per farmer in swamp rice production was about 1.11tons. The yield per hectare was 2.65 tons and was relatively lower than the national mean yield of 2.72 tons reported by Akpokodje *et al*. [3].

The mean labour usage was 99.14 man-days. This is expected, given the tedious operations in swamp rice production. There was low usage of external input (N849.00 as capital) as a result of the small sized (0.42 ha) nature of rice production in the area. Kebede [12] had similar observations in rice production in Nepal.

Maximum likelihood estimates of stochastic frontier production function in swamp rice production in cross river state, Nigeria: The stochastic frontier production function estimates of the sampled swamp rice producers in the State are presented in Table 2. The Table shows that all the coefficients have the expected positive signs.

The coefficients of labour and farm size were significant at the one percent level. Fertilizer was not significant. It was observed that majority of the rice farmers did not apply fertilizer, with the belief that a well puddle soil requires little or no fertilizer application. The coefficient of seed was significant at the 5 percent level. Capital input was not significant, which is an indication of low usage of capital inputs. Labour appears to be the most important variable with elasticity of 0.75. It implies that increasing labour use by 10 percent will lead to about 7.5 percent increase in output in swamp rice. The sum of the elasticity (1.57) indicates that, the swamp rice farmers were operating in the increasing return to scale region (Inefficient stage). The result is consistent with the findings of Kebede [12]. The gamma (ã) value was 0.77 and significant at the 5 level. It is an indication that 77 percent variation in output of rice is attributed to technical inefficiency. It also confirms the presence of the one sided error component in the model, thus rendering the use of the Ordinary Least Squares (OLS) estimating technique inadequate in representing the data. The sigma-square (δ^2) on the other hand was 0.52 and significant, indicating the correctness of the specified assumptions of the distribution of the composite error term.

Technical efficiency levels of swamp rice farmers in cross river state, nigeria: The results presented in Table 3, indicate a technical efficiency range from 0.48 to 0.99. The mean estimate was 0.77.The efficiency distribution had shown that, about 70.64 percent of the rice farmers attained between 0.71 and 1.00 efficiency levels, while none had below 50 percent level of efficiency. This high level of efficiency is an indication that only a small fraction of the output can be attributed to wastage [10].

The result also indicates that, the average swamp rice farmer would realize about 22.22 percent in cost savings, if he or she was to attain the level of the most efficient farmer in the sample. The result further shows that there are allowances for the farmers to improve their efficiency by about 23 percent.

Table 3: Distribution of technical efficiency of swamp rice farmers in the state

Efficiency class	No. of farmers	Percentage
<0.50	3	5.36
0.51-0.60	4	7.14
0.61-0.70	10	17.86
0.71-0.80	18	32.14
0.81-0.90	13	23.21
0.91-1.00	8	14.29
Total	56	100.00
Mean	0.77	
Standard deviation	0.13	
Minimum	0.48	
Maximum	0.99	

Source: Derived from output of computer programme frontier 4.1 by Coelli [6].

Table 4: Maximum likelihood estimates of determinants of technical efficiency of swamp rice producers in cross river state, Nigeria

Variable	Coefficient	t-ratios
Constant	-0.26	0.34
Age	-0.14	1.85
Education (Yrs of Schooling)	0.66	2.67**
Household size	-0.11	1.82
Farming experience	0.07	0.55
Membership of association	0.58	2.33**
Farm size	0.33	1.12
Sex	-0.11	1.23
Extension contact	0.12	1.06
Credit access	2.03	2.97

***Note ***: Significant at 1%, ** Significant at 5%.
Source: Output of frontier 4.1 by 6.

The Likelihood Ratio Tests (LRT) indicate that, the swamp rice farmers were not fully technically efficient ($\chi^2 = 21 > \chi^2_{0.05} = 11.91$).

Determinants of technical efficiency of sampled swamp rice producers in the area: The Maximum Likelihood Estimates (MLEs) of determinants of technical efficiency of swamp rice producers in the area are presented in Table 4. The results indicate that, the coefficients of years of schooling (education), membership of association, farm size extension contact and access to credit have positive signs. However, only years of schooling (education), membership of association and access to credit were significant.

This implies that, the swamp rice farmer's efficiency will increase with increase in their years of schooling, membership of association and access to credit. The coefficients of age, household size and sex had negative signs and were also not significant.

Education enhances the acquisition and utilization of information on improved technology by the farmers as well as their innovativeness [7, 8, 10, 16]. On the other hand, membership in Farmers' Organization/Cooperatives affords the farmers the opportunity of sharing information on modern rice practices by interacting with other farmers. Farmers' access to credit enhances their timely acquisition of production inputs that would enhance productivity via efficiency. The findings are consistent with earlier results by Kebede [12] Ajibefun and Aderinola [2] and Nwaru [14]. On the other hand, coefficient of farming experience had the expected positive sign but was not significant. This means being an experienced farmer was not enough to significantly cause a farmer to attain higher levels of efficiency if he can not rearrange his inputs to obtain higher output levels with a given technology.

CONCLUSION

This study has revealed that small scale swamp rice farmers are not fully technically efficient and therefore there is allowance of efficiency improvement by addressing some important policy variables that negatively and positively influenced farmers' levels of technical efficiency in the area.

Policy implications and recommendations: 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.

Farmers' membership of association was also positively related to efficiency, implying that the making and implementing of policies that would encourage farmers to form cooperatives/farmers organization or join existing ones will be a step in the right direction. The positive relationship between access to credit and efficiency of the farmers implies that policies that will make micro-credit from government and non-governmental agencies accessible to these farmers will go a long way in addressing their resource use inefficiency problems.

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