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A Stochastic Frontier Analysis of Technical Efficiency in Swamp and Upland Rice Production Systems in Cross River State, Nigeria

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Abstract: In this study, the technical efficiency of swamp and upland rice farmers in Cross River State, Nigeria were estimated and compared certain policy variables (farm/farmers characteristics) were identified and quantified. A cost itinerary approach was adopted in obtaining information from 96 (56 swamp and 40 upland) rice farmers were selected by a multistage stratified random sampling technique. A stochastic frontier function that incorporated inefficiency effects was estimated using the Maximum Likelihood Estimation (MLE) technique. The results indicate that, swamp and upland rice farmers in the State were not fully technically efficient. Their mean efficiencies were 0.77 and 0.87 for swamp and upland rice systems, respectively and were not significantly different at the 5% level. The results also indicate that, farmers' educational level, membership of association and access to credit positively influenced their levels of efficiency in both production systems. The coefficients of age and household were negative and significant in determining efficiency of upland rice farmers in the State, while in the swamp they had no significant effect though carried negative signs. Implications are that policies that would encourage relatively younger and educated persons and provide them easy access to credit if made and implemented will go a long way in addressing the resource use inefficiency of the farmers.

Key words: Efficiency, frontier, rice, stochastic, swamp, upland

INTRODUCTION

Of all the basic food commodities produced and consumed in Nigeria, rice is of prime importance as it has remained a major source of calories for the urban poor households (World Bank, 1996). Its consumption has been on the increase over the years as a result of urbanization and constitutes a major portion of the expenditures on cereals and cereal based diets of most Nigerians (Akpokodje *et al*., 2001; World Bank, 1996). Rice is so important as to become a major welfare determinant of the poorest groups of consumers in the country. Its production over the years has been inadequate to bridge the demand supply gap, thereby causing the country to resort to imports. The rising import value of rice made government to place a ban on it in 1985. However, after the lifting of the ban in 1995, about 34.4 billion naira had been spent on rice imports between 1995 and 1999 (Akpokodje *et al*., 2001). This involved the use of hard earned foreign exchange and is quite a drain on the countries finances. Nigeria has the potential to be self-sufficient in rice production as virtually all the ecological zones are suitable for its cultivation either as swamp, upland or under irrigation (FAS, 2002). The setting up of the Presidential Task Force on rice production was to enable the achievement of being self-sufficiency as well as export. However, to achieve this noble objective of government, will demand the knowledge of farmers' current level of productivity and how it can be improved if found to be low. It should be noted that productivity enhancement can be achieved through the use of improved technology and improvement in efficiency of resource use. However, given the low rate of adoption of rice technologies by farmers, improvement in efficiency remains the most cost effective way in enhancing productivity in the short run. (Omotayo *et al*., 2001; Belbase and Grabowski, 1989). Improving rice farmer's resource use efficiency will require the knowledge of their current efficiency levels as well as the identification of some policy variables that can be tinkered with to about to bring about an improvement.

Efficiency was decomposed into technical and allocative by Farrel (1957). He defined technical efficiency as the ability of a farm to produce maximum output with minimum input requirements and available technology. On the other hand, allocative efficiency refers to the ability of a farm to use inputs optimally given their prices. It is an indication that gains could be obtained by the varying of

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input ratios on certain assumptions about the farms price structure (Xu and Jeffrey, 1995; Ajibefun and Daramola, 2001). The combination of technical and allocative efficiencies gives rise to productive or economic efficiency.

Efficiency can be determined using the Ordinary Least Squares (OLS) estimation technique and recently, the Frontier methodology that, involves the Maximum Likelihood Estimation (MLE) technique. The use of OLS, results in the derivation of partial measures of efficiency, which is its greatest limitation (Ajibefun and Aderinola, 2003). The Stochastic Frontier Analysis (SFA) was developed independently by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) and used in determining farm level efficiency of all farmers in a sample using cross-sectional, time series and panel data to overcome this limitation of the OLS.

This model has been used in efficiency studies in other developing countries and is gaining prominence in Nigeria's agriculture. Ajibefun and Aderinola (2003), Udoh and Akintola (2001), Amaza and Olayemi (2000), Nwaru (2004), Onyenweaku *et al.* (2005) had determined the level of technical efficiencies of food crop farmers in Nigeria and obtained a range from 0.25 to 0.84. They also considered the effects of some farm/farmers characteristics on their efficiency and obtain results ranging from positive to negative influences depending on the variables.

For rice specifically, there would have been no published studies using the frontier model in Nigeria except for Ajibefun and Aderinola (2003) who covered the South west. However, they did not consider the efficiencies of farmers in the different rice production systems. For Cross River State (an important rice growing area in the country), there are no evidences of studies that have used the stochastic frontier model to determine efficiency of rice producers generally and in the different rice production systems in particular.

The purpose of this study is to provide information on the technical efficiency of small-scale swamp and upland rice farmers in Cross River State, Nigeria; compare the efficiencies of farmers between the systems and ascertain the influence of some factors on their efficiency levels.

MATERIALS AND METHODS

The study was carried out in Cross River State being one of the most important rice growing areas 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 northern part of the State. The people of the State are mostly farmers cultivating various arable and plantation crops.

A multistage, stratified random sampling technique was adopted in choosing 40 upland and 56 swamp rice farm households in 10 communities in two Local Government Areas (Obubra and Obudu) in the State. A cost itinerary approach was used in data collection on a fortnightly basis between June 2004 and January 2005. Data were collected on quantity of fertilizer used, labour, seeds, capital input, as well as output. The socio-economic characteristics of the farmers were also obtained.

Data analysis: Data on the socio-economic characteristics of the farmers were analysed using descriptive statistics. A Stochastic Frontier production function that incorporated efficiency factors was specified and estimated to determine efficiency levels of the rice producers and the effects of some socio-economic factors on farmers' efficiency level. A Z-test was used to compare the efficiencies of farmers in the two rice production systems. A generalized Likelihood Ratio (LR) test was used to ascertain whether the swamp and upland rice farmers were fully technical efficient.

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

$$Y = f(X_i; \beta) + V - U \quad (1)$$

Where:

- Y = Output of ricer
- X_i = Vectors of inputs used
- β = Vector of production function parameters
- V = Random error term that captures
- U = Non-negative one sided error term that measures inefficiency.

Using the method of Jondrow *et al.* (1982), technical efficiency can be measured using the adjusted output as shown;

$$Y^* = f(X_i; \beta) - U \quad (2)$$

Where U can be estimated as

$$E(U/\varepsilon_i) = \frac{\sigma\lambda}{1+\lambda^2}\frac{f^*}{1} - \left(\frac{(\varepsilon_i \lambda/\sigma) - \varepsilon_i\lambda}{f^*(\varepsilon_i \lambda/\sigma)\,\sigma}\right) \quad (3)$$

Where:

F * (1) and F*(1) are standard normal density and cumulative distribution functions, respectively.

$\lambda = \sigma u/\sigma v$
$\varepsilon_i = V - U$
$\sigma^2 = \sigma v^2 + \sigma u^2$
V* is the observed output adjusted for statistical noise.

When σ_1, σ and λ estimates are replaced in Eq. 2 and 3, the estimates of V and U will be obtained.

In this study a Cobb-Douglas production function was fitted to the frontier model of the two rice production systems and estimated using the maximum Likelihood method. This was specified as follows:

$$Ln\ Y = Ln\ b_0 + b_1\ LnX_1 + b_2\ LnX_2 + b_3LnX_3 + b_4\ LnX_4 + b_5\ LnX_5 + \varepsilon_i) \quad (4)$$

Where:

Y	=	Output of paddy in kg in swamp and upland rice systems.
X_1	=	Quantity of seeds in kg
X_2	=	Fertilizer used in kg
X_3	=	Labour in man-days
X_4	=	Capital input in naira
X_5	=	Farm size in hectares
Ln	=	Natural logarithm
$b_0 - b_5$	=	Coefficients to be estimated
ε_1	=	Composite error term (V – U).

V_1 is assumed to be independent and identically distributed random errors with a zero mean and variance $\delta_U{}^2v$. U is the technical inefficiency effects assumed to be independent of V_1 and non-negative truncating at zero of the normal distribution. It has a mean and variance. Inefficiency factors were incorporated in the model to ascertain the effects of these variables on technical efficiency. It was specified as:

$$T.E = \alpha_0 + \alpha_1Z_1 + \alpha_2Z_2 + \alpha_3Z_3 + \alpha_4Z_4 + \alpha_5Z_5 + \alpha_6Z_6 + \alpha_7Z_7 + \alpha_8Z_8 + \alpha_9Z_9 + e \quad (5)$$

Where;

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

RESULTS AND DISCUSSION

Socio-economic profile of swamp and upland rice farmers: Certain farm/farmers' characteristics that could have bearing on rice production in the area were considered. These include age, sex, years of School, household size, farming experiences, membership of associations, access to credit and extension contact. The results are presented in Table 1. The Table reveals that, majority (69.64 and 70%) of the swamp and upland rice farmers respectively were males. This is expected given the cultural setting of the area that allows for unfettered access to production inputs especially land to males. Majority (57.13 and 55%) swamp and upland rice farmers did not belong to any farmers' organization or cooperatives, while majority also (62.5 and 66%) of swamp and upland rice farmers respectively did not have access to external credit.

Membership of cooperatives or farmers' organization and credit access enhances the sharing of information on improved technologies through interaction as well as enabling the relaxation of inputs acquisition and utilization constraints faced by farmers (Effiong, 2005;Kebede, 2001). Lastly the table indicates that, majority (57.14 and 75%) of the farmers did not have extension contact. The importance of extension on farmers' adoption of improved rice technologies cannot be over-emphasized.

Table 1: Distribution of swamp and upland rice farmers according to their sex, association membership, access to credit and extension contact

Variables	Swamp frequency	Rice %	Upland frequency	Rice%
Sex				
Male	39	69.64	28	70
Female	17	30.36	12	30
Total	56	100	40	100
Assoc. membership				
Member	24	42.87	18	45
Non member	32	57.13	22	55
Total	56	100	40	100
Access to credit				
Access	19	33.93	15	37.5
No access	37	66.07	25	62.5
Total	56	100	40	100
Extension contact				
Coact	24	42.86	10	25
No contact	32	57.14	30	75
Total	56	100	40	100

Source: Field Survey data 2004/2005

Table 2: Distribution of swamp and upland rice farmers according to their level of formal education, household size and farming experience

	Swamp rice		Upland rice	
Variable	Frequency	(%)	Frequency	(%)
Level of Education (Years of Schooling)				
0	4	7.14	30	7.5
6 years	31	55.36	22	55.6
12 years	20	35.71	1	2.5
15 years	1	1.79	1	2.5
Above 15 years	0	0	1	2.5
Total	56	100	40	100
Mean	6.94^a (3.28)	100	7.55^a(1.8)	
Household size				
2-4	8	14.29	3	7.5
5-7	27	48.21	21	52.5
8-0	20	35.71	1	40.0
>10	1	1.79	0	0
Total	56	100	40	100
Mean	7.0^a (1.89)	100	7^a(1.82)	
Farming experience				
<5	1	1.79	0	0
5-10	22	39.29	25	62.5
11-5	20	35.71	13	32.5
16-20	10	17.86	2	5.0
<20	3	5.35	0	0
Total	56	100	40	100
Mean	12.6^a (4.8)	100	10.8^a(2.9)	

Source: Field Survey Data 2004/2005, Note: Values in parentheses are standard deviations. ab: Means in rows having different alphabets are significantly different at 5%

Majority of swamp and upland rice farmers (91.29 and 75%) respectively were between 24 and 45 years of age. Their mean ages were 42 and 35 years in swamp and upland rice systems respectively. It is an indication that relatively younger persons are involved in both production system and therefore there is a likelihood of increase productivity. This result corroborates earlier findings by Umoh (2006) and Nwaru (2004).

The results in Table 2 reveal that, majority of (92.86 and 92.5%) of the swamp and upland rice farmers, respectively have had six or more years of formal education. On the average, a swamp or upland rice farmer had about 7 years of formal education. The importance of education in enhancing information acquisition and utilization and thus improving productivity cannot be over-emphasized (Amaza and Olayemi, 2000). In terms of household size, the swamp upland rice farmers in the State had a mean of about 7 persons per household. Large household sizes have been reported to enhance family labour availability, since it reduces labour constraints in rice production. However, Okike (1999) had reported that labour availability through large household sizes depends on the age structure of the household members.

There was no significant difference in the years of farming experience between the swamp and upland rice farmers in the zone. The mean years of experiences were 12.6 years and 10.8 years for swamp and upland rice farmers respectively. The results also reveal that the farmers were quite experienced on the average.

Summary statistics of output and input variables in swamp and upland rice production in cross river state: The summary of the production function variables in presented in Table 3. The result indicates that, output per farmer in the swamp production system was significantly greater than the upland system.

In fact the yield per hectare was (2.65 tons) and also greater than that of upland (1.54). Akpokodje *et al*. (2001) had reported a national mean yield of 2.72tons and 1.70 tons for swamp and upland rice systems respectively. The mean labour usage was also greater (99.14 man-days) than the upland rice system labour usage which was 950.37 man-days. This is expected, given the tedious operations in swamp rice production. In swamp rice production more capital inputs were used than in the upland rice system. However, in both systems, there was low usage of external input as a result of the small sized nature of rice production in the area. Kebede (2001) had similar observations in rice production in Nepal.

Maximum likelihood estimates of stochastic frontier production function in swamp and upland rice systems in the state: The stochastic frontier production function estimate of the rice production systems in the State is presented in Table 4. The Table shows that all the coefficients have the expected positive signs in both systems.

The coefficients of labour and farm size were significant at the one percent level in swamp and upland systems. Fertilizer was significant at the one percent in upland system, but not significant in the swamp system. It was observed that majority of the swamp rice farmers did not apply fertilizer. It is believed in area that a well puddle soil requires little or no fertilizer application. The coefficient of seed was significant at the 5% level in swamp but not significant in upland rice production. Capital input was not significant in both systems. Labour appears to be the most important variable with elasticity of 0.75 and 0.4. It implies that increasing labour use by 10% will lead to about 7.5 and 4.5% increase in output in swamp and upland rice systems respectively. The sum of the elasticity (1.57 and 1.27) indicates that the swamp and upland rice farmers were operating in the increasing return to scale region. (inefficient stage).

The gamma (γ) values were 0.77 and 0.90 in swamp and upland production systems, respectively and significant at the 5 and 1% levels. It is an indication that 77 and 90% variation in output of swamp and upland rice

Table 3: Summary statistics of output and input variables in swamp and upland rice production in cross river state

		Swamp rice		Upland rice	
Variable	Unit	Mean	Standard error	Mean	Standard error
Output (Y)	Kg	1110.70[a]	776.63	493.73[b]	260.23
Labour (X_1)	Man-days	99.14[a]	34.21	50.37[b]	25.85
Capital (X_2)	N	849.99[a]	570.35	417.96[b]	127.56
Farmsize (X_3)	Ha	0.42[a]	0.14	0.32[a]	0.153
Fertilizer (X_4)	Kg	45[a]	21.37	41.07[a]	14.51
Seed (X_5)	Kg	21. 53[a]	12.55	21.06[a]	9.95

Note: Ab means in rows having different alphabets are significantly different. Source: Derived from Field Survey Data, 2004/2005

Table 4: MLE of the stochastic production frontier function in swamp and upland rice systems in cross river state

Variable	Swamp coefficient	Upland coefficient
Constant	6.95 (1.80)	5.60 (5.56)***
Labour(X^1)	0.75 (3.04) ***	0.45 (3.43)***
Capital (X_2)	0.15 (1.3)	0.07 (1.5)
Farm size (X_3)	0.06 (2.96) ***	0.60 (2.78)***
Fertilizer (X_4)	0.09 (1.89)	0.2 (1.56)**
Seed X_5	0.52 (2.54)**	0.12 (0.60)
Sum of elasticities	1.57	1.27
Diagnostic statistics		
Gamma (λ)	0.77 (2.14)**	0.90 (1.64)**
Sigma-square (d_2)	0.52 (2.14)**	0.51(2.91)***
Log likelihood function	-55.69	-38.13
LR test	21.66	23.83

Note ***: significant at the 1%, ** significant at 5%, t- values are in parentheses. Source: Output of Frontier 4.1 by Coelli (1994)

Table 5: Distribution of technical efficiency of sampled swamp and upland rice farmers in the state

	Swamp rice		Upland rice	
Efficiency class	No. of Farmers	%	No. of Farmers	%
<0.50	3	5.36	-	-
0.51-0.60	4	7.14	2	5.0
0.61-0.70	10	17.86	1	2.50
0.71-0.80	18	32.14	8	2.0
0.81-0.90	13	23.21	9	2.5
0.91-1.00	8	14.29	20	50.0
Total	56	100	40	100
Mean	0.77		0.87	
Std. deviation	0.13		0.11	
Minimum	0.48		0.55	
Maximum	0.99		0.99	

Source: Derived from output of computer programme frontier 4.1 by Coelli (1994)

systems, respectively are 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 were 0.52 and 0.51 for swamp and upland rice systems, respectively. They were significant at the 5 and 1% level and indicate the correctness of the specified assumptions of the distribution of the composite error term.

Technical efficiency levels of swamp and upland rice farmers in cross river state: The results presented in Table 5, indicate a technical efficiency range from 0.48 to 0.99 and 0.55 to 0.99 in swamp and upland rice systems, respectively.

The mean estimates were 0.77 and 0.87 for swamp and upland rice systems respectively. The efficiency distribution had shown that, about 14. 29 and 30% of the swamp and upland rice farmers, respectively attained between 0.91 and 1.00 efficiency levels, while none had below 50% level of efficiency. This high level of efficiency is an indication that only a small fraction of the output can be attributed to wastage (Udoh and Akintola, 2001). The distribution corroborates the findings of Kebede (2001) and Ajibefun and Aderinola (2003).

The result also indicate that the average swamp and upland rice farmers would realize about 22.22 and 12.12% respectively in cost savings, if they were to attain the level of the most efficient farmer in the sample. The result further shows that there are allowances for farmers to improve their efficiency by about 23 and13% in swamp and upland rice production systems respectively in the area.

The Likelihood Ratio Tests (LRT) indicate that, the swamp and upland rice farmers were not fully technically efficient ($\chi^2 = 21; 23 > \chi^2_{0.05} = 11.91$). The Z-test indicated that, there was no significant difference ($Zcal = 1.40 < Z_{0.05} 1.96$) between the technical efficiency of swamp and upland rice farmers in the State.

Determinants of technical efficiency in swamp and upland rice systems: The Maximum Likelihood Estimates (MLEs) of technical efficiency in the rice production systems in the area are presented in Table 6. The results indicate that, the coefficients of years of schooling (education), farming experience membership of association, farm size extension contact and access to credit have the expected positive signs in both systems. However, only years of schooling (education), membership of association and access to credit were significant. This implies that, the swamp and upland rice farmer's efficiency will increase with increase in their years of schooling, membership of association and access to credit.

Education enhances the acquisition and utilization of information on improved technology by the farmers as well as their innovativeness (Dey *et al*., 2001; Nwaru, 2004; Effiong, 2005; Onyenweaku *et al*., 2005). On the other hand, membership in Farmers' Organization/

Table 6: Maximum likelihood estimates of the determinants of technical efficiency of sampled swamp and upland rice farmers in the area

	Swamp		Upland	
Variable	Coefficient	T-ratios	Coefficient	T-ratios
Constant	-0.26	0.34	1.87	1.80
Age	-0.14	1.85	-0.35	2.84***
Education (Yrs of schooling)	0.66	2.67**	0.38	2.68**
Household size	-0.11	1.82	-0.06	2.63**
Farming experience	0.07	0.55	0.52	1.20
Membership of association	0.58	2.33**	0.43	3.17***
Farm size	0.33	2.12	0.20	1.51
Sex	-0.11	1.23	-0.18	1.2
Extension contact	0.12	1.06	0.07	0.61
Credit access	2.03	2.97***	0.90	2.90***

Note ***: Significant at 1%, ** Significant at 5%. Source: Output of Frontier 4.1 by Coelli (1994)

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 Bravo-Ureta and Evenson (1994), Heshmati and Mulugata (1996), Kebede (2001), Ajibefun and Aderinola (2003) and Nwaru (2004).

The coefficients of age, household size and sex had negative signs in both upland and swamp rice systems. They were also not significant in the swamp systems. However, household size and age were significant in the upland system. The significance of these coefficients imply that, upland rice farmers with large household sizes and are relatively older, experienced lower levels of technical efficiency. Large household sizes are expected to enhance labour availability (Nwaru, 2004). However, the use of available family labour on small sized farms will result in over-utilization and hence, inefficiency (Okike, 2000). Bravo-Ureta and Pinheiro (1997) obtained positive and significant relationship between this variable and technical efficiency in their study. In addition, aged farmers are often not amenable to changes and are neither likely to adopt improved technologies nor have the physical strength to do manual work as the younger ones. (Nwaru, 2004; Ajibefun and Aderinola, 2003). This gives credence to why there exist a negative relationship between age and technical efficiency.

CONCLUSION

This study has revealed that small scale swamp and upland rice farmers are not fully technically efficient and therefore there is allowance of efficiency improvement by addressing some important policy variables.

It was shown that education (years of schooling) had a positive correlation with technical efficiency in both systems 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. On the other hand, the negative and significant relationship between household size and efficiency implies that larger household sizes reduces efficiency and therefore, policies that will encourage farm family members to seek off farm employment should be made. And also, the current policies on family planning should be strengthened and intensified. Lastly, policies that would also encourage relatively younger persons into rice production is also suggested, given the negative influence of age on upland rice production.

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