

Analysis of Technical Efficiency of Small-scale Rain-fed Upland Rice Farmers in North-west Agricultural Zone of Adamawa State, Nigeria

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ABSTRACT

This study used stochastic frontier production function to investigate the technical efficiency and its determinants for small-scale rain-fed upland rice farmers in North west agricultural zone of Adamawa State, Nigeria. The empirical results indicate that more than 88% of the sampled farmers were found to be more than 80% technically efficient. It was also found that farming experience, household size and level of educational attainment reduces technical inefficiency, while farmers' age increases technical inefficiency. Policies that would encourage active youth participation in rice production should be pursued. Also, improved farmer's educational status through adult education and literacy campaigns would increase efficiency of farmers in the long term.

Key Words: Technical efficiency; Rice farmers; Stochastic frontier production; Adamawa state

INTRODUCTION

In the past two decades, Nigeria's rice sector has witnessed some remarkable developments. During the period both production and consumption of rice increased tremendously. Although production of rice rose from 2.4 million metric tonnes (mmt) in 1994 to 3.9 mmt in 2005, its demand exceeded domestic production (IITA, 1994; CBN, 2006). The shortfall in supply of rice in Nigeria was as a result of increased population and rapid urbanization (Fabusoro & Agbonlahor, 2002). The increase in population at a rate considerably higher than the rate of increase in food production has continued to widen the gap between domestic supply and demand. In response to the growing demand for rice, the Nigerian government has actively interfered in the rice economy over the years. However, policies and programs in this respect have neither been consistent nor appropriate (Akande, 2001). It has included oscillating import tariffs and import restrictions. For example, from the mid 1986 to mid 1990s, imports were illegal. In 1995 imports were allowed at 100% tariff. In 1996, the tariff was reduced to 50% but increased to 85% in 2001 (Akpokodje *et al.*, 2001). Notwithstanding the various policy measures, domestic rice production has not increase sufficiently to meet the increased demand.

The limited capacity of Nigeria's rice sector to meet the domestic demand could be attributed to low resource productivity. This is because the production of the crop in Nigeria is mainly in the hand of small-scale resource poor farmers who are still using unimproved farming systems. Increased production in rice must therefore come from

efficient utilization of the available scarce resources at the disposal of the many small-scale farmers.

The analysis of efficiency is generally associated with the possibility of farms producing certain optimal level of output from a given bundle of resources or certain level of output at least cost. The reason behind measure of efficiency is that farmers are not making efficient use of existing technologies; and efforts designed to improve efficiency would be more cost effective than introducing a new technology as a means of increasing output (Shapiro, 1983). This study was therefore designed to investigate the technical efficiency (TE) of smallholder rain-fed upland rice farmers in North-west agricultural zone of Adamawa State as well as to identify the factors that influence their technical efficiency.

MATERIALS AND METHODS

Sampling procedure and data collection. The data for this study was collected from randomly selected rain-fed upland rice farmers in North – west agricultural zone of Adamawa State, Nigeria during the 2004/2005 cropping season. A multi-stage random sampling technique was employed in the selection of sixty rice farmers. First, two Local Government Areas (L.G.As) out of the five L.G.As in the zone were purposively selected based on their relative importance in rain-fed upland rice production. They are Demsa and Lamurde L.G.As. Secondly, from each of the selected L.G.As, two districts were randomly chosen. Thirdly, from each selected district, three villages were randomly selected, giving a total of twelve selected villages.

The final stage in the sampling exercise was the selection of farmers from the villages. Thus, five farmers were randomly selected from each village. The instrument used for data collection was interview schedule. The questions were well structured to elicit responses from the selected farmers on their household's farming activities. These include information on material inputs, labor supply and use and farm size as well as quantities of rice output including their prices. Data were also collected on socio-economic variables of the farmers. Such variables include farmers' age, level of education, household size and farming experience.

Analytical technique and the models. Data were analyzed using an econometric method. The econometric method using the stochastic frontier production function was used to estimate the technical efficiency (TE) of the farmers and the factors that influence inefficiency. The Stochastic Frontier Production Function Model has the advantage of allowing simultaneous estimation of individual TE as well as its determinants. Following Dawson and Lingard (1989), the production technology of each farm was assumed to be characterized by a Cobb-Douglas function. Apart from the usual rationale for its use, experience has shown that simple functions involving few parameters as practically feasible perform best since convergence problems in the estimation process occur when there are a large number of explanatory variables in the estimated equation. The Cobb-Douglas functional form is a compromise between a complex production process and a complex estimation technique. It is defined as:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + V_i - U_i \dots (1)$$

Where, \ln = natural logarithm (base e), Y_i = output of rice of the i th farmer in kilogram, X_1 = farm size in hectares, X_2 = labour in mandays, X_3 = quantity of seed in kilogram, X_4 = quantity of fertilizer in kilogram, V_i is the two-sided error component that represent random variations in output due to factor outside the control of the farmers as well as the effects of the measurement error in the output variable, left out explanatory variables from the model and stochastic noise. It is assumed to be normally distributed with zero mean and variance, σ_v^2 ; and U_i is a non-negative random variable that represent stochastic shortfall of outputs from the most efficient production. It is assumed to be independently distributed such that U_i is defined by the truncation (at zero) of the normal distribution with mean μ_i and variance σ_u^2 where μ_i is defined by:

$$\mu_i = \delta_0 + \delta_1 \ln Z_1 + \delta_2 \ln Z_2 + \delta_3 \ln Z_3 + \delta_4 \ln Z_4. \dots (2)$$

Where, μ_i = inefficiency effects, Z_1 = age of farmer (years), Z_2 = farming experience (years), Z_3 = household size (number of persons in household), Z_4 = education (number of years of formal schooling). Given functional and distributional assumptions, maximum-likelihood estimates (MLE) for all parameters of the stochastic frontier production and inefficiency model defined by equations 1

and 2 were simultaneously estimated using the program, FRONTIER 4.1 (Coelli, 1996), which also estimated the variance parameters in terms of parameterization:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \dots (3)$$

And

$$\gamma = \sigma_u^2 / \sigma^2 \dots (4)$$

So that $0 \leq \gamma \leq 1$

The TE of production of the i th farmer (TE_i) given the levels of inputs used is defined by:

$$TE_i = \exp (-U_i) \dots (5)$$

The TE of a farmer was between 0 and 1 and is inversely related to the level of the technical inefficiency effects (Battese & Coelli, 1995). The TE is also predicted using the FRONTIER program, which calculates the maximum-likelihood estimator of the predictor for equation 5 that is based on its conditional expectation, given the observed value of $(V_i - U_i)$ (Battese & Coelli, 1988).

RESULTS AND DISCUSSION

The maximum-likelihood estimates (MLE) for the parameters of the Cobb-Douglas function defined by equation 1 are presented are given in Table I. From the results all except the labour variable had the expected positive signs suggested that more output would be obtained from the use of additional quantities of these variables, *ceteris paribus*. The coefficient of the land variable was positive and statistically significant ($P < 0.01$). This is in line with the findings of Umoh (2006). The significance of the variable is as a result of its importance in crop production in the sense that its shortage would not only have a direct negative effect on production but also an indirect negative effect on output through reducing the marginal productivity of non land inputs. The coefficient of labour input was negative but significant ($P < 0.05$), which suggests its importance in agricultural production. The negative sign however, could be as a result of excessive use. The seed variable had a positive sign, which conforms to *a priori* expectation and statistically significant ($P < 0.05$). This indicated that higher seed rate would result in high crop population and subsequently higher yield except where there is overcrowding leading to competition of available nutrients, which will consequently lead to lower yield. The coefficient of the fertilizer input was positive as expected and statistically significant ($P < 0.01$). The significance of the variable derives from the fact that it is a major land augmenting input in the sense that it improves the productivity of land thus leading to increased yield.

The yield (output) function was expressed as a Cobb-Douglas function; hence, the coefficients of the variables were direct elasticities. The elasticities with respect to land, seed and fertilizer were positive and between 0 and 1 (Table I). This indicates that allocation and use of these resources

were in the rational stage of the production process. The estimated return-to-scale computed as the sum of the estimated output elasticities was 0.37, suggesting decreasing returns to scale. The return-to-scale indicates what would happen to output if all the inputs are increased simultaneously. The result of this study implied that a unit increase in the quantities of the production resources would lead to less than proportionate increase to the output of rice, *ceteris paribus*.

The variance ratio (γ), defined by equation 4, which was associated with the variance of technical inefficiency effects in the stochastic frontier is estimated to be 0.935, suggesting that systematic influences that are unexplained by the production function were the dominant sources of random errors. This indicated that 93.5% of the total variability of rice output for the farmers was due to differences in TE.

The results of the inefficiency model defined by equation 2 are presented in Table II. The variables of the inefficiency model were modeled to explain the determinants of efficiency of production among the rice farmers. The TE difference between farmers could be due to farm-specific or farmer-specific variables. The sign of the variables in the inefficiency model is very important in explaining the observed level of TE of the farmers. A negative sign implied that the variable had the effect of reducing technical inefficiency, while a positive coefficient had the effect of increasing inefficiency. The results of the inefficiency model showed that all the included variables except age had the expected sign. The coefficient of age is estimated to be positive, which suggested that age led to technical inefficiency of the farmers (Seyoum *et al.*, 1998; Amos *et al.*, 2004; Ogunyinka & Ajibefun, 2004). A possible explanation could be that adoption of technology and general ability to supervise farming activities decreases as farmers advanced in age. The estimated coefficient of farming experience variable was negative as expected and significant ($P < 0.05$). This implied that farmers with more year of farming experience tend to be more efficient in rice production, which is consonance with the findings of Amaza and Maurice (2005) for the rice farmers in the Northeast Agricultural Zone of Adamawa State. A likely reason for the positive contribution of the variable to TE could be that farmers with more years of experience tend to become more efficient through 'learning-by-doing'.

The predicted coefficient of household size was negative and significant ($P < 0.05$). The negative coefficient is in agreement with the hypothesized expected sign and implies that as the number of persons (adult) in a household increases, efficiency also increases. This is because more adult members in a household meant that more quality labor would be available for carrying out farming activities in timely fashion, thus making the production process more efficient (Villano & Fleming, 2004). The coefficient of education was estimated to be negative and in consonance to the hypothesized expected sign. This indicates that

Table I. Maximum-likelihood estimates for parameters of the Cobb-Douglas stochastic frontier production function for the rice farmers during the 2004/2005 cropping season

Variable	Parameters	Coefficient	Std. error	t-value
Constant	β_0	3.522	0.213	16.529
Land	β_1	0.309	0.793	3.894***
Labor	β_2	-0.251	0.121	-2.076**
Seed	β_3	0.126	0.635	1.982**
Fertilizer	β_4	0.089	0.019	4.755***
Model variance	σ^2	0.053	0.028	1.876*
Variance ratio	γ	0.935	0.462	20.234***
ln likelihood		60.935		
Number of observations		60		

*** Significant at 1% level ** significant at 5% level *significant at 10% level: Source: Computer print out of field data

Table II. Maximum-likelihood estimates for parameters of the inefficiency model Cobb-Douglas stochastic frontier production function for the rice farmers during the 2004/2005 cropping season

Variable	Parameters	Coefficient	Std. error	t-value
Constant	δ_0	-14.011	7.255	-1.930
Age	δ_1	9.893	4.988	1.983**
Farming experience	δ_2	-2.342	1.128	-2.077**
Household size	δ_3	-1.741	0.949	-1.835**
Education	δ_4	-0.204	0.103	-1.978**

*** Significant at 1% level ** significant at 5% level *significant at 10% level: Source: Computer print out of MLE result

Table III. Frequency and percentage distribution of the technical efficiencies of small-scale rice farmers during the 2004/2005 cropping season

Deciles range	Number of farms	Percentage of farms
0.51 – 0.60	1	1.67
0.61 – 0.70	1	1.67
0.71 – 0.80	5	8.33
0.81 – 0.90	8	13.33
0.91 – 1.00	45	75.00
Total	60	100
Mean Efficiency	0.93	
Minimum Efficiency	0.56	
Maximum Efficiency	0.99	

Source: Computed from MLE result

farmers with greater years of formal schooling tend to be more technically efficient. This agreed with the findings of Ajibefun and Aderinola (2003) who reported that farmers in Southwestern Nigeria become more technically efficient with more years of formal schooling. These data asserted that more years of formal education and new technologies were imperative to better understand and adapt the technologies, which subsequently make it possible to move close to the frontier.

The predicted TEs for the farmers ranged from 0.56 to 0.99 (Table III). The mean TE of 0.93 indicated that the average farmer produced about 93% of maximum attainable output for given input levels. Also, from the result obtained, more than 88% of the respondents were more than 80% technically efficient. The 'best' practice farmer operated at about 99% efficiency; while the 'least' practice farmers

were found to operate at about 56% efficiency level. Although the farmers were relatively efficient, there is still room to increase the efficiency in their farming activities. This is because on the average, efficiency of farmers fall 7% short of the maximum attainable level and 1% from the 'best' practice farmer given the prevailing state of technology at that time.

CONCLUSION

There exist wide TE gaps across the sampled farmers. The attainment of an average TE of 93% indicated that efficiency of the farmers could be increased by about 7% for maximum output. The short-term solution to this therefore lies in more intensive use of seed and fertilizer inputs being used. This could be achieved through the removal by the government all distributional bottlenecks, which affect the availability and prices of these inputs at the grass root. In the long term, higher TE could be achieved by improving farmer's educational status through adult education and literacy campaigns.

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