

Productivity and Technical Efficiency of Small-scale Rice Farmers in Adamawa State, Nigeria

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ABSTRACT

This paper investigates the productivity and technical efficiency of small-scale farmers in Adamawa State, Nigeria using stochastic frontier production function. Primary data were collected using interview schedules administered to a sample of 180 rice farmers selected using multi-stage random sampling techniques. The empirical results indicate that the farmers were operating in the irrational stage of production (stage I) as depicted by the returns to scale of 1.06. The predicted technical efficiencies for the farmers ranged from 74% to 98.9% with a mean of 95.7%. Improvement on farmers' educational levels through adult education and literacy campaign as well as regulating household size by advocating the need for family planning would probably lead to improvement in technical efficiency in the long term.

Key Words: Productivity; Technical efficiency; Small-scale rice farmers; Stochastic frontier production

INTRODUCTION

Agriculture is a significant sector in Nigeria's economy. The sector plays a significant role in food security, poverty alleviation and human development chain. However, in more recent years, the agricultural sector is characterized by marked deterioration. Rice is one of the major staple crops in Nigeria grown on over 1.5 million hectares of land. Its production in the country rose from 2.4 million metric tonnes in 1994, to 3.9 million metric tonnes in 2005 (FAO, 2003; CBN, 2006). But despite the rise in domestic rice production, its demand/consumption far exceeds domestic production. This has precipitated into an increase in rice production bill to high a level of US\$ 60 million in 1994 to US\$ 160 million in 2003 (FAO, 2003). In Adamawa State, rice is grown virtually in all parts of the state but its production is mainly in the hands of small-scale resource poor farmers who use traditional technology with resultant low productivity (Adebayo & Onu, 1999). Since increased productivity is directly related to production efficiency, it is imperative to raise productivity of the farmers by helping them reduce technical inefficiencies. This could be achieved by investigating the nature of resource productivity and efficiency in production of the farmers.

Efficiency is concerned with the relative performance of the processes used in transferring given inputs into outputs. Farrell (1957) identified three types of efficiency-technical, allocative and economic. An important assumption relating to efficiency measurement is that firms operate on the outer bound production function, that is, on their efficiency frontier. When firms fail to operate on outer bound production function, they are said to be technically inefficient. The stochastic frontier production function, which is often used for efficiency studies was first

independently proposed by Aigner *et al.* (1977) and Meeseun and Van Den Broeck (1977). A stochastic frontier production function comprises a production function of the usual regression type with a composite disturbance term equal to the sum of two error components. One error component represents the effects of statistical noise (e.g., weather, measurement error, *etc.*). The other captures systematic influences that are unexplained by the production function and are attributed to technical inefficiency. The major advantage of the stochastic frontier production function model is the introduction of disturbance term representing noise, measurement error and exogenous factors beyond the control of the production unit in addition to the inefficiency component. This property of the stochastic frontier model accounts for its appropriateness for efficiency measurement in agricultural production owing to agriculture's inherent characteristics.

For almost three decades, the modeling, estimation and application of the stochastic frontier production function assumed prominence in econometric and applied economics analyses. In recent years, the application of stochastic frontier production function in efficiency analysis has been employed by Battese *et al.* (1993), Tadesse and Krishnamoorthy (1997), Seyoum *et al.* (1998), Ojo (2003), Amaza and Tashikalma (2003), Helfand (2003), Amos *et al.* (2004), Amaza and Maurice (2005), Umoh (2006), to mention a few.

The objective of this study, therefore was to empirically study the productivity and technical efficiency of resource use among small-scale farmers in zones III and IV of Adamawa Agricultural Development Program using stochastic frontier production function. Specific objectives of the study were to estimate the production elasticity and returns to scale for the farmers and technical efficiency of the farmers are estimated and effort has been made to

identify the determinants of technical efficiency of the farmers. This study would help by providing information that rice producers and policy makers would find invaluable in improving the country's rice economy.

MATERIALS AND METHODS

The study area. The study was carried out in Adamawa State. It is located in the Northeastern Nigeria between latitudes 7°33' and 11°30' north of the equator and longitude 11° and 14° east of the Greenwich meridian (Adebayo, 1999). The State has a total land area of approximately 38,741 square kilometers (Uyanga, 1993) with about 226,040 hectares of land under cultivation (Adamawa Agricultural Development Programme, 1996). The State is predominantly agrarian in nature with most of the inhabitants depending on subsistence agricultural practices mainly food crop production. Major crops grown in the area include rice, maize, sorghum, cassava, yam, cotton, groundnut and sugar cane (Sajo & Kadams, 1999).

Sampling procedure and data collection. The study covered four Local Government Areas (L.G.As) namely: Yola North, Fufore, Demsa and Lamurde selected from zone III and IV of the Adamawa Agricultural Development Program. The choice of the zones was informed by the fact that they comprised of twelve out of the twenty-one L.G.As in the State with a large number of rice farmers and as such the results of the study are assumed to give fair representation of the State. From each of the selected L.G.As, two districts were randomly chosen except in Yola North, which has only one district, giving a total of seven selected districts. Subsequently, from each of the selected districts, three villages were randomly chosen. In the case of Yola North L.G.A., however, political wards were regarded as villages giving a total of twenty-one selected villages. In the last stage, 189 farmers were randomly selected from the selected villages in a ratio proportional to the approximate population of farmers in each village. However, analyses were carried out using responses from 180 respondents whose records were complete. The remaining nine were rejected due to inconsistencies in their responses.

Data were collected from the rice farmers on their household's production activities during the 2004/2005 cropping season. The data were collected with the use of interview schedules designed to collect information on output, inputs, prices as well as socio-economic variables of the selected farmers.

Data analyses. To empirically measure the productivity and technical efficiency of the farmers, the stochastic production frontier was estimated. The model used for this study is implicitly specified thus:

$$Y_i = f(X_k, \beta) + \varepsilon \tag{1}$$

Where, Y_i = rice output of the i th farm, X_k = Vector of k th input of the i th farm, β = Vector of parameters, ε = stochastic disturbance term.

$$\text{Where, } \varepsilon = v - \mu \tag{2}$$

The two components of the composed error term v and μ are assumed to be independent of each other, where v is the two-sided, normally distributed random error, $v \sim N(0, \sigma_v^2)$ and μ is the one sided inefficiency component with a half-normal distribution ($\mu \sim |N(0, \sigma_u^2)|$).

$$\text{The variance parameters are } \sigma^2 = \sigma_v^2 + \sigma_u^2 \tag{3}$$

$$\text{And } \gamma = \sigma_u^2 / \sigma^2 \tag{4}$$

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

The technical efficiency of production of the i th farmer given the level of his inputs is defined thus:

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

So that $0 \leq TE_i \leq 1$.

Following Dawson and Lingard (1989), the production technology of each farm is assumed to be characterized by a Cobb-Douglas function. It is defined as:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + v_i - \mu_i \tag{6}$$

Where, \ln = natural logarithm, 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 = random error (white noise), μ_i = non-negative random variable called inefficiency effects. μ_i is defined thus:

$$\mu_i = \delta_0 + \delta_1 \ln Z_1 + \delta_2 \ln Z_2 + \delta_3 \ln Z_3 + \delta_4 \ln Z_4 \dots \dots \dots (7)$$

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). The β s and δ s coefficients in equations 6 and 7 are unknown parameters to be estimated. Given functional and distributional assumptions, the variance parameters defined by equations 3 and 4, the technical efficiency defined by equation 5 and the maximum-likelihood estimates (MLE) for all parameters of the stochastic frontier production and inefficiency model defined by equations 6 and 7 were simultaneously estimated using the program, FRONTIER 4.1 (Coelli, 1994).

RESULTS AND DISCUSSION

The maximum-likelihood estimates (MLE) for the parameters of the Cobb-Douglas stochastic frontier production function for the rice farmers are given in Table I. The production function estimates indicate the relative importance of factor inputs in rice production. From the results, land factor appears to be the most important factor of production with an elasticity of 0.828. The coefficient of land is positive, conforms to *a priori* expectation and significant at 1% level. The elasticity of 0.828 suggests that a unit increase in farm size results in 0.828% in output. Labor is the second most important factor with an elasticity of 0.364, followed by fertilizer input with an elasticity of 0.141. The production elasticity with respect to labor is

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

Variable	Parameters	Coefficients
Production factors		
Constant	β_0	0.317 (23.232)
Land	β_1	0.828 (16.309)***
Labor	β_2	0.364 (6.417)***
Seed	β_3	-0.274 (-7.693)***
Fertilizer	β_4	0.141 (1.639)
Inefficiency model		
Constant	δ_0	-0.186 (-1.212)
Age	δ_1	0.437 (0.706)
Farming experience	δ_2	0.411 (0.259)
Household size	δ_3	0.655 (0.155)
Education	δ_4	-0.733 (-1.677)*
Diagnostic statistics		
Model variance	σ^2	0.302 (2.161)**
Variance ratio	γ	0.893 (16.439)***
ln likelihood		222.44
LR test		21.21
Number of observations		180

Values in parenthesis are t-ratios; *** significant at 1% level ** significant at 5% level *significant at 10% level. Source: Computer print out of field data, 2006

Table II. Frequency distribution of the technical efficiencies of small-scale rice farmers during the 2004/2005 cropping season in Adamawa State, Nigeria

Range	Number of farms	Percentage of farms
0.71 – 0.75	1	0.56
0.76 – 0.80	1	0.56
0.81 – 0.85	2	1.11
0.86 – 0.90	8	4.44
0.91 – 0.95	50	27.78
0.96 – 1.00	118	65.55
Total	180	100
Mean Efficiency	0.957	
Minimum Efficiency	0.740	
Maximum Efficiency	0.989	

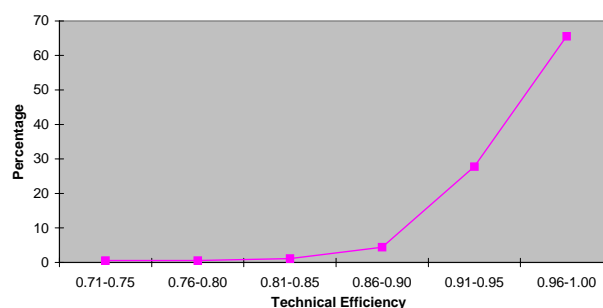
Source: Computed from MLE result

positive as expected and statistically significant at 1%. This implies that labor is a significant factor that influences changes in output of rice. The coefficient of the fertilizer input is positive as expected but not statistically significant even at 10% level. However, the positive coefficient suggests that the output of rice increases with increasing levels of fertilizer.

The elasticity of seed was estimated to be negative but statistically significant at 1% level. However, the negative coefficient of the seed input might be due to over reliance by the farmers on old stocks for planting as well as incorrect spacing, which probably results in overcrowding thereby leading to competition for nutrients and consequently low yield.

On the whole, the return to scale (RTS) was 1.06 indicating increasing returns to scale and that production was in stage I. This indicates that farmers were inefficient in the allocation and use of the productive inputs. Therefore, in the short term, farmers could improve the productivity of

Fig. 1. Percentage distribution of technical efficiencies of small-scale rice farmers during the 2004/2005 cropping season in Adamawa State, Nigeria



the inputs by increasing their levels of use.

The variance ratio (γ), defined by equation 4, which is associated with the variance of technical inefficiency effects in the stochastic frontier is estimated to be 0.893, suggesting that systematic influences that are unexplained by the production function are the dominant sources of random errors. This means that 89.3% of the total variability of rice output for the farmers was due to differences in technical efficiency.

Analysis of the estimated coefficients of the inefficiency variables of the efficiency model tells us the contribution of the variables to technical efficiency. The coefficient of age is estimated to be positive, indicating that age led to technical inefficiency of the farmers in the study area, in other words, technical efficiency of the farmers reduces as they become older. This conforms to the findings of Seyoum *et al.* (1998) and Amos *et al.* (2004) both of whom reported that young farmers are more technically efficient than their older counterparts. The implication is 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 not statistically significant.

The predicted coefficient of household size was positive suggesting that increase in household size led to increase in technical inefficiency. A possible explanation could be as number of people in a household increases, household consumption expenditure increases thereby making little money available for purchase of necessary farm inputs and meeting other farm financial obligation; which consequently results in decreased technical efficiency. The coefficient of education is estimated to be negative and is in consonance to the hypothesized expected sign. This indicates that farmers with greater years of formal schooling tend to be more technically efficient. This agrees with the findings of Coelli and Battese (1996), Seyoum *et al.* (1998), Amaza and Tashikalma (2003), Amos *et al.* (2004) and Amaza and Maurice (2005). The implication is that with more years of formal education, new technologies could be better understood and adopted, which subsequently make it possible to move close to the frontier.

The technical efficiencies of the sampled rice farmers are less than one. The predicted technical efficiencies for the farmers ranged from 0.740 to 0.989 with a mean of 0.957 (Table II). This means that, on the average, efficiency of farmers fall 4.3% short of the maximum possible level and 1.1% from the 'best' practice farmer. Also, more than 93% of the rice farmers had technical efficiencies above 90% suggesting that majority of the sampled farmers had high technical efficiency in rice production given the prevailing state of technology at that time.

The predicted technical efficiencies of the farmers within ranges of 0.05 are given in Fig. 1. It is clearly evident that the distribution of technical efficiencies is closely clustered near 1.0 indicating very high technical efficiencies of the farmers in the study area.

CONCLUSION AND RECOMMENDATIONS

The average technical efficiency of the farmers was 0.957 and more 93% are between 90 and 100% technically efficient. Efficiency of the rice farmers could be increased by more than 4%. In the short term, the solution lies in more intensive use of land factor and land augmenting input such as fertilizer. Given the significance of land, it is imperative for the government to develop more lands for rice production. This is crucial, because reduction in farm size would have not only a direct negative effect on production as land is the most important input but also an indirect negative effect on output through reducing the marginal productivity of non land inputs. There is also the need for farmers to have good access to improved seeds through the removal by the government of distributional bottlenecks of the seed input. Also, extension agents should be adequately trained and equipped to help the farmers imbibe the culture of sound agronomic practices that would ensure increased rice production in the study area.

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