ANALYSIS OF TECHNICAL EFFICIENCY AMONG SMALL-SCALE RAIN-FED RICE (*Oryza sativa*) FARMERS IN ADAMAWA STATE, NIGERIA

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ABSTRACT: The possible way to improve production and productivity with a given input mix and available technology is to improve efficiency of resource use. For this purpose examining the technical efficiency of the production process is very crucial. Thus, the aim of the study was to analyze the technical efficiency of small-scale rain-fed rice production in Adamawa State, Nigeria. Stochastic frontier approach was employed on a data which was collected from 362 sampled rice farmers through multi-stage sampling techniques. The maximum likelihood of the stochastic frontier model revealed that farm size, seed, inorganic fertilizer, hired labour and herbicides are found to be positively and significantly related to small-scale rice production in the study area. The average technical efficiency score predicted from the estimated Cobb-Douglas stochastic frontier production function was found to be 86% implying that there is a room for rice yield increment by improving the resource use efficiency of the rice farmers. The study also revealed there is a wide gap between most technically efficient rice farmer and the least efficient farmer given their efficiency range of 21% and 97%. Thus, the study recommends that expansion of farm size under cultivation, improved access to farm inputs like improved rice seeds, inorganic fertilizer and herbicides and campaigns to disseminate rice farming experiences and improved extension services are crucial to improving the technical efficiency of small-scale rain-fed rice production in the study area.
Keywords: Rice, Rain-fed Small-scale, Efficiency, Technical

INTRODUCTION

Rice production and consumption are of global importance, providing more than 20.0% of caloric needs of millions of people on daily basis (Yang and Zhang, 2010). In terms of annual world production and consumption of major cereals, rice is the third most produced and consumed cereal after maize and wheat (Food and Agriculture Organization [FAO], 2011). Nigeria, like all other rice consuming nations, has experienced a surge in domestic demand for rice since 1970 (Odusina, 2008). As a result, rice has become a strategic staple dietary household item in Nigeria, especially among lower-middle and low-income groups (Kanu and Ugwu, 2012). The annual consumption of milled rice in Nigeria increased from 0.4 million metric tons

in 1960 to approximately 5.2 million metric tons in 2013, reflecting an annual average growth rate of 7.2% (International Rice Research Institute, [IRRI] 2013).

In Nigeria's household consumption, rice is the fifth-most common food after tubers, vegetables, beans, sorghum, and other cereals, representing about 5.8% of households' spending (Johnson *et al*., 2013). The per capita annual consumption in Nigeria has also accelerated from 1.6 kg in 1960 to approximately 31.6 kg per annum in 2013. This increase is driven by growth in population, urbanization, increases in per capita income, and changes in preferences for rice meals (Omojola *et al*., 2006). For instance, average annual growth rate of population has fluctuated between 2.2% in 1960s to 2.9% in 2013 (World Bank, 2014).

The demand for rice has been increasing on a much faster rate in Nigeria than in other West African countries since the mid 1970s. The World Bank in 1986 projected that from 2010, the poorest income class of urban households in Nigeria may obtain not less than 33% of their cereal-based calories from rice annually. This is due to the changing consumer preferences and rapidly increasing population. FAO (2002) reported that as more family income rises in Nigeria there have been a shift in the consumption pattern from roots and tuber crops in favour of rice. This is one of the likely reasons why, rice that was once reserved for ceremonial occasions, has grown in importance as a daily intake for most homes today (Oniah *et al.,* 2008).

Population growth generally induces a rapid increase in food consumption, especially rice. The increase in demand for rice in Nigeria has not been accompanied by a sizeable increase in local rice production, resulting in the widening of the local supply-demand deficit (Damisa *et al*., 2013). As a result, the annual increase in local rice production is lagging behind the annual increase in local demand. This slow growth in local rice production has widened the gap between local supply and demand for rice in Nigeria, meaning that self-sufficiency ratio in terms of local production is continuously declining. To meet this annual deficit, Nigeria has expended substantial foreign exchange earnings to import rice (Amusan and Ayanwale, 2012).

METHODOLOGY
The study area

Adamawa state is located in the North-eastern part of Nigeria and consists of three geo-political zones for the convenience of administration as obtained in other states of Nigeria. These zones are the northern zone, central zone and the southern zone. It shares common boundary with Taraba state in the south and west, with Gombe state in the North-west and Borno state in the North (Figure 1). The State has an international boundary with Cameroon Republic along its eastern side. It lies between Latitude 7° and 11° North and Longitude 11° and 14° East (Adebayo and Tukur, 1999). Adamawa State has a land area of about 38, 741 Km^{2} and a population of 4.2 million people. The state is divided into (21) Local Government Areas.

The state has a tropical climate marked by dry and rainy seasons. The rainy season starts in April and ends in October while dry season spans from November to March. The average rain fall ranges from 700mm in North-western part of the state to 1600mm in the southern part of the state (Adebayo and Tukur, 1999). The maximum temperature in the state can reach $40^{o}C$ particularly in April, while the minimum temperature can be as low as $18^{o}C$ between December and January, monthly mean temperature in the state ranges from $26.7^{o}C$ in the south to $27.8^{o}C$ in the north-eastern part of the state. The northern part of Adamawa State has the sub-sudan vegetation zone marked by short grasses interspersed with short trees, while in the southern part, the northern guinea savannah vegetation exist.

Sources of data and sampling techniques

Primary data were used for the study and it was collected with the aid of well-structured questionnaires administered by trained enumerators under the supervision of the researcher. Adamawa State is made up of 21 Local Government areas (LGAs) divided into four agricultural zones by the Adamawa State Agricultural Development Programme (ADADP) for administrative convenience. Multi-stage sampling technique was employed for the selection of respondents in these zones. In the first stage, two Local Government Areas each was purposively selected from each of the Four ADADP zones since rice is produced across all the Local Government Areas of the state. In the second stage Five Villages were also purposively selected from each of the Local

Government Areas, based on the relative concentration of the rice farmers to give a total of fourty Villages. In the third stage, 362 respondents from the selected villages were randomly sampled proportionate to the size of the villages. Where there was no available sampling frame showing the list of all the rice farmers in the villages sampled, village heads/community leaders were used to provide the list of the farmers which was used as the sampling frame.

Data analysis

Analysis of data employs a Cobb-Douglas production function to simultaneously estimate technical efficiency and the random disturbance term which is outside the control of the production unit and the inefficiency effects. The model was applied to be accomplished by the use of Maximum Likelihood Estimates which have been used extensively by various authors in estimating among crop farmers (Maurice, 2012, Musa, 2014, Adewuyi, 2015 and Osayilusi, 2016). Specified thus:

$$\ln Y_{ij} = \beta_0 + \beta_1 \ln X_{1ij} + \beta_2 \ln X_{2ij} + \beta_3 \ln X_{3ij} + \beta_4 \ln X_{4ij} + \beta_5 \ln X_{5ij}$$
$$\beta_6 \ln X_{6ij} + \beta_7 \ln X_{7ij} + V_{ij} - U_{ij} \tag{1}$$

Where:

Subscript ij refers to the jth observation of the ith farmer.

Ln   = Logarithm to base e

Y   = Output of rice (Kg)

X_1 = Average farm size (ha)

X_2 = Quantity of seed (kg)

X_3 = Inorganic fertilizer (kg)

X_4 = Hired labour (mandays)

X_5 = Family labour (man days)

X_6 = Herbicides (liters)

X_7 = Distance from the farm (kilometers)

The technical inefficiency effects are also defined as:

$$\mu_i = \delta_0 + \delta_1 Z_{1ij} + \delta_2 Z_{2ij} + \delta_3 Z_{3ij} + \delta_4 Z_{4ij} + \delta_5 Z_{5ij} + \delta_6 Z_{6ij} + \delta_7 Z_{7ij} + \delta_8 Z_{8ij} \quad (2)$$

μ_{ij} = The technical inefficiency of the ith farmer

Z_1 = Age of the farmer (years)

Z_2 = Education (years spent in formal education)

Z_3 = Farming experience (years)

Z_4 = Household size (number)

Z_5 = Extension contact (number of extension visits)

Z_6 = Credit facilities (dummy, where: access = 1, and no access = 0)

Z_7 = Seed variety (dummy, where Improved seed =1, and local seed = 0)

Z_8 = Primary occupation (dummy, where: full time farming =1, and otherwise = 0)

RESULTS AND DISCUSSION

The maximum likelihood estimates (MLEs) of the stochastic frontier production function for rice farmers are presented in Table 1. The result revealed that five (5) of the seven inputs used in the model were statistically significant at various levels of probability. They include farm size, seed, inorganic fertilizer, hired labour, and herbicides. However family labour and distance from the farm were not statistically significant, though, family labour was positively related to the output

of rice in the study area. The Sigma squared (0.215) is statistically different from zero at 5% probability level. This indicates a good fit and correctness of the specified distributional assumption of the composite error terms. Also, the variance ratio defined by Gamma (γ) was estimated at (0.893) and was statistically significant at 1% probability level. The Gamma (γ) estimated shows the amount of variation arising from technical inefficiencies of the rice farmers. Therefore, the existence of technical inefficiency among rice farmers accounted for about 89% of the variation in the output level. In other words 89% of the variation in rice farms output was attributed to differences in technical efficiency.

The result in Table 1 showed that farm size was the most important factor in rice production with an elasticity coefficient of 0.37 implying that a 1% increase in farm size will increase output of rice by 0.37%. The result therefore agrees with the findings of Osanyinlusi *et al.,* (2016). The study found that as the size of the farm increases, the productivity of the rice farmers in the area increases. This is an indication that land as a factor of production is very vital in rice production in the study area. Seed was the second significant factor in rice production with a positive elasticity coefficient of 0.34 and was statistically significant at 1% level of probability. This implies that a 1% increase in the quantity of seed used in production will increase output of rice by 0.34%. This result is in conformity with the findings of Musa (2014), Adewuyi (2015) and Abba *et al*., (2015), who found that quantity of seed is one of the important factors in rice production. Inorganic fertilizer was statistically significant at 1% level of significance. The coefficient of fertilizer (0.011) was positive and in conformity with the apriori expectation. This means that the output of rice increases with increase in the amount of fertilizer used by the rice farmers. The result agrees with the findings of Osanyilusi *et al.,* (2016) in the study of the determinants of rice farmer's productivity in Ekiti State, Nigeria. Who found fertilizer to be positively related to the output of rice. Furthermore, hired labour was statistically significant at 1% level. The positive sign of the coefficient of the hired labour indicate that output rises with increase in mandays of hired labour. Similar result was obtained by Abba *et al.,* (2015) who found that labour is one of the most important factors in improving rice productions. Herbicide was also a significant input in rice production with an elasticity coefficient of 0.25 and

was statistically significant at 1% probability level. This implies that a 1% increase in the use of other herbicides in rice production would increase output of rice by 0.25%. Apart from minimizing expenditure on weeding, the use of herbicides reduces stress and fatigue associated with rice production especially land clearing. By implication, the use of herbicides will enable farmers to cultivate large hectares of land, resulting to higher output.

The analysis of the inefficiency parameters is very important as a basis for informing agricultural policies on what need to be done to improve agricultural production. The inefficiency parameters as specified are those that relate to farmers specific socio-economic characteristics which appear to have significant roles in determining the level of technical efficiency of the farmers. The major factors that influence technical efficiency of rice farmers as revealed in Table 1 include; farming experience, extension contact and primary occupation. The farming experience of the rice farmers was found to be statistically significant at 5% level of significant. The farming experience was shown to influence the technical efficiency of the farmer which implies that as farmers acquire more experience in farming their technical inefficiency decreases. As farming experience increases, farmers develop skills and understand farming practices that help them to allocate resources effectively. Similar findings have been reported by Maurice (2012), Ogunniyi (2012), Musa (2014), Adewuyi (2015) and Osayinlusi (2016). The coefficient of extension contact was estimated to be negative and statistically significant at 5% probability level. The farmers are visited by extension agents, their technical inefficiencies decreases and vice-versa. Extension contacts expose farmers to new innovations which will improve their productivity. This result agrees with the findings of Samarpitha *et al*., (2016) who found that contact with extension agents significantly affected adoption of improved varieties in Andhra Pradesh. Also, in the studies of Ayoola *et al.,* (2011), Abba *et al.,* (2015), all reported that efficiency level of farmers was significantly affected by extension contact.

Likewise, coefficient of primary occupation was also statistically significant at 1% probability level and carries the expected sign. The implication of this is that farmers who are full time farmers tends to decrease their technical inefficiencies than part time farmers, this is

because full time farmers may tend to denote more time, resources and energy on the farm and they more dedicated to their farms since they don't have other secondary occupations.

Table 1: Maximum Likelihood Estimates of the Parameters of the Stochastic Frontier Production Function

Variables	Parameters	Coefficients	St. errors	t-ratios
Production Factors				
Constant	β_o	2.490	0.173	14.426*
Farm size (X_1)	β_1	0.371	0.093	3.994*
Quantity of seed (X_2)	β_2	0.343	1.105	3.269*
Inorganic fertilizer (X_3)	β_3	0.011	0.006	3.229*
Hired labour (X_4)	β_4	0.018	0.007	3.051*
Family labour (X_5)	β_5	0.008	0.007	1.205
Herbicides (X_6)	β_6	0.251	0.041	6.472*
Distance from farm (X_7)	β_7	-0.002	0.027	-0.064
Inefficiency Factors				
Age of the farmer (Z_1)	δ_1	-1.971	1.151	-1.698
Education (Z_2)	δ_2	0.055	0.046	1.208
Farming Experience (Z_3)	δ_3	-0.294	0.118	-2.500**
Household size (Z_4)	δ_4	-0.112	0.071	-1.579
Extension contact (Z_5)	δ_5	-0.423	0.163	2.592**
Credit facilities (Z_6)	δ_6	-0.313	0.193	-1.614
Seed variety (Z_7)	δ_7	0.088	0.110	-0.800
Primary occupation (Z_8)	δ_8	-0.031	0.013	-3.000*
Sigma squared	σ^2	0.215	0.084	2.571**
Gamma	Υ	0.893	0.021	42.246*
Log likelihood function		36.001		

Source: Computer Output from Frontier Version 4.1c
* Significant at 1%
** Significant at 5%

Distribution of farmers' technical efficiency indices derived from the analysis of the stochastic frontier production function is presented in Table 2. The Table revealed that, technical efficiency of the sampled farmers was less than one (1.00). This implies that rice farmers in the study area were producing below the maximum frontier output. The range of technical efficiency shows that the most efficient farmer had a technical efficiency of 0.97, that is (97%) while the least efficient farmer had a technical efficiency of 0.21, that is (21%) with a mean technical efficiency of 0.86 that is (86%). The mean technical efficiency of 86% implies that on the average, the farmers were able to achieve about 86% of optimal output from a given set of inputs under given technology. The mean TE therefore indicates that the farmers were technically efficient in rice production. However, their observed output was 14% less than the maximum output. Thus, the output of the rice farmers can be increased by 14% through efficient allocation of resources especially inputs that significantly influences output. The distribution of technical efficiency of farmers further showed that about 38.95% had technical efficiency of 0.91 and above, while majority (42.54%) had technical efficiency within the range of 81-90. Also 0.83% of the rice farmers had technical efficiency of 50% and below. This study is in agreement with the findings of Adewuyi, (2015) who found a mean technical efficiency of 0.86 among rice farmers in Adamawa State.

Table 2: Distribution of Technical Efficiency of Respondents

Efficiency Levels	Frequency	%
≤50	3	0.83
51-60	9	2.48
61-70	6	1.66
71-80	49	13.54
81-90	156	42.54
≥91	141	38.95
Total	362	100.00
Minimum	0.21	
Maximum	0.97	
Mean	0.86	

Source: Field Survey, 2017.

CONCLUSION AND RECOMMENDATIONS

Estimation of technical efficiency is important to increase the productivity of agriculture sector in a developing country like Nigeria. The study finds that the average level of technical efficiency of rain-fed rice production in the study area was 86%. This result means that the small-scale rice farms in the study area have been operating below the maximum level of production frontier. Given the available technology, farmers can increase their production by 14%. The estimated results of Stochastic Frontier Production Function shows that farm size, seeds, inorganic fertilizer, hired labour and herbicides have positive and significant effect on the level of technical efficiency of small-scale rice production in the study area. Thus, the study recommends that expansion of farm size under cultivation, improved access to farm inputs like improved rice seeds, inorganic fertilizer and herbicides and campaigns to disseminate rice farming experiences and improved extension services are crucial to improve the technical efficiency of small-scale rain-fed rice production in the study area.

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