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ECONOMIC EFFICIENCY OF RICE FARMING: A STOCHASTIC FRONTIER ANALYSIS APPROACH

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Abstract. The future of agriculture is dependent on an increase in the use of resources at disposal, it is therefore imperative that strategies to increase agricultural growth should be directed towards increasing efficiency of smallholder farming operations and resource utilization. This study examined the economic efficiency of rice production. A multistage sampling procedure was used to select 240 rice farmers and data were obtained with the use of a structured questionnaire. Data collected were analyzed with descriptive techniques, stochastic frontier analysis (SFA) and the Tobit regression model. The SFA result revealed that input variables such as seed, herbicide and pesticide were positive and had a significant effect on rice output. Rice farmers were able to maximize their output by 74% at the lowest minimum cost possible. Furthermore, economic efficiency was positively influenced by age, level of education, membership in farmers' associations, access to the public market and access to healthcare facilities; while household size, farming experience, poor road conditions and distance to the nearest marketplace had negative effects. The study concluded that rice farmers were inefficient. Therefore, in order to increase rice production efficiency and improve the livelihood of smallholder farmers, farmers should receive formal and informal education. As it is a key policy issue in the study area, farmers should strengthen the existing association structures and organize new farmers' associations. Also, local and regional governments were encouraged to provide good road networks and a public market that will enable farmers to dispose off their produce at attractive places and prices of their choice.

Keywords: economic efficiency, rice farming, return to scale, elasticity, Tobit regression

INTRODUCTION

Rice is a common staple food consumed by more than 50% of the world's population (Ricepedia, 2010). It provides 19% and 13% of global per capita requirements for energy and protein respectively (Maclean et al., 2013), which makes it critical to global food security. Over the last decade, global rice production and global rice consumption have been growing at an annual average rate of 1% and 1.2% respectively, reaching 486.7 million tonnes and 481.64 million tonnes respectively in 2017 (PwC, 2018). However, in the case of Africa the annual consumption growth rate averaged 4.8% in the last decade, overtaking the global rice consumption growth rate, with Nigeria and Egypt accounting for 30% of the growth (PwC, 2018). The demand for rice has been increasing at a much faster rate in Nigeria than in other African countries as a result of the combination of population growth and a change in taste for traditional coarse grains (Ismail et al., 2012). An average Nigerian consumes 24.8 kg of rice annually (Alfred and Adekayode, 2014), which is indicative of a larger percentage of total calorie intake. Rice production capacity is below the national requirements despite its significant contribution to the food requirements of the teeming population (Ogunsumi et al., 2013). Rice farmers are mostly smallholders characterized by low output as a result of inefficient production, the aging of the farming population and low

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technological know-how (Fasoyiro and Taiwo, 2012). Nevertheless, in recent times there has been an increase in rice output with production reaching 3.7 million tonnes in 2017 (PwC, 2018). The growth recorded in rice production has been facilitated by an increase in the area under cultivation for rice. The area under rice cultivation expanded from about 2.4 million harvested hectares in 2010 to 3.2 million harvested hectares in 2017 (PwC, 2018). In spite of this improvement, the yield remained at 2 tonnes per hectare, which is about half of the average achieved in Asia. This suggests there is immense potential to raise productivity and increase production. Improvement in agricultural growth as a result of increasing productivity plays a crucial role in alleviating poverty and increasing food security (Valdés and Foster, 2010). This is true especially for Nigeria which is the world's poverty capital (Olawale, 2018). With the increasing scarcity of agricultural land as a result of the increase in population, the future of agriculture is dependent on an increase in the use of resources at disposal (World Bank, 2007). It is therefore imperative that strategies to increase agricultural growth should be directed towards increasing the efficiency of smallholder farming operations and resource utilization. It is against this background that this research is carried out. Understanding the efficiency of resource use in rice production and its determinants is important considering the immense contribution of rice to the food basket of an average individual globally. Research in these area is vital for understanding the problems related to rice production efficiency; it will also provide knowledge and information for policymakers. Although there is a growing body of literature on efficiency and its determinants, the available studies carried out by Tung (2013), Abate et al. (2014), Ahmed and Melesse (2018), and Ayedun and Adeniyi (2019) only examined technical efficiency, i.e. how farmers were able to obtain maximum output from a combination of their inputs but did not account for how farmers were able to obtain maximum output at least possible cost (economic efficiency). This study therefore examined the technical, allocative and economic efficiency of rice farmers in the study area using a parametric stochastic frontier analysis. It also examined the socioeconomic, demographic and institutional factors influencing rice production efficiency.

METHODOLOGY

This study was carried out in Ogun state, Nigeria. The state is characterised by good climatic and soil conditions that support rice production, and it is one of the leading rice-producing states in Nigeria with a production capacity of 15,000-20,000 tonnes annually (Osabohien et al., 2018). The state is divided into four Agricultural Development Project (ADP) zones. Multistage sampling procedure was used for this study. The first stage involved the purposive selection of one block from each of the four ADP zones due to massive rice production in the blocks. The second stage consisted in a purposive selection of a major rice-producing cell from each of the selected blocks. In the third stage, three villages from each of the selected cells were chosen on a random basis. The last stage involved the purposive selection of twenty rice farmers from each of the selected cells, making a total sample size of two hundred and forty respondents. Only two hundred and twenty-five questionnaires were fit for analysis. Data for this study were obtained from a primary source, primary data were collected from rice farmers through the use of structured interview schedule and guide. Data were collected on socioeconomic characteristics such as age, sex, level of education, household size, primary occupation, secondary occupation, income, etc. Data on the quantity of inputs and outputs were also gathered. The data collected were analyzed with both descriptive and econometric techniques such as mean, standard deviation, stochastic frontier analysis and Tobit regression with the use of the STATA version 14.1 statistical package.

ANALYTICAL METHODS

Stochastic Frontier Analysis

The stochastic frontier analysis has been used by Nyagaka et al. (2010), Akinbode et al. (2011), Ahmed and Melesse (2018), Okello et al. (2019) and Gela et al. (2019). The stochastic frontier production function model for estimating farm level technical efficiency was specified as

$$Q_j = f(X_j; \beta_j) + \varepsilon_j \quad j = 1,2,..., n \tag{1}$$

where: Q_j – output of the jth farm, X_j – vector of input quantities used by the j^{th} farm, β_j – vectors of unknown parameters to be estimated, $f(X_j; \beta_j)$ – production function (Cobb-Douglas, translog, etc.), ε_i – error term that is composed of two elements, that is, $\varepsilon_j = V_j - U_j$ which represents the traditional deterministic production function formulation.

$$Y = f(X;\beta) + v - u \tag{2}$$

V_j – assumed independent distributed random errors. It is assumed to be independent, identical and normally distributed with a mean of zero and constant variance $\{V_j \sim N(0, \sigma_v^2)\}$ and independent of U_j given the stochastic structure of the frontier.

U_j – technical inefficiency effects. It is assumed to be independently, identically and normally distributed $\{U_j\ [N|(0, \sigma_u^2)]\}$ and independent of V_j. Also, the technical inefficiency effects in the stochastic frontier above are expressed in terms of various explanatory variables (assumed to be related to farm and farmers in relation to socio-economic characteristics) which include socio-economic characteristics such as age, sex, etc. This is given by

$$U_j = \tau_0 + \tau_1 K_1 + \tau_2 K_2 + \ldots\ldots + \tau_n K_n \tag{3}$$

$\tau_0, \tau_1, \tau_2 \ldots \tau_n$ – are inefficiency parameters and $K_1, K_2 \ldots K_n$ are the related socio-economic characteristics.

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \tag{4}$$

Furthermore

$$\gamma = \sigma_u^2 / \sigma_v^2 \tag{5}$$

The variance ratio parameter gamma (γ) according to Battese and Coelli (1977) is the total output attained at the frontier which is attributed to technical efficiency and has a value between zero and one. Similarly, $(1 - \gamma)$ measures the technical inefficiency of firms.

Following Jondrow et al. (1982), the technical efficiency estimation is given by the mean of the conditional distribution of inefficiency term U_j given ε_j and thus defined by:

$$E(U_j \mid \varepsilon_j) = ((\sigma_u / \sigma_v)/\sigma) f((\varepsilon_j \lambda)/\sigma)/(1 - f(\varepsilon_j \lambda)/\sigma) - (\varepsilon_j \lambda)/\sigma \tag{6}$$

Farm-specific technical efficiency is defined in terms of observed output (Q_j) to the corresponding frontier output (Q_j*) using the available technology derived from the result of equation (7) below, as

$$(TE) = Q_j/Q_j^* = f(Xj; \beta) \exp(V_j - U_j), \; / f(X_j; \beta_j) \exp(V_j) = \text{Exp}(-U_j) \tag{7}$$

where: Q_j – observed output, Q_j* – Frontier output.

TE takes values within the interval zero and one (i.e. between 0 and 1), where 1 indicates a fully efficient farm. Following Coelli (1995), the technical and allocative efficiency of a firm can be simultaneously predicted from the cost function. Also, it can be used to receive all the economically relevant information about farm-level technology as it is generally positive, non-decreasing, concave, continuous and homogenous of degree one in the input prices (Chambers, 1983).

The stochastic frontier cost function model is specified as

$$C_j = h(Q_j, P_j; \delta_j) + \varepsilon_j \quad j = 1,2 \ldots n \tag{8}$$

where: C_j – represents total production cost, h is a suitable functional form such as the Cobb-Douglas function; Q_j – represents output produced, P_j – represents prices of inputs, δ_j – represents the parameters of the cost function and ε_j – represents the error term that is composed of two elements, that is

$$\varepsilon_j = V_j + U_j. \tag{9}$$

$$C_j = h(Q_j, P_j; \delta) + V_j + U_j \tag{10}$$

Here, V_j and U_j are as defined earlier. However, because inefficiencies are assumed to always increase costs, error components have positive signs (Coelli et al., 1998).

Economic efficiency (EE) is defined as the ratio of minimum observed total production cost (C_j*) to actual total production cost (C_j) using the result of equation 8 above. That is

$$\text{EE} = (C_j^*)/C_j = (\text{E}(C_j | u_j = 0, Q_j P_j))/ (\text{E}(Q_j | u_{(j,)} Q_j P_j)) = \text{E}[\text{Exp}(U_j \mid \varepsilon)] \tag{11}$$

The farm-level efficiency was obtained using the relationship

$$\text{EE} = 1/\text{Cost efficiency}. \tag{12}$$

Hence economic efficiency (EE) is the inverse of cost efficiency (CE) while allocative efficiency was obtained using the relationship

$$\text{Allocative Efficiency (AE)} = \text{EE/TE} \tag{13}$$

Stochastic production function

The technical efficiency of rice farmers was analyzed using stochastic production frontier analysis in particular Cobb-Douglas functional form to estimate the coefficients of the parameters of the production function and also to predict efficiencies of the rice farmer. This model

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was chosen because it allows for the presence of technical inefficiency while accepting that random shocks (weather or disease) beyond the control of the farmer can affect output. The Cobb-Douglas production form of the frontier that was used for this study was specified as

$$LnQ = \beta_0 + \beta_1 lnx_1 + \beta_2 lnx_2 + \beta_3 lnx_3 + +\beta_4 lnx_{4+} + \beta_5 lnx_5 + \beta_6 lnx_6 + \beta_7 lnx_7 + V_j - U_j \quad (14)$$

where: Ln – natural logarithm (i.e. logarithm to the base e), Q_i – output of farmer (kg), X_1 – farm size (ha), X_2 – seed (kg), X_3 – fertilizer (kg), X_4 – labor (man days), X_5 – herbicide (litres), X_6 – pesticide (litres), X_7 – tractor (hours).

The inefficiency model was represented by U_i which was defined as

$$U_j = \tau_0 + \tau_1 K_1 + \tau_2 K_2 + \tau_3 K_3 + \tau_4 K_4 + \tau_5 K_5 + + \tau_6 K_6 + \tau_7 K_7 + \ldots + \tau_{13} K_{13} + \varepsilon_0 \quad (15)$$

where: U_j – technical inefficiency, K_1 – age of farmers (years), K_2 – sex (male = 1, female = 0), K_3 – household size (number of people), K_4 – marital status (married = 1, otherwise = 0), K_5 – level of education (years), K_6 – membership of farmers' associations (member = 1, otherwise = 0), K_7 = farming experience (years), K_8 – type of labor employed (hired = 1, otherwise = 0), K_9 – access to the public market (access = 1, otherwise = 0), K_{10} – access to public health facilities (access = 1, otherwise = 0), K_{11} – road conditions (poor = 1, otherwise = 0), K_{12} – extension contact (had contact = 1, otherwise = 0), K_{13} – distance to the nearest marketplace (kilometers), $\tau_1, \tau_2 \ldots\ldots \tau_{13}$ are parameters to be estimated, τ_0 – intercept.

Stochastic cost function

The allocative efficiency of rice farmers was analyzed using stochastic cost frontier analysis in a particular Cobb-Douglas functional form to estimate the coefficients of the cost function parameters and also to predict allocative efficiencies of the rice farmer. Following Akinbode et al. (2011) and Gela et al. (2019), the Cobb-Douglas cost form of the frontier that was used for this study was specified as

$$\mathrm{Ln}C_j = a_0 + a_1 \ln P_{1j} + a_2 \ln P_{2j} + a_3 \ln P_{3j} + + a_4 \ln P_{4j} + \ldots + a_7 \ln P_{7j} + V_j + \mu_j \quad (16)$$

where: C_j – total input cost of the ith farms (₦), P_{1j} – rent on land per hectare (₦), P_{2j} – price of rice per kg (₦), P_{3j} – average price of fertilizer per kg (₦), P_{4j} – wage rate of labor per man day (₦), P_{5j} – average price of herbicides per liter (₦), P_{6j} – average price of insecticide per liter (₦), P_{7j} – tractor rental cost per hour (₦), V_j – random variability in the cost that cannot be influenced by the farmer, μ_i – deviation from maximum potential cost attributed to allocative inefficiency, – intercept, a_1 – a_7 – parameters to be estimated. The inefficiency variables are as defined in the technical inefficiency model.

Tobit regression model

The tobit regression model was used to estimate the socioeconomic, demographic and institutional factors influencing the economic efficiency of rice farmers. This model was employed because economic efficiency ranges between 0 and 1, that is, it has a lower and upper bound, and using ordinary least square regression will produce bias and inefficient estimates. Following Tobin (1958), Wooldridge (2002) and Cameron and Trivedi (2005), the Tobit model was specified as

$$y_i = y_i^* = X_i\beta + e_i \quad (17)$$
$$y_i = 0 \text{ if } y_i^* \leq 0 \quad (18)$$
$$y_i = y_i^* \text{ if } y_i^* > 0 \quad (19)$$
$$i = 1, 2, 3, 4 \ldots n$$

where:

y_i – is the observable but censored variable measuring economic efficiency

y_i^* – is the latent variable indicating that economic efficiency may or may not be directly observable. Hence,

Economic efficiency is observed if $y_i^* > 0$ and unobservable if $y_i^* \leq 0$

X_i are a set of explanatory variables in the inefficiency model

β are the parameters to be estimated

e_i is the error or disturbance term

Definition and measurement of variables influencing the economic efficiency of rice production

The level of production of rice was hypothesized to be influenced by some variables, the variables influencing the efficiency of rice production were described in Table 1 below.

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Table 1. Description of the variables hypothesized to influence rice production efficiency

Variable	Description	Measurement	Sign
Age	Age of household heads	Years	+/–
Sex	Sex of household heads	Dummy (1 = male, 0 = female)	+
Household size	Number of persons per household	Adult equivalent	+
Marital status	Marital status of household heads	Dummy (1 = married, 0 = otherwise)	+
Level of education	Number of years spent in school	Years	+
Farmers' association	Member of farmers' association	Dummy (1 = member, 0 = otherwise)	+
Farming experience	Rice farming experience	Years	+
Type of labor	Labor employed on the rice farm	Dummy (1 = hired, , 0 = otherwise)	+/–
Public market	Access to the public market	Dummy (1 = access, 0 = otherwise)	+
Public health facilities	Access to public health facilities	Dummy (1 = access, 0 = otherwise)	+
Road conditions	Condition of road	Dummy (1 = bad, 0 = otherwise)	–
Extension contact	Contact with extension agents	Dummy (1 = had contact, 0 = otherwise)	+
Distance to the nearest marketplace	Marketplace distance from place of residence	kilometers	–

Source: own review of literature sources.

RESULT AND DISCUSSION

Socio-economic characteristics

The result revealed that the mean age of rice farmers was 54 years, this implies that most of the rice farmers were old, non-energetic and not within their productive age, which may have a negative influence on their productivity as well as their efficiency. This corroborates the findings of the World Bank (1993) reporting that productivity increases from the age of early twenties until forties and declines afterward. A larger proportion of the rice farmers were male, which implies that there were more male rice farmers than their female counterparts and this can be attributed to the fact that rice farming is tedious and requires a lot of energy which most female might not be able to provide. This result supports the findings of other authors (Adetunji et al., 2007; Ahmed et al., 2015). The average size of a household is approximately 6 persons; this implies that most of the households are fairly large. More than half of the rice farmers were married, which carries the implication that most of the household heads have an implanted sense of responsibility since marital status prompts commitment to business. This is because of the family needs that must be met, whichwould result in enhancing their productivity. This result supports the findings of Ayoade and Adeola (2012) who reported that the majority of the sampled household heads were married. On average, rice farmers spent 6 years in school which implies that most of the rice farmers had elementary education and this might influence their adoption of innovative practices in rice production. This result is consistent with the findings of Ashaolu et al. (2015) demonstrating that the adsorption capacity of an individual requires that the individual is well educated and exposed. The mean farming experience was approximately 26 years which implies that

Table 2. Socioeconomic characteristics of rice farmers

Variable	Mean	Standard Deviation
Age	54.3	14.1
Sex	0.7	0.4
Household size	5.9	2.4
Marital status	0.6	0.5
Level of education	5.5	4.9
Cooperative membership	0.2	0.4
Farmers' association	0.5	0.5
Farming experience	26.4	14.9
Area cultivated	2.8	2.8

Source: field survey data analysis, 2018.

most of the household heads had enough experience in farming and this may positively influence their productivity and efficiency. The result corroborates the findings of Ambali et al. (2012) who reported that the mean farming experience of food crop farmers in Ogun state was 25 years. Most of the rice farmers were smallholders with an average farm size of 2.8 hectares; this result supports the findings of Osabohien et al. (2018) who reported that rice farmers in Ogun state were smallholders with an average farm size of 2 hectares.

In the case of dummy variables, proportions were used instead of mean values.

Technical efficiency analysis

Stochastic production frontier of rice farmers

The result revealed that the quantity of seed ($p < 0.1$), the quantity of insecticide ($p < 0.05$) and the quantity of herbicide ($p < 0.05$) significantly influence the output of rice while labor used ($p < 0.05$), availability of public market ($p < 0.1$) and availability of public health facilities ($p < 0.1$) significantly influence technical efficiency of the rice farmers. The coefficient of seed implies that if the quantity of seed increases by 1%, the output of rice will increase by 0.563%. This implies that the higher the quantity of seed sown, the higher the output of rice. This result is in consonance with the findings of Ambali et al. (2012) and Okello et al. (2019) who reported a positive relationship between the quantity of seed and the output of rice. The coefficient of insecticide implies that if the quantity of insecticide increases by 1%, rice output will increase by 0.092%. The coefficient of herbicide revealed that if the quantity of herbicide increases by 1%, the output of rice will increase by 0.11%. This is so because insect pest infestation and weed were serious challenges facing rice farmers and efforts to eliminate insect pests and weed chemically will increase the output of rice. This result emphasizes the importance of agrochemicals in agricultural production and is consistent with the findings of Gela et al. (2019) who reported that agrochemicals had a significant influence on the output of farmers in the west Gondar zone of Ethiopia.

The sign of the coefficients of the inefficiency variables has important policy implications since the positive sign implies a negative effect on technical efficiency, and the negative sign implies a positive effect on efficiency. The coefficient of type of labor revealed that the technical efficiency of rice farmers who used hired labor increases compared to their counterparts who used household labor. The implication of this result is that using family labor is inefficient since it is the availability of more family labor that resulted in labor market failure among rice farmers. This result confirms the findings of Kamau et al. (2009) and Shittu (2014) who reported that households are inefficient in terms of labor use. The coefficient of the public market revealed that the technical efficiency of farmers who have access to the public market increases compared to their counterparts who do not have such access. Availability of the public market enables farmers to have access to a wider variety of seed, agrochemicals and other farm inputs at a lower cost at the same time improving their technical efficiency. This result is in agreement with the findings of Gautam et al. (2012) who reported that a positive relationship exists between access to market and technical efficiency of farmers in India. Access to public healthcare facilities increases the technical efficiency of rice farmers because farmers who have such access are more likely to receive healthcare services which will reduce their days lost to illness, which, in turn, will invariably increase their technical efficiency.

Elasticity and return to scale of rice farmers

The result in Table 3 revealed that seed has the highest efficiency, followed by herbicide, farm size, insecticide, fertilizer, tractor and labor respectively; the significant positive and higher elasticity effects of production

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Table 3. Maximum likelihood estimate of stochastic production frontier of rice farmers

Variable	Coefficient	Standard error	t-value	P-value
Constant	4.299***	0.425	10.130	0.000
Labor	–0.004	0.044	–0.090	0.927
Farm size	0.093	0.116	0.800	0.422
Seed	0.563***	0.085	6.600	0.000
Fertilizer	–0.009	0.021	–0.440	0.660
Insecticide	0.092**	0.037	2.470	0.013
Herbicide	0.114**	0.052	2.190	0.028
Tractor	–0.009	0.039	–0.240	0.810
Inefficiency Model				
Constant	–1.858*	0.963	–1.930	0.054
Age	–0.008	0.017	–0.440	0.660
Sex	–0.447	0.463	–0.970	0.334
Household size	0.076	0.078	0.980	0.328
Marital status	0.333	0.374	0.890	0.374
Level of education	0.048	0.039	1.230	0.220
Farmers' association	–0.259	0.399	–0.650	0.515
Farming experience	0.024	0.017	1.440	0.150
Type of labor	–1.157**	0.553	–2.090	0.036
Public market	–1.063*	0.600	–1.770	0.076
public healthcare facilities	–18.409*	10.877	–1.690	0.091
Road conditions	5.477	10.998	0.500	0.618
Extension contact	–7.807	12.804	–0.610	0.542
Distance to nearest marketplace	9.530	9.986	0.950	0.340
Diagnostic statistics				
Wald chi^2(7)	1 030.19***			
Prob > chi^2	0.000***			
Log-likelihood	–60.176			

***, ** and * significant at 1, 5 and 10% respectively.
Source: field survey data analysis, 2018.

inputs, such as seed and agro-chemicals (insecticides and herbicides), highlighted the importance of these inputs for rice production. The return to scale value of 0.723 showed that rice farmers operate at decreasing return to scale, which implies that rice farmers are operating at the rational stage of production (stage 2) where the average physical product is above the marginal physical product. This result is consistent with the findings of Ambali et al. (2012) who reported that food crop farmers in Ogun state operate at the rational stage of production.

Table 4. Estimates of return to scale

Variable	Elasticity
Labor	–0.004
Farm size	0.093
Seed	**0.563**
Fertilizer	–0.009
Insecticide	**0.092**
Herbicide	**0.114**
Tractor	–0.009
Return to scale	**0.723**

Source: field survey data analysis, 2018.

Allocative efficiency analysis

Stochastic cost frontier of rice farmers

The result of stochastic cost frontier revealed that rent on land ($p < 0.01$), price of fertilizer ($p < 0.1$) and tractor rental cost ($p < 0.01$) significantly influence the total cost of the rice farmers while marital status ($p < 0.1$) and level of education ($p < 0.1$) significantly influence allocative efficiency of the rice farmers. The coefficient of land rental cost revealed that if land rental cost increases by 1%, the total cost will increase by 0.707%. This is so because land is a particularly vital resource used in production and any attempt to raise its rental cost will increase the total production cost. This result supports the findings of Gela et al. (2019). The coefficient of price of fertilizer revealed that if the price of fertilizer increases by 1%, the total cost will be reduced by 0.417%. This is because most of the rice farmers did not use fertilizer on their farms, and this will therefore reduce production cost. The coefficient of tractor rental cost revealed that if tractor rental cost increases by 1%, the total cost will increase by 0.083%. This implies that the higher the tractor rental cost, the higher the total production cost. The coefficient of marital status revealed that the allocative efficiency of married households decreases compared to their counterparts. The coefficient of level of education revealed that the higher the level of education, the higher the allocative efficiency, which implies that educated farmers are allocatively efficient compared to their counterparts.

Table 5. Maximum likelihood estimate of stochastic cost frontier of rice farmers

Variable	Coefficient	Standard Error	t-value	P-value
Constant	9.562***	1.803	5.300	0.000
Land rental cost	0.707***	0.075	9.410	0.000
Price of rice seed	0.011	0.100	0.110	0.912
Price of fertilizer	–0.417*	0.242	–1.720	0.085
Wage rate of labor	0.061	0.048	1.270	0.204
Price of herbicide	–0.024	0.029	–0.810	0.415
Price of insecticide	–0.048	0.031	–1.570	0.117
Tractor rental cost	0.083***	0.022	3.750	0.000
Inefficiency Model				
Constant	–7.707	7.255	–1.060	0.288
Age	–0.200	0.141	–1.420	0.157
Sex	1.214	2.342	0.520	0.604
Household size	0.393	0.722	0.540	0.586
Marital status	–7.119*	4.086	–1.740	0.081
Level of education	0.379*	0.198	1.910	0.056
Farmers' association	–1.890	2.227	–0.850	0.396
Farming experience	–0.055	0.108	–0.510	0.610
Type of labor	6.953	5.907	1.180	0.239
Public market	1.059	2.157	0.490	0.623
Public healthcare facilities	19.528	52.238	0.370	0.709
Road conditions	72.122	113.100	0.640	0.524
Extension contact	–52.190	111.001	–0.470	0.638
Distance to nearest marketplace	157.915	100.055	1.580	0.115
Diagnostic statistics				
Wald chi² (7)	141.21***			
Prob > chi²	0.000***			
Log-likelihood	–254.820			

***, ** and * significant at 1, 5 and 10% respectively.
Source: field survey data analysis, 2018.

Efficiency distribution of rice farmers

The mean technical efficiency implies that rice farmers were able to obtain about 80% of potential output from their combination of input. In other words, about 20% of the output is lost to the inability of the farmers to optimally combine the available inputs. That is, there is room for about 20% improvement in technical efficiency with the use of the available technology. This result is in line with the findings of Ambali et al. (2012) who reported 80% technical efficiency among food crop farmers in Ogun state. The mean allocative efficiency implies that rice farmers were 94% cost-efficient, that is they were able to maximize their total output by minimizing 94% of their total production cost, which shows that there is room for 6% improvement, and this result is higher than the 93%, 76%, 59% and 49% reported respectively by Akinbode et al. (2011), Ambali et al. (2012), Okello et al. (2019) and Gela et al. (2019). The mean economic efficiency implies that rice farmers were 74% economically efficient, that is they were able to maximize their output by 74% at the minimum cost possible. This shows that there is room for 26% improvement, and this result is in line with the findings of Okello et al. (2019) who reported 75% economic efficiency among rice farmers in Gulu and Amuru districts of northern Uganda.

Determinants of economic efficiency

The sigma revealed the fitness of the model at 1% ($p < 0.01$) level of significance. Age ($p < 0.01$), household size ($p < 0.01$), level of education ($p < 0.01$), farmers' association ($p < 0.01$), farming experience ($p < 0.01$), public market ($p < 0.01$), public health facilities ($p < 0.05$), road conditions ($p < 0.01$) and distance to the nearest marketplace ($p < 0.01$) significantly influence economic efficiency of rice farmers. The coefficient of age revealed that an increase in age increases

Table 6. Distribution of rice farmers by technical, economic and allocative efficiency

Frequency indices	Technical efficiency		Allocative efficiency		Economic efficiency	
	freq.	%	freq.	%	freq.	%
≤0.3	–	–	2	0.89	2	0.89
0.31–0.40	3	1.33	1	0.44	4	1.78
0.41–0.50	4	1.78	2	0.89	13	5.78
0.51–0.60	7	3.11	4	1.78	13	5.78
0.61–0.70	16	7.11	5	2.22	30	13.33
0.71–0.80	52	23.11	12	5.33	66	29.33
0.81–0.90	124	55.11	21	9.33	85	37.78
>0.90	19	8.44	178	79.11	12	5.33
Total	225	100.00	225	100.00	225	100.00
Mean	0.80		0.94		0.74	
Minimum	0.33		0.14		0.11	
Maximum	0.94		1.00		0.97	

freq. – frequency
Source: field survey data analysis, 2018.

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the economic efficiency of the rice farmers; this implies that the older the age of the farmers, the higher their economic efficiency. This is so because the older the farmers, the more experienced they are, which aids their decision making on the farm business and thus results in production of more output at lowest possible cost. The coefficient of household size revealed that an increase in the size of households decreases the economic efficiency of rice farmers. This result implies that households with more members are economically inefficient compared to smaller households. The coefficient of level of education revealed that the higher the level of education, the higher the economic efficiency of rice farmers, which implies that better educated farmers are economically efficient, and this is so because education enables farmers to adopt innovative practices in rice production which will in turn increase output at a reduced cost. This result confirms the findings of Okello et al. (2019) and Gela et al. (2019) who reported a positive relationship between education and economic efficiency. The coefficient of farmers' association revealed that the economic efficiency of farmers who are members of farmers' associations increases compared to those who did not belong to farmers' association. This is so because cooperative membership makes farmers cross-fertilize ideas, experiences and affords access to sources of information regarding credit facilities, knowledge and skills, hitherto not known, with a view to improving their livelihood. This result is in agreement with the findings of Conroy (2005) and Ayodele et al. (2020). The coefficient of farming experience revealed that an increase in farming experience decreases the economic efficiency of rice farmers; this implies that experienced farmers are less economically efficient. This is so because experienced farmers are more likely to rely on their obsolete ideas rather than accept innovative practices that could lead to an improvement in their production efficiency. The coefficient of public market revealed that farmers who have access to the public market are more likely to be economically efficient compared to their counterparts that do not have such access. This is so because access to the public market enables farmers to have access to a wider variety of seed and agrochemicals at a lower cost thereby improving their economic efficiency. This result agrees with the findings of Gautam et al. (2012). The coefficient of public health facilities revealed that rice farmers who have access to public health facilities are more economically efficient compared to their counterparts who do not have such access, this is so because farmers who have access to health facilities are more likely to receive healthcare services which will thereby reduce their days of incapacitation and this will invariably increase their economic efficiency. Poor road conditions reduce the economic efficiency of rice farmers, this is so because poor road conditions increase the cost of transporting farm inputs and output from a nearby marketplace and farm thereby raising production cost, and this will invariably reduce their economic efficiency. The longer the distance to the nearest marketplace, the lower the economic efficiency of rice farmers, this result confirms the study of Gautam et al. (2012).

Table 7. Tobit regression estimates of determinants of economic efficiency

Variable	Coefficient	Robust Standard Error	t-value	P-value
Constant	0.705***	0.049	14.370	0.000
Age	0.003***	0.001	3.590	0.000
Sex	0.009	0.018	0.500	0.619
Household size	–0.011***	0.004	–2.790	0.006
Marital status	0.034	0.022	1.570	0.119
Level of education	0.011***	0.002	5.170	0.000
Farmers' association	0.063***	0.021	2.980	0.003
Farming experience	–0.002***	0.001	–2.760	0.006
Type of labor	0.001	0.020	0.070	0.947
Public market	0.079***	0.023	3.390	0.001
Public health facilities	0.689**	0.320	2.150	0.032
Road conditions	–1.383***	0.431	–3.210	0.002
Extension contact	0.719	0.443	1.620	0.106
Distance to nearest marketplace	–1.717***	0.470	–3.650	0.000
Sigma	0.118***	0.008		
F(13, 212)	8.260***			
Prob > chi^2	0.000***			
Log likelihood	162.101			

***and ** significant at 1and 5% respectively.
Source: field survey data analysis, 2018.

CONCLUSION AND POLICY IMPLICATIONS

This study examined the economic efficiency of rice production in the study area. Cobb-Douglas stochastic production, cost function and Tobit regression model were used to estimate the technical, allocative and economic efficiency of rice farmers. The result revealed that input variables such as seed, herbicide and pesticide were positive and had a significant effect on rice output. Seed input had the highest elasticity followed by herbicide, farm size, insecticide, fertilizer, tractor and labor respectively. Using hired labor, availability of public market and public health facilities positively influences technical efficiency. An increase in land and tractor rental costs increases production cost while an increase in fertilizer price reduces production cost. An increase in the level of education increases allocative efficiency while marital status reduces it. The rice farmers were able to maximize their output by 74% at the minimum cost possible. Economic efficiency was positively and significantly influenced by age, level of education, membership of farmers' associations, access to the public market and healthcare facilities while household size, farming experience, poor road conditions and distance to the nearest marketplace had negative and significant effects. The study results revealed that rice farmers were inefficient. Therefore, in order to increase rice production and improve the livelihood of smallholders towards food security, policymakers should pay due attention to improving the existing level of the inefficiencies of rice farmers in addition to introducing new technology which may require more sophisticated and expensive equipment. The significant positive and higher elasticity effects of production inputs, such as seed and agrochemicals (insecticides and herbicides), highlighted the importance of these inputs in rice production. This implies that enhanced availability and better use of these production inputs could lead to higher rice output in the study area. Farmers' level of education and membership of associations plays a crucial role in improving economic efficiency, which is why education opportunities should be created for all farmers; they should also be encouraged to attend formal and informal education as it is a key policy issue in the study area. Similarly, farmers were encouraged to strengthen the existing association structures and organize new farmers' associations for the common benefit that can improve efficiency. The positive effect between technical efficiency, economic efficiency and infrastructural facilities, such as health care facilities, public markets and roads, emphasized the importance of these infrastructural facilities for improving the efficiency of rice farmers. Local and regional governments are therefore encouraged to provide good quality road networks and a public market that will enable farmers to dispose of their produce at attractive places and prices of their choice.

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