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Economic Efficiency of Farm Size, Fertilizer, and Improve seeds on Rice Production in Kano State, Nigeria

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Abstract

Studies on the efficiency of rice production focused on the technical and allocative; thus, the literature on economic efficiency in Kano is absent. The objective of this study is to identify the economic efficiency of fertilizer, hybrids, and farmland on rice farming. Using the multistage and purposive sampling, questionnaires distributed to a random sample of 768 rice farmers. The result of the socioeconomic characteristics shows that 55.3% of the respondents are within the active population (30 to 49) years, 55.3% have a low level of education, 78.7% spent at least six years in rice farming, 61.9%, 76.7%, and 47.7% have access to nitrogen fertilizer, improved rice, and at least one extension visits respectively. Further, the stochastic frontier result shows that an average rice farmer could economically save inputs worth of 29.54% to meet the most efficient counterpart in the study area. The worst rice farmer could economically save the cost of inputs by 86.18% to meet the best counterpart. The study suggests that overhauling the educational system, guidelines for agricultural inputs usage should have a translated version into the three major Nigerian's languages (Hausa, Igbo, and Yoruba). Collaboration between public and private to provide more extensions, construct rural link roads.

Keywords

Economic efficiency, Farm size, Fertilizer, Improved rice, Kano

JEL Codes: D24, E23, L23

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1. Introduction

Rice is the most consumed and the least among the produced food crops in Nigeria. Further, the country is the largest importer of rice in the African continent, which wasted a lot of its foreign reserves. Rice is now the primary source of diet and calories in Nigeria for all households (low and high-income earners). Despite vast cultivable land in Nigeria, rice production is meagre to match the demand of the population (Uduma *et al*., 2016). Besides, the country had to annually import an average of 4 million metric tons of rice to supplement home production, leading to the draining of the country's foreign reserves (Tanko *et al*., 2019b). The low rice productivity in Nigeria could be linked to the inaccessibility/misuse of fertilizer and improve rice variety by the rice farmers in the country, especially in Kano. Most of the rice farmers in the state could not access the subsidised fertilizer. The few who can access are sometimes at the wrong time, and a high price or it is a mixed fertilizer. Most of the rice farmers could not access the subsidised improved rice seeds. Thus, farmers have to use the local variety, which yields lower output, unresisting to draught, and easily affected by pests. Hence, the failure to access nitrogen fertilizer and high bred seeds forced the rice farmers to use the local fertilizer on improved rice, or use local rice seed with nitrogen fertilizer which may not be suitable. Further, most consumers do not like the taste of local rice. Thus, farmers have fewer markets for their output.

Martey *et al.* (2019) and Abdallah (2016) reported that access to extension services affect productivity. In Nigeria, rice farmers misapplied the fertilizer and improved rice variety due to scarce extension services. There was few/absence of extension agents in most of the rice clusters. The few available extension workers could not effectively deliver the services while others were immobile. Further, some clusters are inaccessible due to remoteness. Farm size affects agricultural productivity (Martey *et al.*, 2019; Sekyi *et al*., 2017; Abdallah, 2016; Akudugu, 2016). In Nigeria, the new government policy banning rice import made many people embrace the production of the crop. The policy leads to small farm holdings, especially in irrigated rice farming though there is a dramatic increase in rice production in the country, especially in Kano. There is an increase in rice milling in the state; thereby, giving rice farmers more encouragement to increase rice productivity. Most literature on rice productivity focuses on technical and allocative efficiency of rice production. Hence, studies on economic efficiency are scarce/absence in Kano state. Therefore, the objective of this study is to assess the technical, allocative and economic efficiency of fertilizer, improved rice seed, and farm size on rice farming in Kano state.

2. Literature review

2.1. Concepts of efficiency

Coelli *et al.* (2002) categorised efficiency into three, namely technical, allocative, and economic efficiency. They further stated that the technical efficiency (TE) refers to the ability of a farmer to produces the maximum possible output from the given variable inputs (output-oriented) or the farmer uses the minimum inputs to produce a given level of output (input-oriented). The allocative efficiency (AE) is the ability of a farmer to select the optimal proportion of inputs given their relative prices to minimized costs of production. The economic efficiency (EE) embraces the technical and allocative efficiency obtained by multiplying the TE with AE.

2.2. Empirical review

The literature on the level of technical efficiency such as Ayedun & Adeniyi (2019) studies the TE of rice farmers in Benue and Nasarawa states North Central, Nigeria. The results show that the TE of the rice farmers ranges between 2% to 93% with an average TE of 61%. Further, 41% of the respondents have TE of 61% to 80%, and that age, family size, tractor usage, and intercropping are the primary determinant of TE in the area. Another study conducted by Tanko, Kang, and Islam (2019) in Kadawa rice cluster Kano North West, Nigeria. They reported that mean TE of the rice farmers is 81.25%, and least TE is 71% in the study area. Further, gender, qualification, and marital status reduce TE while experience in rice farming increases the TE of the rice farmers in the study area. A study by Chandio *et al.* (2019) examine the TE of rice farmers in Singh, Pakistan, using the SFA. The result shows that the average TE of rice farmers is 97% with a TE ranging from 91% to 99%. Further, more than 53% of the respondents have a TE between 96% 98% and farm size, fertilizer, labour, and credit determined the TE of rice farmers in the area. Also, Yiadom-Boakye *et al.* (2013) analyse TE of rice farmers using the SFA in Ashanti Region, Ghana. The result shows that the average TE of the respondents is 24.5% with a TE ranging from 2% to 85%. Also, gender, age, experience, credit access, and use of improved rice determined the TE of rice farmers in the area.

Gedara *et al.* (2012) studied TE of irrigated rice farming in Sri Lanka. The result shows that the mean TE of the rice farmers is 72%, though 63% exceeded the average. Also, Narala and Zala (2010) analysed TE of irrigated rice farmers in Central Gujarat, India. The result revealed that the average TE of the farmers is 72.78%, ranging from 71.39% to 99.82%. Also, farm size, experience, education and family size are significant in determining TE in the area. Further, Shehu (2007) examines the TE of rice farming using the SFA in Adamawa state, Nigeria. The results show that the average TE of the rice farmers is 95% with a range of TE 74% to 98%. Further, 93% of the farmers have TE above 90%, and education is the primary determinant of TE of rice farmers in the study area. Furthermore, the literature on the TE, AE, and EE such as Melese *et al.* (2019) examined the TE, AE, and EE of smallholder rice farmers in Guraferda Woreda, Ethiopia. The study conducted in the 2017/2018 cropping season using the SFA. The results show that the mean TE is 78.5%, AE is 80.56%, and EE is 63.18%. Further, land, labour, seed, oxen power, herbicide, and DAP positively and significantly affect rice output. Also, education, frequency of extension visit, membership of cooperative positively and significantly affects EE while, proximity to market, and non-farm income negatively and significantly affect EE in the study area.

Rizwan *et al.* (2017) measured TE, AE, and EE of rice farmers in Punjab, Pakistan, using DEA. They reported that the mean TE of the farmers with off-farm is 90% and 82% for non-off farm rice farmers. Further, AE for off-farm and the non-off farm was 88% and 76% while EE of with and without off-farm was 83% and 74% respectively. Also, Dhungana *et al.*, (2004) measured the economic inefficiency of rice farmers in Nepalese using DEA. They reported that mean EE is 34%, AE is 13%, TE is 24%, pure TE is 18, and scale efficiency is 7%. Further, the causes of inefficiency among the farmers were due to gender, age, education, family size, seeds, labour, fertilizer, and power. Further, Coelli *et al.* (2002) examined the TE, AE, and EE of rice farms in Bangladesh using DEA. The results revealed that mean TE was 69.4%, AE is 81.3%, cost efficiency was 56.2% and scale efficiency 94.9%. Further, fertilizer, large family size, and overuse of labour are the causes of inefficiency while access to modern input markets, less off-farm activity leads to efficiency in the area.

Similarly, Ahmed *et al.* (2015) examined the TE, AE, and EE of maize producers in Central Rift Valley, Ethiopia. The results show that the TE, AE, and EE of the farmers were 84.87%, 37.47%, and 31.62% respectively. Further, education, number of extension visits, access to credit, market distance, and soil fertility were the primary determinant of efficiency in the area. Another study in South Ethiopia by Sisay *et al.* (2015) uses the SFA to determine the TE, AE, and EE of maize farmers. The results revealed that TE is 62.3%, AE is 57.1%, and EE is 39% of the farmers and that farm size, education, family size, extension services, livestock, membership of the cooperative, and mobile phones are the significant determinant of the efficiency of the farmers in the area.

Asghar, Sasaki *et al.* (2018) examined the TE, AE, and EE of wheat farms in Pakistan using DEA. They reported that the TE of the tube well owners' score is 99% and water buyers 97%. Also, the result shows that tube well owners (75%), tube well shareholders (71%), and water buyers (65%) had a 100% TE. The mean AE for tube well owners, tube well shareholders, and water buyers were 70%, 56%, and 69% respectively. Further, the EE of tube well owners is 97%, tube well shareholders 96%, and water buyers are 94%. Gebretsadik (2017) analysed the TE, AE, and EE of Sesame farms in Kafta Humera District, West Zone, Tigray Ethiopia. The result shows that TE is 71%, AE is 90%, and EE 64% and that education, experience, frequency of extension visit, road type, and amount of credit accessed found to be the significant determinant of TE, AE, and EE in the study area.

3. Methodology of research

Kano is among the 36 states of Nigeria, created on 27th of May 1967. The population of the state based on the 2006 population census was 9.4 million, with a 3.5% rate of annual population growth. The location of the state is at latitude 130 N and 11.50 S, and longitude 8.50 W and 100 E. Also, the state bordered Jigawa in the east, Bauchi and Kaduna in the south, Katsina in the west, and Katsina and Jigawa states in the north. Further, the daily mean temperature in Kano between March and May is 300 C to 330C with the lowest temperature of 100C between September to February, an average rainfall of 600 mm and an average literacy level (Nuhu, 2014). Kano is in the Sahel Savannah with a tropical climate, a land area of 20,760 square kilometres, agriculture 1,754,200 hectares, and forest vegetation and a grazing land 75,000 hectares. Most of the indigenes are agrarian involving 55% of the rural dwellers. Crops produced in the state include sorghum, maize, millet, cowpea, rice, cotton, wheat and varieties of vegetables (Agronigeria, 2016).

3.1. Sampling Technique and Sample Size

The study used multistage, purposive, and random sampling techniques to select the sample. Seven local governments who are producing rice were purposely selected from the forty-four local governments of Kano state. Therefore, the selected local governments are; Bunkure, Doguwa, Garun Malam, Garko, Kura, Tudun Wada, and Warawa local governments. The selected seven local governments have seventeen rice clusters. Thus, nine rice clusters were purposely selected based their productivity. The selected clusters are Lautaye, Doka sati, Kadawa, Garin Ali, Kura, Karfi, Bugau, Nata'ala, and Larabar G/sarki, and 768 rice farmers randomly selected.

3.2. Method of data collection

A structured questionnaire used to collect data in the selected nine rice clusters of Kano state during 2018 irrigated and rain-fed rice cropping. One extension worker in each cluster was used to identify the rice farmers in their respective cluster because not farmers are cultivating rice. Then, one research assistant is used to administer the questionnaire and collect the response from the respondents. Thus, nine extension agents and nine research assistants, together with the researcher, collected the data for this study. The questionnaires distributed were 768 randomly to the rice farmers in each rice cluster. The distribution of the questionnaire based on the proportion of rice farmers in each cluster. The returned questionnaires were 739 (96.22%), but the usable questionnaires were 656 (85.42%) response rate as presented in Table 1.

Table 1. Response rate of the questionnaires

Cluster	Questionnaires distributed	Questionnaires returned	Questionnaires returned and usable	Questionnaires returned excluded	Unreturned questionnaires	% Response rate	%Usable response rate
Lautaye	75	70	66	4	5	93.33	88.00
Dokasati	75	72	66	6	3	96.00	88.00
GarinAli	80	75	69	6	5	93.75	86.25
Kadawa	80	77	66	11	3	96.25	82.50
Bugau	75	73	59	14	2	97.33	78.67
Karfi	100	96	88	8	4	96.00	88.00
Kura	90	88	78	10	2	97.78	86.67
Nata'ala	75	73	64	9	2	97.33	85.33
Larabar G/Sarki	118	115	100	15	3	97.46	84.75
9clusters	768	739	656	83	29	96.22	85.42

3.3. Method of data analysis

The socio-economic characteristics of the respondents analysed using descriptive statistics. Moreover, the econometric analysis uses the Cobb-Douglas stochastic frontier approach (SFA) to identify the TE, AE, and EE of the rice farmers. Further, the inefficiency model was used to determine the determinant of productivity level among the rice farmers.

3.4. Model specifications

Following Melese *et al.* (2019) and Ahmed *et al.* (2018), this study used the SFA. The study decomposes TE, AE, and EE. The SFA separates inefficiencies from random errors that are beyond the control of a farmer such as a drought, pests and insects, weather deterioration (Coelli, 1995). Moreover, rice farmers in Kano are mostly small scale with a low level of formal education; this may not necessarily keep records of farm expenditures. Hence, the existing data are subject to measurement errors. The functional form of the model specified as;

$$\ln Y = f(B_n \ln X_n) + E \quad (1)$$

Where: In = natural logarithm, y = is the output of the ith farmer, X = vector of the inputs, n number of inputs, and B is vector of the unknown parameter to be estimated, and E is the error term further expressed as $E = V_i - U_i$; V_i is random error assumed N $(0, q_v^2)$ independent of the U_i which is non-negative accounting for the technical inefficiency of the farmer.

3.5. Selection and Estimation of the Empirical Model

Following Ahmed *et al.* (2018) and Melese *et al.* (2019), this study uses the Cobb-Douglas in log functional form of the SFA despite its restrictions. The Cobb-Douglas functional form provides a yardstick for the adequacy of a data and feasibility of computations. Further, the function is suitable for duality (Xu & Jeffrey, 1998) and for expressing elasticity of production and stingy to the degree of freedom. Also, it is ideal for uncertainty condition of production of which most farmers operate. Therefore, Stata 14 was used to estimate the result of this study. In line with Gebretsadik (2017), the Cobb-Douglas in double log form as specified by Aigner & Chu (1968) and Meeusen & van Den Broeck (1977), selected based on the generalised log-likelihood ratio (LR) test specified as;

$$\ln\gamma = \beta_0 + \sum_{j-1}^{k} \beta_1 X_1 + \mathrm{v} - \mathrm{u} \quad (2)$$

Where: In = natural logarithm; Y = rice output in quantity; Xi = input used, β = unknown vector of parameters to be estimated through the maximum likelihood (ML), V = is the symmetric error term accounting for inefficiencies beyond the control of the farmer, and U = is the asymmetric error term accounting for the inefficiencies resulting to the farmer. Besides, the generalised likelihood ratio (LR) test was used to test some hypotheses regarding the chosen model.

Furthermore, Coelli & Battese (1996) developed the dual cost function of the Cobb-Douglas production function with its inefficiency; thus, the cost function signifies the dual method (Chambers, 1988). Therefore, the stochastic cost frontier function specified as;

$$C = C(P, Y^*, \Upsilon) \quad (3)$$

Transformed to In

$$\mathrm{Ln}\, C_i = \Upsilon + [\sum_{j-1}^{k} P_y\, \Upsilon_i] + \Upsilon_i\, Y^* \quad (4)$$

Where; i = is i^th^ rice farmer, C_i is minimum cost, j = 1 … k, inputs used, P_y input price, Y^* = farm revenue adjusted for noise Vi, and Υ_i = parameters to be estimated.

3.6. Variable of rice production efficiency

The variables are the inputs used in the efficient production of rice. The inputs could be production or cost inputs which determine the general production efficiency. Hence, the functional form of the model depicting the relationship between the dependent and the inputs as;

$$\ln Y_i = \beta_0 + \beta_1 \ln\mathrm{Fsz} + \beta_2 lnFtz + \beta_0 lnIps \quad (5)$$

where Fsz is farm size, Ftz is fertilizer, Ips is improved rice seed.

3.7. Estimation of cost function for rice production

The production cost function shows the costs incurred by the rice farmer taking the price of the inputs presented as;

In C_j = $\text{ɗ}_0 + \text{ɗ}_1 \ln cFsz + \text{ɗ}_2 \ln cFtz + \text{ɗ}_0 \ln cIps$ + $(V_i – U_i)$ (6)

where j is j^{th} rice farmer, C_j is actual cost, In is natural logarithm, cFsz is land cost, cFtz is fertilizer cost, cIps is improved rice seed cost, ɗ is the coefficient of the parameters to be determined, V_i is the error term (symmetric), and U_i is the inefficiency resulting farmer (asymmetric error term).

The equation that minimize cost of production can be expressed as;

$\Delta C_i / \Delta P_i = X_{ie} (P, Y^*_i, \gamma)$ (7)

Hence, to optimise of profit, the rice farmer minimizes cost subject to optimum output. Following Gebretsadik (2017), the cost minimisation function is presented as;

Min $\sum C = \sum_{j=1}^{k} (X_j \; P_j)$ (8)

Subject to

$Y^*_i = \hat{A}\Pi X_j \beta j$ (9)

$\hat{A} = \text{Exp } \beta_0$ (10)

Substitute the expenditure function and the adjusted yield for stochastic error into the above minimisation function to derive the following;

$C \{Y^*_{i,} Y_i\} = H Y^{*u} \Pi_i P_i^{\&j}{}_i$ (11)

The explained cost measures allow to estimate the AE and EE thus, TE defined as the ratio of observed output (Yi) to the corresponding frontier output (Y*) presented as;

$TE_i = Y_i/Y^*_i = \sum_i X_{it}, P_i / \sum_i X_i, P_{ip}$ (12)

The EE is the ratio of the maximum costs adjusted or expenditure (C*) to the actual total cost of production or expenditure (C) presented as;

$EE = C^*/C = \sum X_{ie} P_i / \sum X_i P_i$ (13)

Thus, from equation 11 and 12 the AE can be deduced as the ratio of EE to TE expressed as;

$AE = EE/TE = \sum X_{ie} P_i / \sum_i X_{it}, P_i$ (14)

Furthermore, the likelihood ratio (LR) was conducted to test some hypotheses given as;

$LR = \lambda = -2\ln[L(H_0) / L(H_1)$ (15)

By the law of logarithm, the functional form becomes;

$LR = -2\ln[L(H_0) - L(H_1)]$ (16)

Where $L(H_0)$ is the value of log-likelihood function for the hull hypothesis, $L(H_1)$ is the value of log-likelihood for the alternative hypothesis.

3.8. Sources of inefficiency in rice farming

The socioeconomic characteristics as identified to affect the efficiency of rice farmers are age, level of education, experience, access to fertilizer, access to improved rice seed, and access to extension services. Thus, the inefficiency model estimated to identify the effect of the socioeconomic characteristics on the efficiency of rice farmers in Kano state for the 2018 rice cropping. The model specified by Coelli & Battese (1996) as;

$U = \delta_0 + \sum_{n=1}^{\infty} \delta_1 Z_1 + v$ (17)

Where: U = is random symmetric error term, Z_1 is the socioeconomic characteristics identify to cause inefficiency in rice farming. and V is the random symmetric error term. Furthermore, the U has asymmetric distribution equivalents to the chi-square distribution. The total variation from symmetric and asymmetric (δ_2), and the ratio of output that deviates from the maximum likelihood (γ) as presented by Aigner, Lovell, and Schmidt (1977) and Battese and Corra (1977) estimated as:

$$\delta_2 = \delta_{u^2} + \delta_{v^2} \quad (18)$$

$$\gamma = \delta_{u^2} / \delta_2 \quad (19)$$

$$\lambda = \delta_{u^2} / \delta_{v^2} \quad (20)$$

so that $0 \leq \gamma \geq 1$

where; δ_{u^2} is the variance of the error term due to technical inefficiency (showing how far is the observed output deviates from the maximum output), δ_{v^2} is the variance of the error term, δ_2 is the total variation of the output produced due to random shocks (δ_{v^2}) and the technical inefficiency (δ_{u^2}). γ is the amount of output lost from the maximum due to the technical inefficiency of the farmer. Further, γ lies between 0 and 1, if $\gamma = 0$, the production function signifies absence of U thus, all deviation from the frontier is due to noise. But when $\gamma = 1$, the production function implies all shortfalls from the frontier are caused by technical inefficiency.

4. Results and Discussions

4.1. Definition of explanatory variables and socioeconomic characteristics of the respondents

A summary of info on the sample respondents and variables used in the econometric analysis would be presented in this section. Following Melese *et al.* (2019), Ahmed *et al.* (2018), and Gebretsadik (2017), this study selects the socioeconomic characteristics of the sampled respondents in the study area, as presented in Table 2. The result of the socioeconomic characteristics (Table 2) shows that 55.3% of the respondents are within the age bracket of the active population (30 to 49) years and a prospect of (20.4%) good working population (20 to 29) years. Abdallah *et al.* (2019) reported that the age of a farmer significantly affect access to credit which permit access to modern farm input that increases output. Hence, productivity might be high in the study area. The result of educational qualification shows that 16.6% do not have western education, 55.3% have a low level of education, while 27.1% attained a higher education level. Abdallah (2016) reported that education is vital to productivity of farmers. But the result of qualification in the study area put some doubt on the possibility of high productivity by the rice farmers, because the low level of education may not necessarily positively affect productivity. Further, 78.7% spent six and above years in rice farming which is a sign of the possibility of high productivity while 21.3% spent one to five years in rice farming. Most of the rice farmers (61.9%) have access to nitrogen fertilizer and 76.7% have access to improved rice seed, indicating that productivity would high. But access to at least one extension visit is 47.7% which is low and can negatively affect the productivity of the rice farmers. As reported by Martey *et al.* (2019) and Abdallah (2016) that access to extension services increases productivity.

Table 2. Socioeconomic results of the respondents

Variable	Unit	Description	Mean	Std. Dev.
Age	Nominal	Number of years lived by the respondent: 0 if below 20 years; 1 if 20 – 29 years; 2 if 30 – 39 years; 3 if 40 – 49 years; 4 if 50 and above years	2.10	1.19
Qualification	Nominal	0 if respondent no formal education; 1 if respondent has primary education; 2 if respondent has secondary education; 3 if respondent has tertiary education	1.68	1.05
Experience	Nominal	Number of years spent in rice farming by the respondent: 0 if 1 – 5 years; 1 if 6 – 10 years; 2 if 11 and above years.	1.22	0.77
Access to fertilizer	Dummy	1 if respondent has access to fertilizer; 0 otherwise	0.62	0.48
Access to hybrid seed	Dummy	1 if respondent has access to seed; 0 otherwise	0.77	0.42
Access to extension visit	Dummy	1 if respondent has access to at least one extension visit; 0 if otherwise	0.48	0.50

Table 3 presents a summary of the cost of inputs in the production of rice in the study area. The average price of fertilizer for the acre of the rice field is N22,278.50, the average cost of improved rice seed for the acre is N13,855.12, and the average cost of renting an acre of the rice field is N1,165.03. Further, the average cost of labour required to cultivate the rice field is N3,791; the average cost of transportation incurred is N1,886.47 making a total sum of N42,992.93. Moreover, the average cost of producing an acre of the rice field is 42,992.93 in the study area.

Table 3. Description and summary of variables used in the production function

Variable	Unit	Description	Mean	Std. Dev.
Fertilizer	Kg	Amount spent on nitrogen used for rice production in 2018	22,278.50	6275.62
Seed	Kg	Amount spent on hybrid seed used for rice production in 2018	13,855.12	4,745.61
Farmland	Acre	Amount spent renting farmland used for rice production in 2018	1,165.03	353.99
Labour	Man-day	Amount spent hiring labour used for rice production in 2018	3,791.05	3,810.92
Transport	Naira	Amount spent involve transportation of rice produced in 2018	1,886.47	1,205.17
Total cost	Naira	On average, total amount spent in rice produced by a rice farmer in 2018	42,992.93	10,873.37

4.2. Econometric result

Diagnostic tests. The tests conducted for the study includes the heteroscedasticity, multi collinearity, and specification tests. The result presented in Table 4, shows that multi collinearity test by the VIF result is 1.21, which is less than ten. The result indicates that the data is normal, thus no multi collinearity problem. Further, the result of the Breusch-Pagan test shows that the data has no problem of heteroscedasticity. Also, the specification test indicates that the model is correctly specified, thus no issue of an omitted variable.

Production efficiency: The result of production efficiency in Table 4 shows that the error terms U and V were statistically significant at 1% level. Also, the value of gamma (ɣ = 2/2) is 0.9461 signifying that 94.61% variability attributed to the farmers' decisions in rice farming. The Cobb-Douglas stochastic frontier result of the maximum likelihood ratio shows that the elasticity of improved rice seed is positively significant at 1% level. Thus, a 1% increase in the use of hybrid rice would lead to an increase in rice output by 0.10% in the study area. Further, the elasticity of farm size is negatively insignificant, indicating a 1% increase in rice farmland would lead to a 0.052 decrease in rice output. The negative elasticity follows the finding of Yan *et al*., (2019). The likely reason could be the smaller farm holding by the rice farmers because banning rice import attract more people into rice farming. Thus, leading to farmland fragmentation as reported by Bhattacharyya & Mandal (2016). Also, the elasticity of fertilizer is negatively insignificant. The negative sign is in line with Dang (2017), who reported a negative effect of fertilizer on rice production. Part of the reasons could be that the rice farmers were using the nitrogen fertilizer contrary to technical specification. Because 52.3% of the respondents do not have access to at least one extension supervision in a rice season; thus leading to inappropriate use of nitrogen in the study area. Further, rice farmers who are familiar with traditional manure can apply the same quantity of nitrogen; contrary to the guidelines of nitrogen usage, leading to a decline in rice harvest. Thus, the need to regulate fertilizer management to increase yield (Guo *et al*., 2017).

The elasticity of rice production: The summation of production inputs' coefficients in Table 4 is 0.021, implying that 1% upsurge in inputs would concurrently lead to a 0.025% rise in rice yield. The result is far below compared to Gebretsadik (2017), Mekonnen *et al.* (2015), and Ibrahim *et al.* (2014); who reported a range of scale between 0.84% to 1.21%, hence, signifying poor efficiency in the use of inputs in the study area.

Table 4. Maximum likelihood result of the Cobb-Douglas frontier production function in Kano

	Coefficient	P-value	Std. Error
Constant	0.814***	8.22	0.0990073
Ln Farm size	-0.052	-1.02	0.0520673
Ln Fertilizer	-0.027	-0.46	0.058948
Ln Improved rice seed	0.100***	2.70	0.0372053
Total (elasticity)	0.021		
Total elasticity	0.021		
Wald chi^2 (3)	8.60	P = 0.0351	
Sigma u	0.375***	21.27	0.017
Sigma v	0.124***	15.89	0.007
Lambda	3.020***	146.99	0.020
Sigma^2	0.2886		
Gamma (ɣ)	0.9449		
Log likelihood	-200.5587		
hettest. Prob > chi2	0.7175		
Mean VIF	1.21		
Ovtest Prob > F	0.3419		

Note: *** significant at 1% level

The generalised likelihood ratio conducted to test some hypotheses and the results presented in Table 5. The first null hypothesis states that there is no inefficiency in the model. The LR test shows that there is inefficiency; therefore, the null hypothesis rejected. The second null hypothesis states that the inefficiency is non-stochastic. The LR test shows that the inefficiency is stochastic; thus, the null hypothesis rejected.

Table 5. Generalise likelihood ratio test of the efficiency in rice production

Null hypothesis	LR test	Critical value 5%	Decision
H_0: $\gamma = 0$ there is no inefficiency in the model	32.50	11.911	Reject H_0
H_0: $\delta_1 = \ldots = \delta_9 = 0$ the inefficiency is non stochastic	7.09	7.045	Reject H_0

4.3. Sources of technical inefficiency

The socioeconomic characteristics of the respondents possess the required sign though only two are significant. The coefficient of age is negatively significant at 5% level which conforms to Amaza *et al.* (2006) and Amaza & Olayemi (2002) who reported the age of a farmer is negatively significant. The result signifies that a unit increase in the age of a rice farmer would reduce technical inefficiency of rice farming by 0.09% in the study area. In other words, the age of the farmer increases the efficiency of rice production. Thus, as the age of farmer increases the technical inefficiency associated with rice farming decreases, due to acquired resources, skills, and credit worthiness. The coefficient of educational qualification, experience, access to fertilizer, access to hybrid rice, access to extension visits are negatively insignificant. The negative relation of education implies that an additional year of formal training would reduce the technical inefficiency of the rice farmer. Thus, the higher the qualification, the higher the technical efficiency as reported by Coelli & Battese (1996) and Shehu (2007). Higher training permits the rice farmer to appreciate and accept modern farming technologies.

The negative effect of experience is in line with Ahmadu & Erhabor (2012) and conform to a prior expectation that practice makes perfect. The more years spent in rice farming, the lesser the technical inefficiency. Also, the negative impact of access to fertilizer means that a unit increase access to nitrogen would reduce technical inefficiency in rice farming in the study area. The negative result conforms to a prior expectation because nitrogen usage positively affects rice production (Olarinre & Omonona, 2018). Further, the negative relation of access to hybrid rice means that a unit increase access to improved rice variety would reduce technical inefficiency of the rice farmer. The negative effect conforms to a prior expectation and in line with Ahmed *et al.* (2018). Similarly, the negative effect of access to at least one extension visit means that a unit increase to extension services offered to a farmer would reduce technical inefficiency of rice farming. The sign conforms to a prior expectation and in line with Ahmed *et al.* (2018). As farmers have access to extension advice, their understanding of modern farming improves, leading to a decrease in technical inefficiency.

Table 6. Results of the technical inefficiency model

	Coefficient	P-value	Std. Error
Constant	-0.3953***	-2.53	0.1561
Age	-0.0948**	-2.20	0.0430
Qualification	-0.0188	-0.40	0.0468
Experience	-0.0724	-1.09	0.0662
Access to fertilizer	-0.0616	-0.61	0.1050
Access to rice seed	-0.4907***	-4.67	0.4849
Access to extensions	-0.3953***	-4.61	0.1051

Similarly, Cobb-Douglas stochastic frontier results of maximum likelihood for the cost Table 5, shows that all the variable used in the model were positively significant at 1% level. The result indicates that a 1% increase in nitrogen fertilizer, hybrid rice, farmland, labour, and transport usage cost by 96%, 6%, 4%, 11%, and 0.06 respectively. Further, the result shows that there is a need to adjust the production process for that every input increases cost of production; leading to economic inefficiency in the study area. Thus, rice farmers need to minimize cost pf inputs to maximize profit.

Cost efficiency: The result of cost efficiency shows that the error terms U and V were statistically significant at 1% level. Also, the value of gamma (γ = 2 / 2) is 0.7410 signifying that 74.10% variability attributed to the farmers' decisions in rice farming. Further, all the variable inputs used in the cost function were positively significant at 1% level.

Table 7. Maximum likelihood results of the Cobb-Douglas frontier cost function in Kano

	Coefficient	P-value	Std. Deviation
Constant	-14.686***	-60.11	0.244
Ln Cost of fertilizer	0.967***	47.74	0.020

	Coefficient	P-value	Std. Deviation
Ln Cost of improved seed	0.462***	25.71	0.017
Ln Cost of land	0.048***	3.14	0.015
Ln Cost of labour	0.113***	22.81	0.004
Ln Cost of transport	0.061***	7.78	0.007
Total (elasticity)	1.651		
Wald chi^2 (5)	5904.53	P = 0.000	
Sigma u	0.0778***	7.58	0.0102
Sigma v	0.1197***	20.36	0.0058
Lambda	0.6498***	43.93	0.0147
Sigma^2	0.0399		
Gamma (γ)	0.7274		
Log likelihood	350.7899		

Note: *** significant at 1% level.

Table 8 presents the generalised likelihood ratio (LR) test conducted to test the following hypotheses; the first null hypothesis states that there no inefficiency in the stochastic cost model. The LR test shows that there is inefficiency; therefore, the null hypothesis rejected. The second null hypothesis states the inefficiency is non-stochastic. The LR test shows that the inefficiency is stochastic; thus, reject the null hypothesis.

Table 8. Generalise likelihood ratio test for the efficiency in cost of producing rice

Null hypothesis	LR test	Critical value 5%	Decision
H_0: $\gamma = 0$ there is no inefficiency in the model	12.46	11.91	Reject H_0
H_0: $\delta_1 = \ldots = \delta_9 = 0$ the inefficiency is non stochastic	1467.13	10.371	Reject H_0

4.4. Technical, allocative, and economic efficiencies estimate of rice farmers in Kano state

The estimated mean TE of a rice farmer in the study area is 71.60% level. The result implies that an average rice farmer in the study area could save inputs (land, fertilizer, improved variety) by 25.57% to meet the most efficient rice farmer. Also, the most inefficient rice farmer could save inputs by 54.89%. Thus, the result of TE shows that rice farmers in the study area can improve efficiency in rice production by technically identifying the combination of the inputs that produce the optimal output. Further, the result of the cost efficiency shows that the mean allocative efficiency is 92.6% level. The result signifies that an average rice farmer could save cost by 5.32% to meet the most efficient rice farmer in the study area. Also, the most inefficient rice farmer could save cost by 69.43%.

Furthermore, the average EE of an average rice farmer is 66.3%, implying that the farmer could save inputs worth of 29.54% to meet the most efficient counterpart in the study area. So, also the most inefficient rice farmer could save inputs worth of 86.18% in the study area. The economic performance of the most inefficient rice farmer in the study area requires attention because most of the farmers lack financial discipline and can further discourage rice production. Moreover, other people wishing to join the rice production may be discouraged.

Table 9. Results of TE, AE, and EE

Variable	TE	AE	EE
Mean	0.716	0.926	0.663
Minimum	0.434	0.299	0.130
Maximum	0.962	0.978	0 .941
Std. deviation	0.193	0.043	0.008

4.5. Sources of allocative inefficiency

Table 7 presents the socioeconomic characteristics of the respondents that cause allocative inefficiency; the only experience is positively significant at the 10% level in the study area. The positive relation implies that a 1% increase in years spent in rice farming would increase allocative inefficiency of rice farming by 0.15% in the study area. The result is contrary to a prior expectation that more years of rice farming reduces allocative inefficiency because practice makes perfect (Ahmadu & Erhabor, 2012). The possible explanation is that though there are more experience rice farmers (78.7%), it could be that it is on the use of local variety. Even though access to improved rice is high (76.7%), access to at least one extension visit is low (47.7%). It may be due to low level of education (55.3%) which may not necessarily affect efficiency positively.

The coefficient of qualification is positively insignificant signifying that additional formal training increases allocative inefficiency in the study area, which is contrary to prior expectation. The possible explanation is that most of the respondents (55.3%) attained a low level of education, while 16.6% has no formal education. The guidelines of using modern rice inputs are written in English, which most of the respondents do not fully understand even though some can read. Further, the coefficient of age is positively insignificant, implying that older rice farmers are inefficient in allocating rice inputs. The coefficient of access to fertilizer and hybrid rice is negative, which conforms to a prior expectation though insignificant. Access to nitrogen and improved variety permits rice farmers to buy the fertilizer that suits the rice variety at the right time and use the correct quantity, thereby, minimising costs of production. Also, the coefficient of access to extension visit is negative, which conforms to a prior expectation though insignificant. Further, access to extension advice by a rice farmer improves the rational of farmers in decision making in the use of modern inputs to optimise output and minimize costs of production.

Table 10. Result of the allocative inefficiency model

	Coefficient	**P-value**	**Std. Error**
Constant	-0.7621***	-3.76	0.2026
Age	0.0155	0.29	0.0535
Qualification	0.0089	0.16	0.0567
Experience	0.1497*	1.75	0.0857
Access to fertilizer	-0.0467	-0.37	0.1249
Access to rice seed	-0.0800	-0.53	0.1499
Access to extensions	-0.1048	-0.87	0.1209

Note: ***, * significant at 1% and 10% level respectively

5. Conclusions and recommendations

The results of the study show that the average rice farmer could economically save inputs worth of 29.54% to meet the most efficient counterpart in the study area. Further, the worst rice farmer in the study area could economically save the cost of inputs by 86.18% to meet the best counterpart. To attain the most economically efficient point of rice production in the study area, the quality of education requires overhauled. Though there is an improvement in primary and secondary enrolment, most secondary school graduates could not read and write in the study area, which poses a serious concern. The government should establish more schools (primary and secondary), construct more classes/lecture rooms to decongest pupils/students, provision of tables and chairs for pupils/students and teachers, provision of instructional materials. Also, the government should employ more qualified teachers at all levels and backed them with better remunerations.

The agricultural inputs' guidelines for usage especially pesticides/insecticides, fertilizer, and improved variety should have accompanied by a translated version into the three major Nigerian's languages (Hausa, Igbo, and Yoruba). The government, in collaboration with private, should provide more extension workers to increase access by the farmers. Further, the government should construct rural link roads to connect rice farmers with more markets/areas for a better price. The link roads would permit extension agents to have more access to rural farmers.

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