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Technical efficiency of rice farmers in Anambra State value chain development programme

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The study is aimed at determining the technical efficiency of rice farmers in Anambra State value chain development programme. A well-structured questionnaire was administered to elicit information from 372 rice farmers from the five participating Local Government Areas (Ayamelum, Awka North, Anambra West, Anambra East, and Orumba North) after which only 337 respondents were fit for the study. Cobb Douglas stochastic frontier model was used to ascertain the frontier line of the farmer's production potentials. The determinant of technical inefficiency was sex and farming experience. The findings revealed that the gamma value (0.0315) captures the variation in technical efficiency by farmers, therefore, about 3.15% variation is observed and frontier output is due to rice farmer's technical inefficiency effect. The study equally showed that the mean technical efficiency as predicted in the study was 84.76% implying that the farmers are operating 15.24% below their optimum production capacity. These, therefore, justify the need for policymakers to constantly organize training and sensitization workshops for the rice farmers in Anambra State and Nigeria at large paying particular attention to women farmers and the general farmer's farming experience which will help to tailor down training to specific needs.

Key words: Stochastic frontier, technical efficiency and inefficiency, return to scale, influence, utilization, sensitization.

INTRODUCTION

Nigerian agricultural sector is undergoing series of reformation that will help to bring about food security and stabilization in the country. Confirmation to this was the recent border closure by the Nigeria government aimed at spurring farmers especially rice farmers to increase production and equally force the consumers to demand more domestic food products. Rice botanically known as *Oriza sativa* is a tropical crop cultivated in almost all parts of Nigeria including Anambra State. Many rice small growers are resource-poor and cultivate about 0.5 and 3 ha. Rice is the main cereal crop, which is seriously affected by climatic factors (Abu et al*.,* 2017) even in Anambra State. It is one of the fastest-growing food commodities in Nigeria with a likelihood of continued growth; its increase in demand is associated with the rapid population growth, urbanization and consumer's

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preference for rice as convenience food (Akande, 2003; Obianefo et al., 2019; USDA, 2014).

Nigeria as a country is yet to attain self-sufficiency in rice production since demand is yet to equal supply (Nkwazema, 2016). Foyeku and Rice Millers, Importers and Distributors Association of Nigeria (2019) reported that Nigeria annual rice demand in 2018 was 7 million metric tonnes while only 56% of this demand was produced in Nigeria. Equally, the annual rice demand growth rate in Nigeria is 7.8% and the supply growth rate is 5.5% which leaves a deficit demand-supply gap of 2.3%.

Many researchers have reported that the problems hindering Nigeria from meeting local demand were low productivity, inefficiency in resource allocation, little or no access to improved varieties, and production in the hand of small scale out-growers who rely heavily on traditional technology (Oluwadamilola, 2018). Also, farmers are challenged by inadequate farm inputs like improved seeds, cost of agrochemicals, insufficient knowledge and information for best practices (Banful, 2011; Keelan et al., 2014). These farmers need to be abreast with the knowledge of efficiency in agricultural production especially in the area of resource allocation that will help to bring about increased agricultural productivity (Wategire and Ike, 2015). Corroboratively, researchers in Nigeria have argued that low productivity and high technical inefficiency are the major problems of rice production in Nigeria and Africa at large (Chaovanapoonphol et al., 2009). This suggests the need for farmers in Nigeria to be abreast with efficiency in resource allocation.

Though, input-output process in arable crop production is important in four major areas like; the distribution of farmer's income, allocation of farm input resources, the relation between stocks and flows, as well as the measurement of efficiency or productivity (Olayide and Heady, 1982; Nnamdi et al., 2016). Thus, an increasing rate of investment in agricultural production will correspond with increasing rate of returns with a high production efficiency (Assa et al., 2012). Hence, farmers input mix decisions on rice farming will affect their input-output processes and returns per hectare either positively or negatively depending on decision made.

This work was anchored on Aigner (1977)'s relative term technical efficiency which many researchers argued that technical efficiency is the ability of a farm to obtain maximum output from a given set of inputs under certain production technology. Identification of the technical efficiency level and the determinants of inefficiency effects will go a long way to assist the policymakers and other governmental and non-governmental agencies to tailor down training that will help the farmers optimize their production capacity to bring about self-sufficiency in rice supply in the country. Thus, the study specifically looked at the rice farmers' overall technical efficiency and inefficiency factors in Anambra State value chain development programme.

Concept of technical efficiency

Efficiency was described by Nnamdi et al. (2016) as the extent to which time, effort, or cost is well managed for an intended task or purpose; it also refers to the success of producing a large amount of output as possible given a set of input (Ajayi et al., 2018; Ohajianya et al., 2013b). Measuring efficiency is an important process because it is the first step in production that leads to substantial resource savings that have its implication for policy formulation and farm management (Amos, 2018). Aigner (1977) defined "efficiency" in three related terms: First, was technical efficiency" as the measure of a firm's success in producing maximum output from a given set of input; second, "price or allocative efficiency," which measures a firm's success in choosing an optimal set of input based on their relative prices. Khan et al. (2010) regarded it as the ability of a farm to use the inputs in optimal properties given their respective prices. The third is the "overall or economic efficiency," which is simply the product of both technical and price efficiencies.

Efficiency measurement is very important because it has a direct effect on productivity and economic growth; scholarly authors affirmed that efficiency study helps firms to determine the extent to which they can raise productivity, incomes, and profit by improving their efficiencies, with the existing resource base and the available technology (John et al., 2018). Insights into the distribution of technical efficiency and identification of important inefficiency factors on rice production cannot be overemphasized (Surendra, 2016). For farmers to maintain efficiency in rice production, their input allocation capacity, especially in seed, fertilizer, agrochemical, farm size and labour, must be built (Sani et al., 2010).

Researchers identified level of education, farm size, training, and extension contact as factors influencing the technical efficiency of Golda farmers in coastal areas of Bangladesh (Rahman et al., 2014), while other authors reported household size, age, farm size as the variables significantly impacting on technical efficiency (Piya et al., 2012); age, marital status, farming experience and level education were also reported by Ashagidigbi et al. (2011) as the inefficiency factors. Thus, the mean technical efficiency of rice farmers in Bangladesh was estimated at 0.80 and 0.75 in Thailand and 0.819 in Upper North Thailand (Abu et al., 2017; Mohammad et al., 2013; Chaovanapoonphol et al., 2009). Thus, Coelli (1996) proposed a formula for measuring these technical efficiency and inefficiency factors using the stochastic production frontier defined by:

$$Yi = f(X_i; \beta) \exp (V_i - U_i), i = 1, 2 \ldots.n$$

Where;

Yi is output of the ith farm or farmers
Xi is the vector of input quantities used by the ith farm
β is a vector of unknown parameters to be estimated.

The term V_i is a symmetric error, which accounted for random variations in rice output due to factors beyond the control of the farmer such as weather, measurements errors, disease outbreaks, among others (Nnamdi et al., 2016). This random error V_i is assumed to be identically and independently distributed as $N(0, \sigma^2 V)$ independent of the Ui's which are assumed to be non-negative truncations of the $N(0,\sigma^2)$ distribution representing technical inefficiency in rice production relative to the stochastic frontier. The error terms εi = (Vi-Ui) is the composed error terms, consisting of Vi, which is the two-sided error term while Ui is the one-sided error term (Osawe et al., 2018).

METHODOLOGY

Anambra state is located in the south-eastern part of Nigeria, and comprises of 21 Local Government Areas which include Aguata, Awka North, Awka South, Anambra East, Anambra West, Anaocha, Ayamelum, Dunukofia, Ekwusigo, Idemili North, Idemili South, Ihiala, Njikoka, Nnewi North, Nnewi South, Ogbaru, Onitsha North, Onitsha South, Orumba North, Orumba South and Oyi. The state is sub-divided into four (Onitsha, Aguata, Awka and Anambra) agricultural zones to aid planning and rural development. Its name is an anglicized version of the original Oma Mbala, the Igbo name of the Anambra River. The state administrative head quarter is in Awka (Obianefo et al., 2019b).

The state is bounded with Delta State to the West, Imo State and Rivers State to the South, Enugu State to the East, and Kogi State to the North. The indigenous ethnic groups in Anambra state comprised of 98% Igbo and 2% Igala mainly living in the north-western part of the state. Anambra East, West and Ayamelum (Anambra zone), Orumba North (Aguata zone) and Awka North (Awka zone) play a host community to the value development programme due to their comparative advantage in the rice and cassava production (FMARD, 2016). Anambra State is situated between Latitudes 5°32ˊ and 6°45ˊ N and Longitude 6°43ˊ and 7°22ˊ E. The State has an estimated land area of $4{,}865 sqkm^2$ with a population of 4,177828 people as at the last census (NPC, 2006). The State equally have an annual temperature and rainfall of 25.9^oC and 138 mm respectively (Retrieved March 14, 2020 from Anambra Climate Summary).

It is very important to bring to the public notice that value chain development programme activities in the 5 LGAs of operation include; farmers organization strengthening on good governance and business development, 50% input support to farmers, 70% support to farmers on farm machineries, contiguous land development to support mechanized agriculture, construction of farm access road, among others (Figure 1 and Table 1).

A multi-stage sampling technique was employed by the researcher for the selection of the study representative. In the first stage, the sample frame (5396) was obtained from the list of registered/participating rice farmers from the programme database in Anambra State. Taro Yamane (1967) sample size determination in Otabor and Obahiagbon (2016) was further used to calculate the sample size for the study as defined by;

$$n = \frac{N}{1 + N(e)^2}$$

Where:
N=population of the study, n=sample Size, (e) =margin of error, 1= unit (a constant), (e)=0.05.

$$n = \frac{5396}{1+5396(0.05)^2} = \frac{5396}{1+5396\ (0.0025)}$$
$$= \frac{5396}{1+13.49} = \frac{5396}{14.49}$$ =372.39 = approximately = 372 farmers.

In the second stage, the researcher adopted R. Kumaison formula to allocate sample stratum for the study; the R. Kumaison formula for stratum calculation is defined by:

$$i_{th} = \frac{n_i}{N} * n$$

Where;
n = total sample size, n_i = number of items in each stratum in the population, N = the population size in the strata, i_{th} = sample allocation.
Thus,

Ayamelum: $ith = \frac{2558}{5396} * 372 = 176$

Awka North; $ith = \frac{1066}{5396} * 372 = 73$

Anambra West; $ith = \frac{1027}{5396} * 372 = 71$

Anambra East; $ith = \frac{436}{5396} * 372 = 30$

Orumba North; $ith = \frac{309}{5396} * 372 = 21$

Finally, 7 villages make up a rice cluster in value chain programme and each village must have at least 3 rice farmers cooperative from which farmers were randomly selected based on the LGA stratum values as shown in Table 2 and a well-structured questionnaire was used to primarily collect data from a cross section of 372 out of which only 337 questionnaire was valid. Farmer's level of technical efficiency and determinants of inefficiency factors were analyzed using the stochastic production frontier defined by:

$Yi = f(X_i; \beta) \exp(V_i - U_i)$, i = 1, 2 ….n

Where;
Yi is output of the ith farm or farmers, Xi is the vector of input quantities used by the ith farm, β is a vector of unknown parameters to be estimated.
The technical efficiency of an individual farmer is defined in terms of the ratio of the observed output to the corresponding frontier output given the available technology as the defined by:

$$TE = \frac{Yi}{Yi^*} \frac{f(Xi,\beta)\exp(Vi-Ui)}{f(Xi,\beta)\exp(Vi)} = \exp(-Ui)$$

Where:
Yi is the observed output of rice and Yi* is the frontier output which the farmer is expected to attain given his/her input level. The parameters of the stochastic frontier production function are estimated using the maximum likelihood method. This stochastic production frontier function is empirically defined by:

$$LnY = \beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_5 LnX_5 + \beta_6 LnX_6 + (V_i - U_i)$$

Where Y is the output of rice in kg, X_1 = rice seed measured in kg, X_2 = Fertilizer used measured in kg, X_3 = Agro-chemical used measured in liter, X_4 = Farm size measured in hectare, X_5 = Labour measured in man-days, X_6 = Capital depreciation measured in Naira.

It is expected that all the included explanatory variables will have

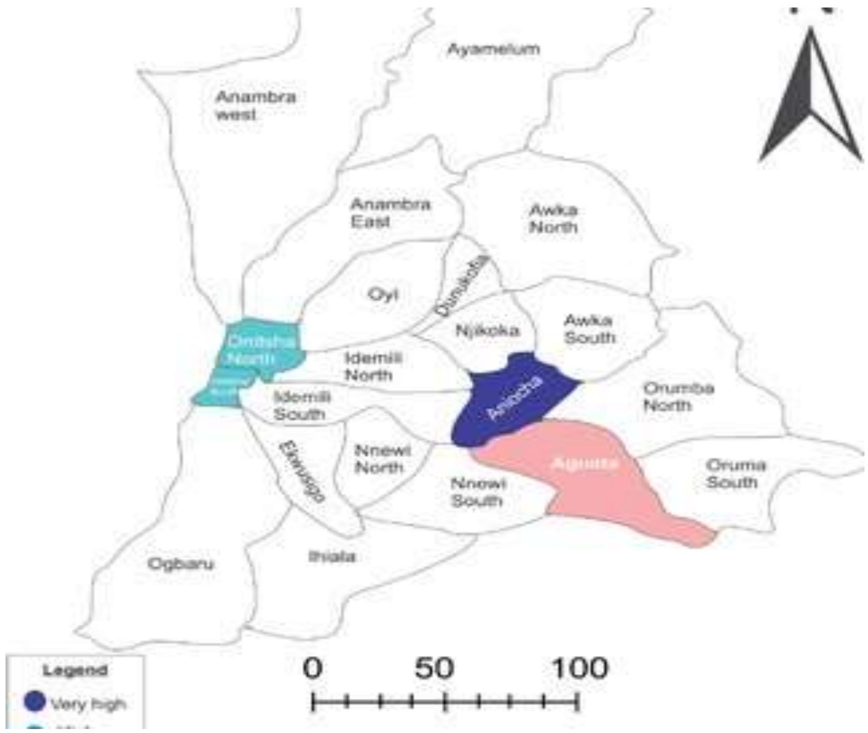

Figure 1. Map of Anambra State showing the areas of programme implementation.

Table 1. Coordinate of the participating local government area.

S/N	Local government	Coordinate
1	Awka North	6.2636° N 7.1252° E
2	Anambra East	6.3093° N 6.86375°E
3	Anambra West	6.4902°N 6.7922°E
4	Ayamelum	6.4878° N 6.9639°E
5	Orumba North	6.0543° N 7.2194°E

Table 2. Sample representation of rice farmers in the 5 local government areas.

S/N	Local government area	No of farmers	Sample size
1	Ayamelum	2558	176
2	Awka North	1066	73
3	Anambra East	436	30
4	Anambra West	1027	71
5	Orumba North	309	21
Total		5396	**372**

Source: Researcher's computation, December (2018).

a positive sign. Therefore, $\beta_0 > 0$; $\beta_1 > 0$; $\beta_2 > 0$; $\beta_3 > 0$; $\beta_4 > 0$; $\beta_5 > 0$ and $\beta_6 > 0$.

Vi and Ui remained as defined earlier. Furthermore, for the purpose of this study, Ui is assumed to follow a half normal distribution. Therefore, the farm specific efficiency is given as 1 – TE values (Assa et al., 2012). The determinants of technical inefficiency in rice production follow the model formulated and estimated jointly with the stochastic frontier model in a single stage maximum likelihood estimation procedure as described by (Coelli, 1996) and expressed as:

$$TIEi = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5$$

Where TIEi is the technical inefficiency of the i-th farm
Z_1 = Sex of farmers (dummy; "1" if male and "2" if female)
Z_2 = Age of the farmers measured in years
Z_3 = Level of education measured in years
Z_4 = Farming experience measured in years
Z_5 = Household size of farmers measured by number of persons in the household
It is expected that δ_1, δ_2, δ_3, δ_4 and δ_5 are negative

RESULTS AND DISCUSSION

Description the efficiency and inefficiency variables

Table 3 reflects the summary statistics of the sampled rice farmers, a typical rice farmer is 42 (42.26) years of age with 11 (11.13) years of formal education and household size of 9 (8.83) persons, 15 (15.41) years of farming experience, farm size of 2.41 ha, employed 126.46 man-days of labour and produced an output of 4.81 tons/ha.It is worthy to note that the average capital depreciation is ₦127,622.98 (USD 349.65 at ₦365 per USD 1), seed use is 119.42 kg, fertilizer is 727.45 kg, and agro-chemical is 4.72 L.

Factors of rice production in Anambra State value chain development programme.

Table 4 reflects the parameters and related statistical test results obtained from the stochastic frontier production function analysis using Maximum Likelihood Estimates (MLE). The functional parameters of maximum likelihood estimates has a sigma square (σ^2) value of 0.0669, significant at $p < 0.05$ critical level. The variance parameters (lamda), which showed the ratio of standard error {u (∂u)} to the standard error {v (∂v)} is 5.548479. Furthermore, the gamma ratio estimated from the sigma square value is 0.0315 and significant at $p < 0.05$ critical level. This gamma value is not up to 1.0 which is in agreement with Assa et al. (2012)'s postulation that a true gamma value should be less than 1.0 and significant. The value captures the variation in technical efficiency by farmers and about 3.15% variation is observed and frontier output are due to rice farmers technical inefficiencies. Gamma ratio according to Ogundari and Ojo (2006) in Nnamdi et al. (2016) is the relative magnitude of variance associated with inefficiency effect. Therefore, the goodness of fit and correctness of the specified assumptions of dominance of U on V can be ascertained provided the value is significantly different from zero (Ume and Ochiaka, 2016).

Apart from seed, other variables; fertilizer, agro-chemical, farm size, labour and capital depreciation were significant at either alpha level of 5 and 1%. Also, apart from seed and agro-chemical, other variables are in agreement with the *a priori* expectation. The coefficient of seed was negative and not significant at either 5% or 1% level of probability. Thus, increasing the quantity of seed does not guarantee an increase or decrease in rice yield. This finding is in agreement with Sani et al. (2010) in Resource-Use Efficiency in Rice Production under Small Scale Irrigation in Bunkure Local Government Area of Kano State.

The coefficient of fertilizer (0.0587001) was positive and significant at 5% level of probability; this implies that a unit increase in the quantity of fertilizer used by the farmers will equally increase rice output by 0.0587001 unit in the study area. This was expected by a priori expectation as fertilizer help to improve soil fertility and plant vegetation especially in grains production which rice belong. This is also in line with Md. Abu et al. (2017) on Rice farmers' technical efficiency under abiotic stresses in Bangladesh.

The coefficient of agro-chemical (0.1300962) was negative and significant at 1% level of probability. This implies that a unit increase in the number of farmers that wrongly apply agro-chemical will reduce the farmer's output by 0.1300962 units in the study area. This agrochemical is in the form of selective and non-selective. Therefore, wrong choice and application of these chemicals will adversely affect rice yield, this finding is in akin with Mohammad et al. (2013) in the assessment of technical efficiency of rice farmers in a selected Empoldered area of Bangladesh. The coefficient of farm size (1.050276) was positive and significant at 1% level of probability. This implies that a unit increase in the total number of hectares cultivated by the farmers will increase output or yield by 1.050276 units in the study area. This is justifiable as mechanization is easy to practice on contiguous land. This finding is equally in agreement with Sani et al. (2010) whose farmland was also significant at 1% level of probability in their study on Resource-Use Efficiency in Rice Production under Small Scale Irrigation in Bunkure Local Government Area of Kano State.

The coefficient of labour (0.1428544) was positive and significant at 1% level of probabilityl the implication is that a unit increase in the number of labour force supplied to the farm or an increase in the number of hours the labour force put into farming operation will increase rice output by 0.1428544 unit in the study area. This result is equally in agreement with Chaovanapoonphol et al. (2009) on the impact of agricultural loans on the technical efficiency of rice farmers in the Upper North of Thailand. The coefficient of depreciated capital (0.0199831) utilized by the farmers was positive and significant at 1% level of probability; this implies that an increase in the amount of capital equipment the farmers employ in rice farming operation will increase their rice output scope by 0.0199831 unit in the area. The model also show s an

Table 3. Description of input used by the rice farmers.

Variable	Description	Mean	Std. Dev.
	Socioeconomic		
Z_1	Age (years)	42.26	11.38
Z_2	Farming experience (years)	15.41	5.89
Z_3	Household size (No)	8.83	3.27
Z_4	Level of education (years)	11.13	4.40
	Input use		
Y	Output (ton)	4.81	0.51
X_1	Capital depreciation (₦)	127,622.98	2.33
X_2	Farm size (hectare)	2.41	0.55
X_3	Seed (kg)	119.42	0.55
X_4	Fertilizer (kg)	727.45	0.54
X_5	Agro chemical (liters)	4.72	0.56
X_6	Labour in man-days	126.46	0.46

Source: Field Survey Data (2019).

Table 4. Maximum likelihood estimates for the stochastic frontier production function of rice production.

Production variables	Model parameter	Estimates	SE	t-value
Constant	β_0	8.002606	0.3125609	25.60
Seed (kg)	β_1	-0.1112745	0.0762407	-1.46
Fertilizer (kg)	β_2	0.0587001**	0.0223661	2.62
Agro-chemical (lt)	β_3	-0.1300962***	0.0392855	-3.31
Farm size (ha)	β_4	1.050276***	0.0850059	12.36
Labour (man-day)	β_5	0.1428544***	0.0270535	5.28
Capital depreciation (₦)	β_6	0.0199831***	0.0045343	4.41
Return to scale		1.0304		
Diagnostic statistics				
Log likelihood function		173.454		
Sigma squared	δ^2	0.0669***	0.00036	
Gamma	Y	0.0315***	0.8376	
Lamda		5.548479***	0.0173795	319.26

*,Significant at 10%, **, Significant at 5% and ***, Significant at 1%.
Source: Field Survey Data (2019).

increasing return to scale of 1.0304 in rice production in the area. This implies that an increase in the use of aggregate farm inputs in rice production by 1 unit can give more than 1 unit of rice output in the area.

Technical efficiency of rice production in Anambra State value chain development programme

Table 5 reflect the mean technical efficiency of rice farmers, the predicted technical efficiency is 0.8476, implying that, on average, the technical efficiency of the farmers in the area is about 84.76%. This suggests that rice farmers can still optimize or increase their output by 15.24%. This finding is in akin with the study of Abu et al. (2017) on rice farmers' technical efficiency under abiotic stresses in Bangladesh. This value ranges from a minimum efficiency level of 23.76% to a maximum efficiency level of 97.70% in the area. The researcher could deduce from this result that there is a wide disparity in farmers' technical efficiencies suggesting the need to bridge their technical efficiencies.

Cumulatively, many (31.2%) farmers are found below the overall mean technical efficiency. For 68.8% are above the overall mean technically efficiency in the area. This shows that with efforts made by the programme implementing unit and the farmers toward efficient technology use in rice production, high technical efficiency will be maintained in a long run to enhance output.

Table 5. Distribution of farmers according to their technical efficiency level.

Technical efficiency limit	Frequency		Percentage (%)
Technical efficiency $\leq$ 25	2		0.6
25 – 54	6		1.8
55 – 84	97		28.8
Technical efficiency > 84	232		68.8
Total	337		100.0
Mean technical efficiency		84.7	
Minimum efficiency		23.7	
Maximum efficiency		97.6	

Source: Field Survey Data (2019).

Table 6. Determinants of Technical Inefficiency in rice Production in Anambra State value chain development programme.

Inefficiency effect	Parameter	Estimates	SE	t-value
Constant	δ_1	0.2129465	0.0415732	5.12
Sex	δ_0	-0.0399863***	0.0122338	-3.27
Age	δ_2	-0.0001788	0.000687	-0.26
Education	δ_3	-0.0002355	0.0014965	-0.16
Experience	δ_4	-0.0021556**	0.0011845	-1.82
Household size	δ_5	-0.0021433	0.0019869	-1.08

*,Significant at 10%, **, Significant at 5% and ***, Significant at 1%.
Source: Field Survey Data (2019).

Determinant of technical inefficiency of rice production in Anambra State value chain development programme

Table 6 reflect the technical inefficiency model, this variables show the influence exerted upon farmer's ability to optimally utilize production input which is termed technical inefficiency. The variable with a negative sign is the one contributing to the technical efficiency of input use while those with a positive sign are the major contributors to technical inefficiency of input utilization. Thus, the coefficient of sex, age, experience, level of education and household size are the variable contributing to the technical efficiency of rice production in the study area. The coefficient of age, level of education and household size were not statistically significant at 10, 5 or 1% alpha level of probability.The predictive value of sex was negative and significant at 1% level of probability; this implies that an increase in the number of female rice farmers participating in the programme will reduce technical inefficiency by 0.0399863 unit (4%). This indicates that female rice farmers are technically efficient than their male counterpart. Rice production is time consuming especially during the bird-scaring stage of the production, at this stage, only women can exercise such needed patient to scare bird for 21 days. This finding is also in line with the *a priori* expectation. The coefficient of farming experience was negative and significant at 5% level of probability, suggesting that a unit increase in the number of farmers that are experienced in rice farming practice will reduce technical inefficiency of rice output by 0.0021556 unit in the area. This is in akin with MAbu et al. (2017) on rice farmers' technical efficiency under abiotic stresses in Bangladesh, and consistent with the a priori expectation.

Conclusion

The study on technical efficiency of rice farmers in Anambra State value Chain Development Programme is very important at this time Nigeria as a nation is struggling to attain self-sufficiency in rice supply; over many years now, demand has always grown above supply trend. Though, this demand deficit has been linked to explosive population growth on an annual base. Self-sufficiency in rice production and supply is likely to remain a mirage if farmers' input utilization pattern is not constantly under check to enable the policymaker's easy identification of the area that needs to be worked upon. Thus, the need for this study at this very time Nigeria as a country is struggling to attain self-sufficiency in rising supply cannot be overemphasized. The study through the predicted mean technical efficiency of 84.67% revealed that a good number of the farmers are producing 15.25% below their optimum capacity and/ or potentials. Also, the study has been able to establish that sex and farming experience of the farmers are the major determinant of technical inefficiency in the study area. Therefore, value chain development programme should put in more effort to encourage women's participation especially the experienced ones, since the programme will help to change farmer's conventional ideology on rice production. Importantly, agricultural programs should target more youths for sustainability sake.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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