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Full Length Research Paper

Towards rice self sufficiency in Nigeria: an analysis of technical efficiency of irrigated rice farms in Kebbi State

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The study investigates technical efficiency of irrigated rice farmers in Kebbi State. Data from a total of 240 rice farmers were collected using multi-stage and simple random sampling procedures with the aid of structured questionnaire. The study employed descriptive statistics and a trans-log stochastic frontier production model in describing and analyzing the data. The results revealed that output is positively influenced by seed (0.456), herbicide (0.145) and labour (0.094). It was also revealed that education, farming experience, extension visit, credit access, seed variety and harvesting technology significantly reduces the technical inefficiency of producers. The mean technical efficiency of rice farms was 86.1% indicating that losses of rice output exist by 13.9% is due to inefficiency attributed to the farmers in the study area. It is concluded that farmers in the study area possesses inefficiency levels in their resource use, therefore, recommended that farmers should be encouraged to join cooperative society and extension services agents should intensify their efforts in training and mobilizing farmers for improved production practices of rice.

Keywords: Analysis, technical efficiency, irrigated, rice farms, stochastic frontier

INTRODUCTION

The Nigerian rice sector is special within the West Africa context. Principally, rice is a cash crop in Nigeria produced primarily for the market. Hence, in rice producing areas, the enterprise provides employment for more than 80% of the inhabitants in various activities along the production/distribution chain from cultivation to consumption. Rice is now a structural component of the Nigerian diet and rice imports make an important share of Nigerian agricultural imports with considerable political interest in increasing the consumption of local rice Olorunfemi and Victor, (2006). Despite the fact that domestic rice production has increased in Nigeria since 1960s, given increases in rice land area, rice production has not been able to keep pace with rice consumption (demand). Nigeria's inability to meet her rice consumption needs through local production has resulted in high cash outlays for importation. While progress has been made in increasing the hectares of land under rice cultivation, apparent declines in rice yield within the period has offset the gains in the harvest area. However, given the natural endowment of land, labour, available technologies, human and material resources, Nigeria should be self-sufficient in rice production. This will however depend on a sustained efficient use of production resources at the farm level. Regardless of the importance of Nigerian rice production even within the West African sub region, comprehensive and up-to-date information about the level of resource use efficiencies of the farmers in the study area is still lacking. Most of these studies focused primarily on the profitability of the enterprise, without indepth enquiry into efficiencies of farmers and factors that determine their levels of inefficiency. To address that gap, this study was designed to determine technical efficiency in rice production in Kebbi State.

The crucial role of efficiency in increasing agricultural output has been widely recognized by researchers and policy makers alike. It is no surprise therefore, that considerable effort has been devoted to the analysis of farm level efficiency in developing countries, Nigeria inclusive. An underlying premise behind much of this work is that if farmers were not making efficient use of existing technology, then efforts designed to improve efficiency would be more cost effective than introducing new technologies as a means of increasing agricultural output (Belbase and Grabowski, 1985). The efficiency of a farm/firm refers to its success in producing as large amount of output as possible given a set of inputs. To determine the efficiency of a particular firm, there is need for efficiency measurement through the production factor inputs and processes. This (efficiency measurement) has received considerable attention from both theoretical and applied economists. From a theoretical point of view, there has been a spirited exchange about their relative importance of the various components of firm efficiency (Leibenstein, 1996; 1978 and Comanor and Leibenstein, 1969). From an applied perspective, measuring efficiency is important because this is the first step in a process that might lead to substantial resource savings, these resource savings have important implications for both policy formulations and firm management (Bravo-Ureta and Rieger, 1991).

Farrell, (1957) proposed an approach that distinguishes between technical and allocative efficiency. Technical efficiency refers to the ability of producing a given level of output with a minimum quantity of inputs under a given technology. Allocative efficiency refers to the choice of the optimal input proportions given relative prices. Economic or total efficiency is the product of technical and allocative efficiency. Farrell's model, which is known as a deterministic nonparametric frontier (Forsund et al., 1980), attributes any deviation from the frontier to inefficiency and imposes no functional form on the data. Several extensions of Farrell deterministic model have been made by Economists such as Aigner and Chu (1968), Afriat (1972), Richmond, (1974), Schmidt (1976) and Greene, (1980) among others.

A deficiency characterizing all deterministic frontier models is their sensitivity to extreme observations. A more recent approach for measuring efficiency, which seeks to ameliorate the extreme observation problem, is the stochastic frontier model developed by Aigner et al. (1977) and by Meeusen and Van den Broeck, (1977). The stochastic frontier model assumes an error term with two additive components a symmetric component that accounts for pure random factors, and a one-sided component which captures the effects of inefficiency relative to the stochastic frontier. Thus, the main focus of this study was to determine the levels of technical efficiency for a sample of rice farmers in Kebbi State, Nigeria and explain those factors that determine their levels of technical inefficiency.

METHODOLGY

Study area

The study area is Kebbi State, Nigeria. The area is located approximately within latitudes 10° and 13N, and longitudes 30 and 70E. It has estimated population of about 3,351,831 million people as at 2006 (NPC, 2006) and projected population in 2015 is 3,998,067 people. It is bounded by Niger and Benin Republic in the West, Sokoto State in the East and Niger State in the South. The State comprise of 21 Local Government Areas that make four Emirates: Gwandu, Argungu, Zuru and Yauri. The major ethnic groups in the State are Hausa, Fulani, Dakarkari, Kambari, Zabarmawa, Gungawa, Fakkawa and Dukkawa. The vegetation is broadly classified as Savannah. Farming is generally subsistence to commercial producing wide varieties of rain fed and irrigated food crops such as Millet, Sorghum, Cowpeas, Groundnut, Maize, Acha, Onions, Rice, Tomatoes and other Vegetables. Other economic tree crops grown are Gum Arabic, Shea nut, Cashew, Mangoes and other tropical fruit trees. Animal rearing features prominently as means of livelihood to many homes in the State.

Data collection

Data was collected from the rice farmers through a structured questionnaire administered by trained enumerators. Information on socio-economic characteristics of rice producing households such as age, marital status, gender, household size, farming experience, level of education, extension contacts and access to credit and agrochemicals used was collected. The input-output data such as quantity and cost of various rice production inputs, quantity of output obtained and the price of output, other information includes number of farms and their sizes, land cultivation method, seed variety used, planting method, harvesting method and other relevant information.

Sampling techniques and sample size

The study employed a multi-stage and simple random sampling procedures in arriving at the sample size for the study. At the first stage, contact was made with the Kebbi State Agricultural and Rural Development Authority (KARDA) and Ministry of Agriculture and Natural Resources (MOANR) Kebbi State and a comprehensive list of all rice producing local government areas was obtained. At the second stage, out of the list obtained, a purposive selection of eight most predominant rice producing local government areas in the State was made. The third stage involved random selection of three rice producing villages in each of the selected local government area making a total of 24 villages. The fourth and final stage was the random selection of 10 rice producing households from each of the selected village making a total of 240 rice producing households used as sample size for the study.

Data analysis

The data collected was subjected to descriptive statistics in the form of frequencies and percentages to describe the socio-economic characteristics of the respondents. A stochastic frontier production technique was used by employing frontier 4.1 version in the analyzing mean production, technical efficiency scores and determinants of technical inefficiency.

Theoretical framework

A stochastic frontier analysis which requires a parametric representation of the production technology was employed in the research. In addition, it incorporates stochastic output variability by means of a two-part error term. This approach was pioneered independently by Aigner et al. (1977) and Meeusen and Van den Broeck, (1977). The general notation of the model is as follows:

$$y_i = h(x_i;\ \alpha)\exp(\varepsilon_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: y_i is output of producer i (bounded above by the stochastic component $h(x_i;\ \alpha)\exp(\varepsilon_i)$, x_i is vector of inputs used by producer i, α is a vector of unknown technology parameters, $h(x_i;\ \alpha)$ is production frontier. The composed error term is $\varepsilon_i = v_i - u_i$. Where v_i captures the effect of pure noise in the data attributed to measurement error, extreme weather conditions etc and u_i is one-sided error that captures the inefficiency effects. The symmetric element v_i account for random variation in output quantity attributed to factors outside farmer`s control e.g. disease and weather while $u_i$ account for random variation in output quantity attributed to factors under farmer`s control. A one-sided component $u_i \leq 0$ reflects technical inefficiency relative to stochastic frontier. Thus $u_i = 0$ for farm output that lie on the frontier (100% technical efficiency in resource use) and $u_i < 0$ for farm output below the frontier as $N(\delta_u^2, v)$.

Empirical model specification

To any empirical research, the decision to select a functional form is very important because the selected functional form can significantly affects the parameter estimates (Kebede, 2001). The most two common functional forms of stochastic frontier model generally used are: Cobb-Douglas and Trans-log functional forms. Cobb-Douglas functional form is very easy to adopt but it imposes a severe restriction on production elasticity to be constant and the elasticity of input substitution to be unitary. On the other hand, Trans-log functional form is known to be less restrictive, permitting for the combination of squared and cross product terms of the exogenous variables with the view of having goodness of fit of the model. Thus, the study used trans-log production function model in its estimation.

Mean production function specification

This research employed trans-log stochastic production function model specified as follows:

$$Iny_j = \alpha_0 + \sum_{i=1}^{n} \alpha_i Inx_i + \frac{1}{2}\sum_{i=1}^{n} \alpha_{ii} Inx_i^2 + \sum_{i=1}^{n}\sum_{k=1}^{k} \alpha_{ik} Inx_i Inx_k + \varepsilon_j$$

Where: y_j is output of producer j, x_i is vector of inputs used by producer j, α0, αi, αii and αik is a vector of unknown technology parameters to be estimated, j is j-th farmer where j = 1, 2, 3, ..., 240 and i is i-th input where i = 1, 2, ..., 4 that consist of seed, fertilizer, herbicide and labour. The composed error term is $\varepsilon_j = v_i - u_i$. Where v_i captures the effect of pure noise in the data attributed to measurement error, extreme weather conditions etc. and u_i is one-sided error that captures the inefficiency effects.

Inefficiency model specification

Following the specification in equation above, the linear technical inefficiency model is specified as follows:

$$u_i = \delta_0 + \sum_{r=1}^{11} \delta_r w_{ri}$$

where Ui`s are inefficiency effects, δo and δr`s are estimated coefficients of technical inefficiency model and wr`s are vectors of i producer technological/socioeconomic variables that consists of age, education, marital status, household size, farming experience, extension contact, credit access, planting technology, seed variety, agrochemical technology used and harvesting technology.

Table 1. Distribution of socio-economic characteristics of rice farmers.

Variable	Frequency	Percentage
Gender		
Male	207	86.25
Female	33	13.75
Marital Status		
Married	176	73.34
Single	42	17.50
Divorce	14	5.83
Widow/Widower	8	3.33
Age (Years)		
20 – 30	29	12.08
31 – 40	73	30.42
41 – 50	111	46.25
> 50	27	11.25
Level of Education (Years)		
< 6 years	52	21.67
6 years	94	39.17
12 years	76	31.67
> 12 years	18	7.50
Farming Experience (Years)		
1 – 5 years	131	54.58
6 – 10 years	87	36.25
> 10 years	22	9.17
Household Size (Number)		
1 – 5	41	17.08
6 – 10	151	62.92
> 10	48	20.00
Extension Contact (Number)		
No contact	146	60.83
1-2 contacts	79	32.92
3 and above contacts	15	6.25

Source: field survey, 2019

RESULTS AND DISCUSSION

Socio-economic characteristics of rice farmers

The average age of rice farmers was estimated to be 44 years (Table 1). As revealed, the average age is tending towards the declining productivity class of greater than 50 years. The implication with present situation is that unless the enterprise witnesses the injection of young able farmers in the next decade, rice production in the study area will suffer a setback as the existing farmers would have reached the declining productivity level. Olorunfemi and Victor, (2006) reported that most of the farm operations in rice cultivation, such as land clearing, tilling, weeding and harvesting, require a lot of strength and energy. Thus, only those farmers within the productive age group of 20–45 years are likely to possess the necessary strength to carry out these operations. Therefore, with farmer's age, there is a tendency that productivity will continue to fall due to their declining strength. Education plays a significant role in skill acquisition and technology transfer. It enhances technology adoption and the ability of farmers to plan and take risks. Farmers with higher levels of education are likely to be more efficient in the use of inputs than their counterparts with little or no education. The results on the level of education of rice farmers displayed in (Table 1) show that majority of the farmers did not complete secondary school education. Many of them did not go beyond primary school, while a few who attempted secondary education did not complete. The average years of schooling of the farmers were nine years. This low level of education no doubt affects the level of technology adoption and skill acquisition. It may also constitute a block to the effectiveness of extension activities.

The average number of rice farmers related extension visits during the cropping season the result is as shown in (Table 1). The three visits recorded during the cropping season by the farmers is an indication of the deliberate attempt by the government to promote new technologies in the study area. Experience is the best teacher. Thus, the longer a person stays on a job, the more likely the person is to become an expert. Farming involves a lot of risks and uncertainties; hence, to be competent enough to handle all the vagaries of farming, a farmer must have

Table 2. Maximum likelihood estimates of frontier production function model.

Variable	Parameter	Coefficient	Std. Error	T-Value
Constant	$\alpha0$	0.212	0.049	4.32***
Seed	$\alpha1$	0.456	0.121	3.77***
Fertilizer	$\alpha2$	0.0394	0.073	0.541
Herbicide	$\alpha3$	0.145	0.052	2.791**
Labour	$\alpha4$	0.094	0.046	2.036**
½*(Seed)2	$\alpha11$	-0.079	0.101	-0.783
½*(Fertilizer)2	$\alpha22$	-0.096	0.039	-2.461**
½*(Agrochemicals)2	$\alpha33$	0.207	0.402	0.514
½*(Labour)2	$\alpha44$	0.137	0.069	1.991**
Seed*Fertilizer	$\alpha12$	0.068	0.034	0.220
Seed*Agrochemicals	$\alpha13$	0.047	0.039	1.193
Seed*Labour	$\alpha14$	0.042	0.031	1.364
Fertilizer*Agrochemical	$\alpha23$	0.424	0.206	2.057**
Fertilizer*Labour	$\alpha24$	0.358	0.063	5.681***
Agrochemicals*Labour	$\alpha34$	0.317	0.336	0.942
Variance Parameters				
Sigma-Squared(u)		0.0611		
Sigma-Squared(v)		0.0305		
Lambda(λ) = (δu/δv)		2.003		
Sigma2 (δu2)		0.0037		
Gamma (γ) = (λ2/(1+λ2))		0.8001		

Source: Field survey, 2019
Note: ** and *** denote significance at 5% and 1% level respectively.

stayed on the farm for quite some time. A farmer who has been growing rice for, say, 10 years is likely to be more knowledgeable about the pattern of rainfall, the incidence of pest and diseases, and other agronomic conditions of the area than a farmer who is just coming into the business irrespective of their level of education. It is obvious from (Table 1) that the farmers in the study area have a level of farming experience with an average of 8 years. Household size plays a significant role in subsistence farming in Nigeria where farmers rely on household members for the supply of about 80% of the farm labour requirement. This is particularly so, in view of the increasing cost of hired labour and the inability of the farmers to make use of improved mechanical tools either due to high cost or relative smallness of farm sizes. In this regard, it has been observed Olorunfemi and Victor, (2006) that the impact of household size on productivity depends on the quality and capabilities of the household members, rather than on the sheer magnitude of the household size. From Table 1, the farmers had larger households at an average size of 8. As shown earlier, however, this average larger size does not translate to higher use of family labour. This may result from the fact that with higher output and income they can afford to send their children to school, thereby reducing the number of hands available on the farm, or it may be that many of the household members are dependents.

Maximum likelihood estimates for mean production function model

From the estimates of the stochastic frontier production in (Table 2), the variance parameters sigma square (δ^2) and lambda $\lambda = \delta_u/\delta_v$ are 0.0611 and 2.003 respectively and is significantly different from zero thus indicates a good fit of the model and the correctness of the specified distributional assumptions. The lambda value greater than zero further indicate that the variation in the observed output from the frontier output is due to technical inefficiency and random noise. Moreover, the result reveals that the variation in the output explained by technical inefficiency is relatively greater than the deviation in output explained by the pure noise component of the composed error term. Gamma (λ) is a parameter in the variance parameters that indicate a measure of the level of the inefficiency in the variance parameter and is estimated to be 0.8001 and is significant at 1% which implies that 80.01% of the total variations in the rice output in the study area are due to technical inefficiency.

Table 2 indicates that seed, herbicide and labour contributed significantly to the mean output of the farmers. The coefficients of seed, herbicide and labour were 0.456, 0.145 and 0.094 were all positive Significant at 1 and 5% respectively. The positive coefficients indicate that as the value of the independent variable increases, the mean of the dependent variable also tends to increase. This implies that if one unit of predictor variable (seed) is increased by 0.456 units while holding other predictors in the model constant there will be a corresponding increase in mean output by 0.456 units. Similarly for predictor variables herbicide and labour, an increase in herbicide by 0.145 holding other predictors

Table 3. Maximum likelihood estimates for parameters of inefficiency effects model.

Variable	Parameter	Coefficient	Std. Error	T - Value
Constant	$\delta 0$	-3.484	1.160	-3.003***
Age	$\delta 1$	0.549	0.110	4.990***
Education	$\delta 2$	-0.018	0.007	-2.529**
Marital Status	$\delta 3$	0.739	1.123	0.658
Household Size	$\delta 4$	0.045	0.048	0.929
Farming Experience	$\delta 5$	-0.015	0.008	-1.876*
Extension Visit	$\delta 6$	-0.036	0.012	-3.000***
Credit Access	$\delta 7$	-2.481	1.199	-2.069**
Planting Tech.	$\delta 8$	-0.177	0.233	-0.758
Seed Variety	$\delta 9$	-0.541	0.207	-2.614**
Agrochemicals Tech use	$\delta 10$	-1.550	2.331	-0.665
Harvesting Tech.	$\delta 11$	-0.010	0.005	-2.012**

Source: Field survey, 2019
Note: *, ** and *** denote significance at 10% and 5% and 1% level respectively.

variable constant will lead to an increase in mean output by 0.145. Furthermore increasing labour by 0.094 holding other predictors variable constant will result in an increase in mean output by 0.094. It was also observed that fertilizer, which is the most critical input in rice cultivation, was not significant. This underscores the low use of the input as a result of the erratic supply occasioned by continuous fertilizer subsidies.

Estimates for parameters of the inefficiency effects model

The inefficiency parameters were specified as those relating to farmers` specific socio-economic characteristics, institutional and technological factors. Eight out of eleven variables used in the model have expected signs and six of them are significant. A negative coefficient indicates that the variable increases the efficiency (reduces inefficiency) in rice production and vice versa. The results of the technical inefficiency effects presented in (Table 3) shows that technical inefficiency is reduced significantly with education, farming experience, extension visit and access to credit. Similarly, broadcasting technology, application of agrochemicals and harvesting technology had a negative effect on technical inefficiency. From the estimates age positively affect technical inefficiency, implying that farmers who are older are more inefficient (less efficient). This could be possible as ageing farmers are less energetic to work on farm and may likely lower their technical efficiency. It is also possible that older farmers could be more traditional and conservative and therefore show less willingness to adopt new practices. Villano and Fleming, (2006) argue that the influence of age on technical efficiency is relative to the empirical data being analysed. Age can only influence technical efficiency positively if the older farmers gain experience to know the best practices. On the other way, age can influence technical efficiency negatively if the farmers are unwilling to take risk to adopt the best farm practices. However, the finding is consistent with study of Ogundari, (2008). Experience is the best teacher. Farming involves a lot of risks and uncertainties; hence, to be competent enough to handle all the unexpected changes of farming, a farmer must have stayed on the farm for quite some time. A farmer who has been growing rice for many years is likely to be more knowledgeable about the pattern of incidence of pest and diseases and other agronomic conditions of the area than a farmer who is just coming into the business. Result of the analysis revealed that experience negatively relates with technical inefficiency meaning that the more farmer become more experience the less inefficiency. The finding is consistence with the findings of Ogundari and Akinbogun, (2010) and Alam et al. (2011).

The coefficient of household size is positive. This signifies that as the household size increases farmers' technical inefficiency increases. This agrees with Okike, (2000) and Yusuf and Malomo, (2007) where they reported that family size have a negative influence on famers productivity. In a situation where the family size is large and only a small proportion of farm labour is derived from it, then the inefficiency effect are expected to be greater. The coefficient of education was negative. This by implication implies that higher level of education increase farmers` chances of using improved and sophisticated technology and techniques which requires training and reading manuals and has attendance increase in yield and optimum use of inputs resources. This result is consistence with the findings of (Amaza and Maurice, (2005); Muhammad-Lawal et al. (2009) and Oladimeji and Abdulsalam, (2013). The estimated coefficient of farmer`s access to credit was negatively related to technical inefficiency. This implies that the use of credit could decrease the inefficiency effect to production. The result is in agreement with finding of Bravo-Ureta and Pinheiro, (1993) and Mailena et al. (2014).

Table 4. Frequency distribution of technical efficiency scores among rice farmers.

Range of TE Scores	Frequency	Percentage
40 < 50	16	6.67
50 < 60	21	8.75
60 < 70	27	11.25
70 < 80	64	26.67
80 < 90	82	34.16
90 < 100	30	12.50
Total	240	100.00
Mean	0.861	
Minimum	0.389	
Maximum	0.967	
Standard Deviation	0.317	

Source: Field survey, 2019.

Extension agents are supposed to provide advisory services and training of farmers to improve upon their efficiency. According to the result in (Table 3), the coefficient of extension visit negatively relates with inefficiency and by implication it means that the more the farmer acquired knowledge from the extension services the more the farmer become less inefficient. According to Al-hassan, (2008) extension visits to farmers enable them to use recommended cultural practices in a production to improve upon their efficiency. The observed result is consistence with the finding of Ghee-Thean et al. (2012). Planting method captures whether a farmer employed broadcasting or transplanting method for the production. From the result farmers who adopted broadcasting method are less inefficient compared to those who use transplanting method. The estimated parameter reveals that planting method negatively relate with farmers inefficiency. This indicates that planting method employed by the farmers (broadcasting) reduces inefficiency compared to transplanting means of planting. On the other hand, improve or traditional seed variety used by the producers influences their efficiency. The finding shows that improve variety reduce inefficiency compared to traditional variety. The parameter coefficient is significant at 5% and negatively related to inefficiency. The analysis on agrochemicals usage by the producers reveals that agrochemical increases the efficiency of the farms as it has negative relationship with inefficiency. Furthermore, result from the harvesting method employed reveals that farmers harvesting with machine were more efficient than those who did manual harvesting. The coefficient of the parameter is significant at 5% and negatively related with inefficiency.

Estimates of technical efficiency scores among rice farmers

The frequency distribution of technical efficiency presented in (Table 4) shows that about 73.33% of the rice farmers had technical efficiencies score above 70% which indicates that there is very little opportunity to increase technical efficiency among these rice farmers. In fact, the average technical efficiency of 86.10% shows that given the level of technology of these farmers little can be done to increase their production capacity.

Conclusion

A production function was estimated by maximum likelihood estimation method (MLE). The results revealed that technical efficiency of rice farmers varied due to the presence of technical inefficiency effects in the production process. Seed, labour and herbicide were found to be the significant production factors which accounted for variations in the output of rice. The overall distributions of the technical efficiency scores revealed that majority of the farmers were technically efficient. The results of the inefficiency model indicated that education level, farming experience, access to credit and extension contacts significantly decreased the farmers' technical inefficiency. The study revealed that rice farmers were not fully technically efficient and therefore there is potential of increasing their rice output through improving efficiency level by addressing some important socioeconomics variables that could negatively and positively influence farmers' technical efficiency in the area.

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Authors' declaration

We declared that this study is an original research by our research team and we agree to publish it in the journal.

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