American-Eurasian J. Agric. & Environ. Sci., 12 (12): 1610-1616, 2012
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2012.12.12.1918

Estimation of Technical Efficiency of Irrigated Rice Farmers in Niger State, Nigeria

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Abstract: The study estimated the technical efficiency of irrigated rice farmers in Niger State of Nigeria. A multi-stage sampling technique was employed for the selection of respondents for the study. A total of 60 respondents selected at random from the study area were administered structured pre-tested questionnaires. Data analysis was done using descriptive statistics, stochastic frontier production function and inefficiency model. The results showed that the irrigated rice production in the study area was practiced under small-scale production system. The average observed output of the farmers and frontier output were 3.63 and 4.11 metric tons per hectare, respectively. The presence of technical inefficiency effect in the irrigated rice production as indicated by the log-likelihood ratio test (7.044) was not significant. The insignificant presence of inefficiency in the farmers' production was confirmed by the gamma coefficient (0.003) which indicated that only 0.3% of the deviation of output from the production frontier was attributed to technical inefficiency. The average technical efficiency of the farmers was 92%, leaving a gap of 8% for improvement. Despite the high level of technical efficiency of the farmers, their average observed output and the output of the most efficient farmers per hectare given the production technologies employed were lower than the maximum potential yield of the irrigated rice by 3.37 and 2.89 metric tons per hectare, respectively, indicating low levels of production technologies utilized by the farmers. Thus, boosting irrigated rice production in the study area requires improvement in the levels of technologies used by the farmers.

Key words: Stochastic frontier · Technical · Efficiency · Irrigated rice · Farmers · Nigeria

INTRODUCTION

Agriculture is still the most important sector in the economy of Nigeria despite the fact that it is not accorded the required priority. Priority shifted to oil after its discovery in the early 1970s with marked deterioration in the performance of the agricultural sector. However, over 70% of the livelihood of the Nigerian populace today depends on agriculture. Thus, emphasis is gradually being shifted back to boosting agricultural production. Among the staple crops that are marked for massive production by the Federal Government of Nigeria to achieve food sufficiency by the year 2020 are rice, maize, cassava and sorghum. Boosting rice production requires, among other things, the maximization of the limited available land and other productive resources of the nation for dry season irrigated rice production.

Rice is the second most important cereal in the world after wheat in terms of production [1]. It is an ancient staple food crop consumed by more than half of the world population - about 4.8 billion people in 176 countries. It is the most important food crop for over 2.89 billion people in Asia, over 40 million in Africa and over 150.3 million people in America [2]. In Nigeria, rice consumption has increased tremendously (+10% per annum), emerging from being a food reserved for ceremonial occasions to a major component of the people's diet [3].

Though Nigeria is the highest producer of rice in the West African Sub-region, she is also the highest consumer of the commodity. Annual domestic production of the commodity hovers around 3 million metric tons, while demand is as high as about 5 million metric tons, leaving a huge gap of 2 million metric tons annually which is often filled by importation [2]. Rice import stands at

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about 1,000,000 metric tons with the country spending over US$300 million annually [4]. This worrisome situation requires urgent attention, among which are expanding the hectares under rice production including dry season irrigation practice, improving the level of production technologies for rice and utilizing the resources for rice production efficiently to increase productivity. For intervention in any of these areas in order to boost rice production, adequate information is needed.

It is in view of this that this study seeks to estimate the technical efficiency of irrigated rice farmers in Niger State of Nigeria. The specific objectives of the study are to: examine the socio-economic characteristics of the irrigated rice farmers in the study area; estimate the quantities of inputs used and output realized; the production function for the irrigated rice; the level of technical efficiency of the farmers; and examine the factors influencing the farmers' inefficiency, if any.

MATERIALS AND METHODS

Study Area: Niger State is located between latitude 8° 15' and 10° 45' North and longitude 5° 15' and 8° 15' East; and occupies land area of 76, 363km^2 with the population of 3, 950,249 according to the 2006 population census. The state has two distinct seasons - the wet season from April to October and dry season from November to March. The mean annual rainfall is about 1258mm with high relative humidity. The study area falls within the guinea savannah zone of Nigeria with thick vegetation cover with tall grasses and trees. The predominant occupation of the inhabitants of the area is agriculture and some of the major arable crops grown are rice, maize, sorghum, millet, groundnut, cowpea, cassava, yam and tomatoes.

Sampling Procedure: A multi-stage sampling technique was employed to select the respondents for the study. The first stage of the sampling technique was the purposive selection of all the three (3) agro-ecological zones of the state (Niger North, Central and South agro-ecological zones), because rice is produced in virtually all the three (3) zones. This was followed by a random selection of one (1) Local Government Area (LGA) from each zone giving rise to three (3) LGAs and 2 communities from each LGA giving a total of 6 communities. Finally, 10 irrigated rice-based farmers were randomly selected from each community for the study giving a total sample size of 60 respondents.

Data Collection: Data collection for the study was achieved by the use of a well-structured pre-tested questionnaire administered to the respondents and complemented with personal interview. Data were collected on the socio-economic characteristics of the farmers, farm size (ha), quantity of rice seed (kg), labour (man days) fertilizer (kg), herbicides (litre) and output (kg) realized.

Data Analysis: The data collected were analyzed by using descriptive statistics, stochastic frontier production function and inefficiency model.

Descriptive Statistics: The descriptive statistics such as the means, percentages and frequencies were used to analyzed the socio-economic characteristics of the farmers, input and output variables and the distribution of efficiency levels of the farmers.

Stochastic Frontier Production Function: The stochastic frontier production function using Maximum Likelihood Estimation (MLE) technique was used to estimate the production function for the irrigated rice and obtained the farmers' specific levels of technical efficiency. The Cobb-Douglas function linearized in log-form fitted for the estimation of the stochastic production function given by Aigner *et al*. [5] and Mecusen and Van den Broeck [6] was adopted for the analysis. This is expressed as:

$$\text{In } Q = a_0 + a_1 \ln X_{1i} + a_2 \ln X_{2i} + a_3 \ln X_{3i} + a_4 \ln X_{4i} + a_5 \ln X_{5i} + a_6 \ln X_{6i} + (V_i - U_i) \ldots \text{eqn.} \quad (1)$$

Where:

It is the ith farmer, Q is output of irrigated rice (kg), X_1 is farm size (ha), X_2 is family labour (man-day), X_3 is hired labour (man-day), X_4 is rice seed (kg), X_5 is fertilizer (kg), X_6 is herbicides (litre), V_i is the symmetric random error term responsible for variation in output due to factors beyond the control of the farmers such as weather, disease outbreak, government policy, etc. and U_i is the random error term denoting the inefficiency effects, a_0, a_1, ….. a_6 are unknown parameters to be estimated and ln is natural logarithm.

It follows that the MLE of the model in eqn. (1) also yielded other parameters such as sigma squared (δ_s^2) and gamma (γ) along with a's earlier defined, as well as the log-likelihood function. These parameters, according to Aigner *et al.* [5] and Mecusen and Van den Broeck [6], are discussed as follows:

The δ_s^2 gives an indication of the goodness of fit of the model used. The δ_5^2 is defined as:

$$\delta_s^2 = \delta_{vi}^2 + \delta_{ui}^2 \quad (2)$$

Where: δ_{vi}^2 and δ_{ui}^2 are the variances of the error term due to noise and technical inefficiency for the ith farmer respectively.

The gamma (γ) which gives the proportion of the deviation of output from the production frontier due to the farmers' technical inefficiency is given as:

$$\gamma = \delta_u^2/\delta_s^2 \quad (3)$$

So that $0 \leq \gamma \leq 1$. If $\gamma = 0$, it means all deviations of output from the production frontier are caused by noise and if $\gamma = 1$ all deviations are attributed to technical inefficiency.

A generalized log-likelihood ratio test was carried out to ascertain whether there is significant presence of technical inefficiency in the farmers' production. The log-likelihood ratio (LR) test is given as:

$$LR = -2\,[L\,(H_0) - L\,(H_l)] \quad (4)$$

Where: L (H_0) and L (H_l) are values of log-likelihood function under the null and alternative hypotheses respectively. The LR test has a chi-square (X^2) distribution.

The measure of technical efficiency (TE) for the ith farmer is thus expressed as:

$$TE = Q_i/Q_i^* = \exp\,(-U_i) \quad (5)$$

Given that $0 \leq TE \leq 1$

Where: Q_i is the observed output of the ith farmer, Q_i^* is the frontier output of the ith farmer and U_i is as earlier defined.

Inefficiency Model: The random error term, U_i accounting for inefficiency effects in the farmers' production is influenced by a number of the farmers' socio-economic factors and is defined by the inefficiency model as:

$$U_i = b_0 + b_1Z_1 + b_2Z_2 + b_3Z_3 + b_4Z_4 + b_5Z_5 + ei \quad (6)$$

Where: Z_1 is age of the farmers (years), Z_2 is gender (male = 1, female = 0), Z_3 is household size (in number), Z_4 is educational level (years), Z_5 is years of farming experience, ei is the random error term and b's are the unknown coefficients to be estimated.

The computer program, FRONTIER version 4.1 proposed by Coelli [7] was used to jointly estimate the parameters of the stochastic frontier production function and the inefficiency model jointly.

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Irrigated Rice Farmers: The summary statistics of the socio-economic characteristics of the irrigated rice farmers are presented in Table 1. The results indicated that irrigated rice production in Niger state was dominated by married males who were relatively young (average age = 42 years) with high family size (13 persons). Majority (54%) of the farmers had at least primary education with long years of farming experience (19 years), corroborating the finding of Ugwuanyi *et al*. [8]. The dominance of males in the irrigated rice production confirmed the fact that males are the household heads and therefore are in charge of the core farm production activities while women are mostly into processing and marketing [8]. The average age of the respondents showed that they were still in their active productive age. The large household size might have positive implication on the farmers' production due to the family labour contribution from the household members, *ceteris paribus*. The high literacy rate and long years of arming experience acquired by the farmers might improve their ability to use resources more efficiently in production.

Inputs and Outputs of Irrigated Rice Production: The production inputs and output in the irrigated rice production are shown in Table 2. The farmers were found to be small-scale farmers cultivating less than 2 hectares of farm land. The implication of the low farm size is that the vast land area for rice production in the country [9] which would have been exploited for irrigation during dry season is left unused, thus contributing to inadequate food supply and hence food insecurity in the country. The total average family and hired labour usage per hectare was 86.84 man-days. This is lower than the mean labour usage of 99.14 and 144 man days per hectare reported by Idiong [10] and NCRI [9] respectively. This is expected because the labour usage by the irrigated

Table 1: Summary Statistics of Socio-economic Characteristics of Irrigated Rice farmers in Niger Stat

Variable	Unit	Average statistics
Gender:		
Male	%	87
Female	%	13
Age	Years	41.78
Marital status: Single	%	10
Married	%	79
Widow/Widower	%	11
Household size	Number	13
Educational level: No formal education	%	46
Primary education	%	10
Secondary education	%	13
Tertiary education	%	31
Farming experience	Years	19.18
Sample size	Number	60

Source: Field Survey, 2009

Table 2: Input and Output Variables in Irrigated Rice Production in Niger State

Variable	Unit	Value/Farmer	Value/ha
Farm size	Ha	1.36	1
Family labour	Man days	66.60	48.97
Hired labour	Man days	51.50	37.87
Tractor hiring	Hours	2.04	1.52
Rice seed	Kg	104.54	76.89
Fertilizer	Kg	102.00	75
Herbicide	Litres	4.31	3.17
Observed output	Kg	4934.08	3628
Frontier output	Kg	5592.93	4112
Sample size	Number	60	

Source: Field survey, 2009

Table 3: Maximum Likelihood Estimates of the Stochastic Frontier Production Function for Irrigated Rice in Niger State

Variable	Parameter	Coefficient	t-ratio
Constant	a_0	11.877	18.804
Farm size (X_1)	a_1	0.392	1.082
Family labour (X_2)	a_2	0.141	2.434**
Hired labour (X_3)	a_3	-0.060	-1.522
Rice seed (X_4)	a_4	0.717	2.114**
Fertilizer (X_5)	a_5	0.111	1.000
Herbicide (X_6)	a_6	0.272	3.254***
Sigma squared	δ_s^2	0.113	5.147***
Gamma	γ	0.003	0.288
Log-likelihood function (H_1)	$L(H_1)$	-16.685	-
Log-likelihood function (H_0)	$L(H_0)$	-20.207	-
Variance of error caused by noise	δ_v^2	0.1127	-
Variance of error accounting for inefficiency	δ_u^2	0.0003	-
Log-likelihood ratio test	LR	-	7.044

*** Significant at 1%, ** Significant at 5%,

Table values: Chi-square at 5% = 16.949, $t_{0.01}$ = 2.617, $t_{0.05}$ = 1.980, $t_{0.1}$ = 1.658

Source: Computed from Field data, 2009

Table 4: Frequency Distribution of Technical Efficiency of Irrigated Rice Farmers in Niger State

Technical efficiency (TE)	Frequency	Percentage (%)
0.601 - 0.700	1	2
0.701 - 0.800	3	5
0.801 - 0.900	14	23
0.901 - 1.000	42	70
Total	60	100
Minimum TE	0.696	
Maximum TE	0.998	
Mean TE	0.920	

Source: Computed from Field data, 2009

Table 5: Estimates of Technical Inefficiency Parameters of Irrigated Rice Farmers in Niger State

Variable	Parameter	Coefficient	t-ratio
Constant	b_0	-0.171	-0.681
Age (Z_1)	b_1	0.009	1.370
Gender (Z_2)	b_2	0.080	0.595
Household size (Z_3)	b_3	-0.027	-1.738*
Educational level (Z_4)	b_4	-0.002	-0.207
Farming experience (Z_5)	b_5	0.009	0.501

t-tabulated: $t_{0.1}$ = 1.658

*Significant at 10%

Source: Computed from Field data, 2009

rice farmers was complemented by tractor hiring (1.50 hours/ha) for ploughing/harrowing and herbicides usage (3.17 litres/ha) for weeds control. The family labour was higher than the hired labour by 11.10 man days per hectare indicating that the large number of household members contributed to the farm production. The quantity of rice seed (76.89/ha) used by the farmers compares favourably with the recommended average seed rate of 80kg/ha by NCRI [9]. Fertilizer usage (75kg/ha), however, was very low compared with the rate of 375kg/ha recommended for lowland rice [9]. This may imply low rice productivity, all things being equal. Evidently, the observed output of the farmers and the frontier output per hectare were lower than the maximum yield of 7.0 metric tons per hectare expected from irrigated rice [9], leaving wide gaps of 3.37 and 2.89 metric tons,respectively for improvement.

Stochastic Frontier Production Function for Irrigated Rice: The stochastic frontier production function for irrigated rice in Niger State presented in Table 3 showed that with the exception of hired labour, all inputs under consideration (farm size, family labour, rice seed, fertilizer and herbicide), correlated positively with rice output, consistent with a priori expectation. The coefficients of family labour, rice seed and herbicide were significant while others were not significant. High quantities of family labour and rice seed used (Table 2) might have accounted for their significant effects on output. The significant effect of herbicide on the output may imply increasing production efficiency by effective chemical weed control. The farm size, hired labour and fertilizer, on the other hand, were not significant probably due to their low quantities used by the farmers. These results compares with a number of findings. Idiong [10] reported that labour, farm size and seed positively and significantly related to swamp rice output while fertilizer was not significant. Similarly, the results of the Cobb-Douglas maximum likelihood estimate given by Backman *et al.* [11] showed that land, labour and seed, among others factors, positively and significantly influenced rice production, while fertilizer had no significant effect.

The coefficient of gamma (0.003) which indicated that 0.3% of the variation in the output of the irrigated rice was attributed to technical inefficiency was not significant. This means that 99.7% of the deviation of output from the production frontier was occasioned by noise. The log-likelihood ratio test confirmed that the presence of inefficiency effect in the irrigated rice production was not significant, implying that the Ordinary Least Squares (OLS) estimation technique which attributes random effect in production to all factors beyond the control of the farmers can adequately estimate the production function for the irrigated rice. The sigma squared (0.113) was significant indicating the correctness of the specified assumptions of the composite error term. This finding is, however, at variance with the findings of Okoruwa and

Ogundele [12] and Idiong [10] who established that rice production in Nigeria is characterized by significant presence of technical inefficiency effects.

Technical Efficiency of Irrigated Rice Farmers: The technical efficiency (TE) estimates of the irrigated rice farmers are presented in Table 4. Technical efficiency of the farmers ranged from 69.60 to 99.80% with the average of 92%, corroborating the finding of Onoja and Achike [13] who reported high technical efficiency of 95% for irrigated and rainfed rice production systems. The mean TE indicates that given the level of technology of the irrigated rice farmers, little (8%) can be done to increase their technical production capacity. The low level of technical inefficiency (8%) is confirmed by the results of the gamma and log-likelihood ratio test (Table 3) where only 0.3% of the variation in the output of the farmers was attributed to their inefficiency and the presence of technical inefficiency effect in the stochastic frontier production function was insignificant respectively.

Despite the high level of technical efficiency of the farmers, their observed output as well as the output of the most efficient farmers based on the available technologies employed (Table 2) was lower than the maximum potential yield of the irrigated rice by 3.37 and 2.89 metric tons respectively. This means that the existing levels of technological practices employed by the irrigated rice farmers were still low, a pointer to the need for improvement. The low levels of the technologies raises a question of the where about of the numerous improved technologies developed to boost rice production. It is either there are lapses on the part of agricultural extension services in transferring the improved technologies to the farmers or the farmers could not afford the technologies.

Technical Inefficiency Parameters of Irrigated Rice Farmers: The estimated technical inefficiency parameters of the irrigated rice farmers presented in Table 5 showed that only household size significantly ($P<0.1$) influenced the technical inefficiency of the farmers. All other variables (age, gender, educational level and farming experience) were not significant, confirming the low level of technical inefficiency effect in the farmers' production. The negative sign of the household size indicated that increased household size decreased the inefficiency of the farmers. This is expected in view of the large household size (Table 1) which contributed higher family labour than hired labour (Table 2) for the rice production.

CONCLUSION AND RECOMMENDATIONS

The study has established that irrigated rice production in Niger State was practiced under small-scale production system. The presence of technical inefficiency effect in the farmers' production was found to be insignificant as only an average of about 0.3% of the deviation of output from the production frontier was accounted by technical inefficiency. The average TE of the farmers was 92%, leaving 8% gap for technical improvement. Despite the high level of TE of the farmers, the average frontier output based on the available production technologies employed was 2.89 metric tons lower than the maximum potential yield of the irrigated rice, implying that the levels of production technologies employed by the farmers were still low.

Based on these findings, it is recommended that the irrigated rice farmers should intensify effort to expand their farm size to maximize the use of the vast land area for rice production during the dry season. The farmers need to be empowered for this expansion. Thus, government, non-governmental organizations and financial institutions should provide adequate needed capital for the farmers. Also, adequate irrigation facilities (e.g. dams) should be provided (existing ones rehabilitated and new ones constructed) for the expansion of the irrigated rice production. Furthermore, a detailed study should be conducted to ascertain the levels of production technologies for irrigated rice in the study area with a view to improving the standards of the technologies or transferring the technologies to the farmers.

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