Technical Efficiency of Rice Farming in South-western Niger: A Stochastic Frontier Approach

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Abstract
The study estimated the technical efficiency and its determinants of rice farming in south-western Niger. The data were obtained from a total of 148 respondents who provided useful information through face-face question using prepared questionnaires. The analysis of the data was done using Cobb-Douglas stochastic frontier production model to find the technical efficiency. A positive coefficient was observed for parameters such as seed, fertilizer, chemicals and the ploughing for all rice farmers which therefore suggested that an increase in each of these variables could increase rice output. However, farm size and labor were recorded with a negative coefficient which presupposed over utilization and hence the inefficient use of these variables in rice production in the area. The technical efficiency had a mean value of 0.612, which implied that on average the producers were able to obtain only 61% of the optimal output from a given combine inputs. The result also showed that experience, gender, cooperative membership and main occupation positively influenced technical efficiency. However, farm size, age, education and land ownership had a negative influence on technical efficiency. The study, therefore, recommends sustainable policies to guarantee the supply fertilizers at suitable prices for farmers to ensure maximum rice output.
Keywords: Stochastic Frontier Analysis, Rice Production, Farming, Technical Efficiency, Western Niger

1. Introduction

Rice (Oryzae Sativa) is one of the cereals most commonly consumed in the world, particularly in Asia and Africa notably in the Niger Republic. It was noted that West Africa's rice demand had grown at an annual rate of 6% since 1973 driven by a population growth of 2.9% (FAO, 1995). Although rice production is far below the demand of the country, rice is imported and hence we need to boost the national production to fill this gap. To salvage this situation, since the droughts of the 70s, the Sahelian countries turned to the intensification of irrigated crops with much attention on rice whose consumption grows in a vertiginous way. The government of Niger together with its development partners undertook projects in water management for the agricultural sector of which 58 was for the growing rice (Sido *et al.,* 2011). Modernization of the agricultural sector presents another chance for agriculture constitutes 39% of GDP and employs 55% of the active workforce, yet it does not employ modern practices and is predisposed to climactic shocks which slow the economy (U.S. Department of State, 2014). Agriculture therefore determines the stability of overall economic growth of Niger. The agricultural sector of the county is dominated by small-scale farmers in rural areas upon whose shoulders rest the performance of the country's economy. Given agriculture's importance in Niger's economy, the performance of small farmers in the sector should be of great concern to policy makers.

Rice is a staple and strategic cereal crop in Niger with consumption of about 338 934 tones in 2014 of which local production could only meet 31% of this consumption (Republic of Niger, 2015). Despite its strategic function, increasing in rice production caused by land extension is extremely difficult in this modern era due to the decreasing area for arable activities as a result of land degradation (drought, flood) and the country's rapid growth population occupying the more arable area and thereby threatening food security. This fact has prompted the Nigerien authority to systematically increase rice production by the enhancement of yield through the use of optimal inputs, modern technologies and farm management and by the provision of incentives to farmers with high paddy rice yield. However, despite numerous efforts and policies to increase rice farming, there has not been any significant improvement. The difficulties in improving the yield could be attributed to the inefficient farm management despite intensive use of inputs. Thus, in this context, the measurement of the vacant farm's efficiency is much more useful as it can help solicit for information relating to the gap of efficiency in production among the farms and the potential for improvement (Kumbhakar & Lovell, 2000). Moreover, the analysis of technical efficiency in the agricultural sector has been widely used in both developed and developing countries due to the importance of productivity growth to improve the economic development. Therefore, the core objective of this research was to estimate the possibilities of technical gains from enhancing the efficiency of rice farmers. The analytical method of the research was to determine the technical efficiency of rice farmers in Niger by employing stochastic frontier to identify some factors of technical efficiency. Estimation of farm-level technical efficiency (TE) was done followed by calculation of Tobit function with the dependent variables (TE) and the independent variables of the major factors leading to technical inefficiency and social characteristics of the farmers.

2. Materials and methods

2.1 Study area and data collection

The study was carried out in the south-western part of Niger, and the data was obtained through a survey of 148 rice farmers within Kollo department area by the use of random sampling. The data for this research work were collected between January and March of 2015. This research employed the collection of data from both primary and secondary sources. Information obtained from both oral interview and by the use of structured questionnaires together formed the primary source. The community and farmer's household levels were the two sets of interview schedules that were used in the data collection. Data about farmer's last harvest was obtained through the use of interviews. Secondary sources of data including information from journals, text books and internet searches which included both published and unpublished materials related to the study.

2.2 Analytical framework and data analysis

The discrepancy in output by different farmers as a result of technical inefficiencies could be apprehended by the specification of a production function. Stochastic Frontier Approach (SFA) or Data Envelopment Analysis (DEA) which is a non-parametric approach could both be utilized in the estimation of Technical efficiency. The use of DEA has the assumption that there are no random effects in the production. This current research hereby employed the use Stochastic Production Frontier Approach since most farmers operate under uncertain conditions (Abdellah & Ahmed, 2006). According to literature, there are several functional forms for estimating the physical relationship between inputs and output. The Cobb-Douglas (CD) functional form is preferable to other forms if there are three or more independent variables in the model (Hanley & spash, 1993). The current study, therefore, estimated a Cobb Douglas production function specified as:

$Y_i = f(X_i;\beta) + V_i - U_i$ ………………………………………………… equ1

Where $_iY$ = output or production (or logarithm of production) of the i-th farm,

X_i = vector of input quantities used by the i^{th} farm,

β = vector of unknown parameters to be estimated,

f = represents an appropriate function (e.g Cobb Douglas, Translog, etc.).

The term V_i is a symmetric error which accounts for random variations in output due to factors outside the control of the farmer such as disease outbreaks, weather, etc, and measurement of errors. The term U_i is a non-negative random variable instead of inefficiency in production relative to the stochastic frontier.

The random error vi is assumed to be independently and identically distributed as $N(0, \sigma_v^2)$ random variables independent of the U_i; which are assumed to be non-negative truncation of the $N(0, \sigma_u^2)$ distribution (i.e half-normal distribution) or half-exponential distribution.

Technical Efficiency (TE) mode is thus:

$TE = Y_i/Y_i^* = f(X_i;\beta) \exp(V_i - U_i)/f(X_i;\beta)\exp(V_i) = \exp(-U_i)$ ………… equ2

Where:

Y_i = vector of the observed output;

Y_i^* = vector of the frontier output.

Measurement of efficiency in production can be estimated using this production function and the use of it is associated with two merits. Firstly is the introduction of a disturbance term denoting statistical noise, measurement error and exogenous shocks beyond the control of production units which could otherwise affect technical efficiency. It also provides the basis for production structure and the degree of inefficiency.

Technical Efficiency (TE) is stipulated regarding the observed output about the production frontier in the context of available technology such that $0 \leq TE \leq 1$.

In this study, Cobb-Douglas production function with six input independent variables was applied. These independent variables were rice farm size, seed, fertilizer, chemicals, labor and the ploughing for rice production in western Niger. Farm size of rice was measured in units of hectare (ha), while seed, fertilizer and chemicals were measured in units of kilograms/ ha respectively. Labor was calculated according to the FAO convention in man-days/ ha and the ploughing was measured in units of hours/ ha. Hence, the production function can be log linearized to be:

$\ln Y_i = \beta_0 + \sum_{j=1}^{6} \beta_{ij} \ln X_{ij} + V_i - U_i$ ………………………………… equ3

Where: Y_i = the output of the i^{th} farmer;

X_i = the vector of the six input quantities used by the i^{th} farmer;

β_0, β_{ij} = the vector of regression parameters to be estimated;

V_i = symmetric error which accounts for random variations in output due to factors beyond the control of the farmer;

U_i = a non-negative random variable representing the inefficiency in production about the stochastic frontier. Concerning to the literature in most frontier production, U_i is assumed to follow a half normal distribution in this study.

Specifically, the production technology (Technical efficiency) of rice farmers in West of Niger was estimated

using the Cobb Douglas function form of the stochastic frontier production function model defined as follows:
$LnY_i = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_6 + V_i - U_i$ …equ4
Where: Y_i = rice output (kg
X_1 = farm size (Ha)
X_2 = seed input (kg)
X_3 = fertilizer (kg)
X_4 = chemicals (Kg)
X_5 = labour (man-days)
X_6 = ploughing (Hours)
$\beta_0, \beta_1, \beta_2, \ldots\ldots \beta_6$, are regression parameters to be estimated; while
V_i and U_i are as defined in equation 3
The variance for certain errors such as the total variance of the model's errors (σ^2) can be calculated using the stochastic frontier model as follows:
$\sigma^2=\sigma^2_u+\sigma^2_v$……………………………………………equ5
Whereby
σ^2_u = the variance of u_i and $\sigma^2 v$ = the variance of v_i.
Statistical significance of σ^2 suggests the quality of the fitness of the model and a test of the applied specification assumption for the distribution of those errors that are related to technical inefficiency (u_i). Moreover, (λ) is a representation of the ratio between standard deviation of the errors of the technical inefficiency (u) and the model specification errors (v) which can be formally expressed as:
$\lambda=\sigma_u/\sigma_v$………………………………………………….. equ 6
When either σ_v is very large or σ_u is nearing to zero, λ will approach zero. Similarly, if λ becomes large and the one-side error becomes the dominant source of random variation in the model, then σ_v is close to zero. Furthermore, the ratio of variances (γ) which relates the variability of u_i to the total variability of the model's errors is represented as follows:
$\gamma=\sigma^2_u/ \sigma^2_u +\sigma^2_v$ …………………………………………… equ7
This equation is an estimation of the level of inefficiency of the stochastic frontier production model with values ranging between 0 and 1.
To accurately determine the factors contributing to the observed technical inefficiency in rice farming in western Niger, the Tobit function with a dependent variable of technical efficiency was applied. The Tobit function is given by:
$TE_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8$ ……equ8
Where, TE_i = the technical efficiency of i^{th} farmer,
Z_1 = farm size (Ha);
Z_2 = farmer's age (yrs);
Z_3 = education level (yrs);
Z_4 = farmer's experience in rice farming (yrs);
Z_5 = farmer's gender (Dummy variable: 1= male, 0 = female);
Z_6 = cooperative membership (Dummy variable: 1 = yes, 0 = no);
Z_7 = farmer's main occupation (Dummy variable: 1 = rice farming, 0 = otherwise);
Z_8 = land ownership (Dummy variable: 1 = own land, 0 = otherwise).
While $\delta_0, \delta_1, \delta_2, \ldots\ldots \delta_8$ = estimated regression parameters.

Utilization of Stochastic Frontier Production function in this study is consequences of the coefficients which estimated directly correspond to elasticity of production (Abdellah & Ahmad 2006). According to Taylor & Ahonkwiler (1986), SFA is precise in the representation of the production process since our major focus is in the measurement of efficiency but not production structure. Furthermore, SFA has been extensively utilized in the estimation of farm efficiencies (Onyenweaku & Ohajianya, 2005; Hussain *et al.,* 2012; Samuel & Kelvin, 2013; Syed & Mahammad, 2014; Ouedraogo, 2015).

Descriptive statistics, Stochastic Frontier Production function and Tobit model were used to analyze data. STATA13 was used to estimate the elasticity of production and to analyze the factors affecting efficiency.

3. Results and discussion

The data obtained from the research were divided into two categories namely; production and socio-economic characteristics of respondents.

There was an average rice yield level of 3719.38 $Kgha^{-1}$. This result was consistent with the 3.5 to 4.5 tones as indicated by Mounirou *et al.,* (2015) in the same agrosystem. The average farm size was 0.59 Ha and the average number of seeds per hectare was 66.90 Kg which conformed to the average seeds of 68 Kg and 63.45 kg used on paddy farms as revealed by Lira *et al.,* (2014) in MADA Malaysia and Kadiri *et al.,* (2014) in Nigeria respectively. Utilization of fertilizer and chemicals among inputs used on farms recorded large variabilities of

136.94 and 1.37 respectively which suggested the inaccurate use of these inputs by farmers.

The distribution of participants on the age, education, experience, gender, cooperative membership, main occupation and land ownership showed that rice farmers in Western Niger had much experience in the production rice with a mean age of 16 years and an average of almost one year of education. The results revealed that farmers in Niger had a low level of education but with much experience in rice production.

Table1: Descriptive statistics for variable used in the study

Variable	Mean	Standard deviation	Minimum	Maximum
Output (Kg ha^{-1})	3 719.385	1 972.411	280	7 800
Farm size (Ha)	0.5928	0.5756	0.10	4
Seed (Kg ha^{-1})	66.9054	17.9190	10	100
Fertilizer (kg ha^{-1})	184.109	136.9439	17	625
Chemicals (Kg ha^{-1})	0.9510	1.3754	0.125	15
Labour (man-days)	180.2123	97.5639	13	917.5
Ploughing (Hour)	4.7874	1.0247	3.95	8.33
Socioeconomic characteristics				
Farmer age (year)	44.7973	12.8756	20	75
Education level (year)	1.3648	3.0841	0	17
Experience (year)	16.054	10.2145	2	50
Gender (Dummy)	0.9324	0.2518	0	1
Cooperative (Dummy)	0.9054	0.2936	0	1
Occupation (Dummy)	0.3918	0.4898	0	1
Land ownership (Dummy)	0.8243	0.3818	0	1

Source: survey data (2015).

The estimation of Cobb-Douglass SFA function (equation3) is shown in table 2. The estimated coefficient for seeds, fertilizer, chemicals and ploughing were all positive. The positive coefficient of these inputs variables suggested that an increase in the quantities of these inputs would result in an upsurge in rice output. A positive coefficient of fertilizer was observed which was statistically significant at 1% level hence 1% increasing in expenditure on fertilizer will lead to about 0.305% upsurge in rice output which is consistent with the work of Sibiko *et al.,* (2013) and that of Emmanuel & Isaac, (2014). Despite the fact that fertilizer is not easily accessible within the study area at reasonable prices, it serves as the most significant factor for rice production. It is, therefore, pertinent for the government to ensure the ready availability for fertilizers to farmers in the country at reasonable prices and in due season.

On the other hand, land (farm size) and labour had a strong negative correlation with production output and also found to be significant at 1% level of probability. This inferred that a unit surge in land and labour would result in a reduction of 0.382 and 0.767kg respectively on output (*Citeris Paribus*). Labour input gave the impression to be excessive due of the negativity of its coefficient which contrasted the finding of Surendra, (2016) and Micah & Musa, (2015) who observed a positive effect of land variable.

The maximum likelihood estimates of the model parameters are computed using the frontier models of the statistical package STATA with a Cobb-Douglas functional form. The test for the presence of inefficiency was assessed by estimating the SFA function and conducting a likelihood ratio test with the assumption that there is no technical inefficiency for the null hypothesis. This test statistic is automatically generated when the frontier model is assessed by the use of STATA. Considering the first hypothesis, the incidence of technical inefficiency impact in the model, in addition to all deviations from the production frontier are as a result of statistical noise if $\lambda = 0$ as cited by Ceolli *et al.,* (2005). Hence, the impact of technical inefficiency in rice production is tested using significance of variance parameters. With reference to table 2, there is a rejection of the null hypothesis that there is no technical inefficiency in rice production is at 1% significance level as the estimated value for λ is large and significantly different from zero (λ =4.581). The estimated variance parameter sigma square ($\sigma^2 = 0.9312$) was significantly different from zero at 1% probability level indicative of that the inefficiency impacts are random and stochastic. The ratio of plot-specific technical efficiency impacts to total output variance denoted as Gamma (γ) records a value of 0.9545. Observed disparities in technical efficiency among rice farmers can about 95% be attributed to the variation in rice output.

Table2: Estimation of the stochastic frontier function CD

Variable	coefficient	Standard-error	Z
Intercept	7.6775***	0.8694	8.83
Lnfarm size	-0.3827***	0.1262	-3.03
Lnseed	0.0144	0.0938	0.15
Lnfertilizer	0.3056***	0.0846	3.61
Lnchemical	0.0794	0.1094	0.70
Lnlabour	-.7675***	0.0779	-9.96
Lnploughing	0.0220	.3143	0.07
Variance measures			
σ_u	0.9428***	0.0857	10.99
σ_V	0.2058***	0.0581	3.54
Sigma-square (σ^2)	0.9312***	0.1485	6.26
Gamma (γ)	0.9545		
Lambda (λ)	4.5811***	0.1293	35.41
Likelihood function	-124.3662		

Note: *** Significance at 1% level.

Source: field survey data (2015)

The data from Table 3 revealed that the individual technical efficiency indices ranged between 0.126 and 0.925 with a mean of 0.612. The data also revealed that 76.5% of the rice farmers recorded technical efficiency index greater than 0.50 which presupposes that rice farmers in Niger were technically inefficient in the use of resources as the total technical efficiency index was below 1.0. Thus, the hypothesis that rice farmers in Niger were technical inefficient in the usage of resources is putative.

The mean technical efficiency of 0.612 from this research could be compared favorably with the 0.61 and 0.626 obtained respectively for rice production by Onyenweaku & Ohajianya, (2005) in Ebonyi state of Nigeria and Kadiri *et al.,* (2014) in Niger Delta area of Nigeria. However, this is in contrast with the technical efficiency of 0.784 and 0.81 recorded respectively by Sokvibol *et al.,* (2016) on the rice production in Cambodia and Le *et al.,* (2016) on rice farm in Cooperative in Vietnam.

Table3: Distribution of technical efficiency of rice farmers

Efficiency class	Frequency	percentage
<0.50	35	23.50
0.51-0.60	23	16.00
0.61-0.70	22	15.00
0.70-0.80	35	23.50
0.81-0.90	30	20.00
0.91-1.00	3	2.00
Total	148	100
Mean efficiency	0.612	
Minimum efficiency	0.126	
Maximum efficiency	0.925	

Source: field survey data, (2015).

Table 3 summarizes the factors that influenced technical efficiency of the rice farmers in Niger. The factors include farm size, farmer's age, and educational level, farming experience, farmer's gender, main occupation, cooperative membership and land ownership. The results show regression coefficient, standard error and t-value. The coefficient designates how the factors are related with the dependent variable (paddy rice) at 1%, 5%, 10% significant level. However, coefficients of farmer's age, education and cooperative membership were not significant.

The coefficient of experience, gender and main occupation were positive and significant, which were an indication of a direct association with the technical efficiency. However, the coefficients of farm size and land ownership were negatively significant signifying an inverse association with technical efficiency. The information hereby, clearly specified that these five variables were the determinants of technical efficiency of rice farmers in Niger.

The coefficient of land size was negative and significant at 10% level of probability, implying that the bigger the farm size, the less efficient the farmer in rice production. On the other hand, if the farm size is small, the farmers can combine their resources better. These results are in contrast with the findings of Oladimeji & Abdulsalam, (2013) and Boubaker *et al.,* (2012).

The estimated coefficients for experience is positive and significant at 5% level of probability, suggesting that the more experienced the farmer, the higher the chances of the farmer being more efficient. This can be explained by the fact that in Niger farming is done under risky environmental conditions such as irregular rainfall patterns etc. Therefore, farmers who have cultivated the same crop over a long period of time are able to make accurate predictions on when to plant, the inputs to use, the quantity to use as well as the timing of the use of these inputs and are therefore, more efficient in the use of the inputs as compared to inexperienced farmers. This finding is in accordance with Oyenweaku & Effiong, (2005); Onyenweaku & Nwary, (2005); Idiong *et al.,* (2007) but it is contrasted with that of Osanyinlusi & Adenegan, (2016).

A positive coefficient was observed for gender which was significant at 1% level of probability, indicative of the fact that being a male rice farmer increases technical efficiency than being a female. This result is in agreement with that of Kibaara, (2005) that being a male farmer increases technical efficiency. However, Dolisca and Jolly, (2008) and Shresthra *et al.,* (2016) had a contrasting result that women farmers are more effective than their males. Therefore, this study contributes to the debate on the role of gender in farmers' level of efficiency.

The result of the coefficient of farmer's main occupation was positive and statistically significant at 5% level of probability. This observation could be ascribed to the fact that farmers tended to be more active, acquiring more skills, and training as more time spent on the cultivation of one crop which culminated in an upsurge in productivity.

The coefficient for land ownership had a significant effect at 5% level of probability but in the negative direction, which implied farmers who owned the land tended to be more inefficient than those who rented. This phenomenon could best be attributed to the motivation to produce as farmers who rented were more motivated to improve their production and got higher income hence they strived to manage the production in a professional manner and thereby were very receptive to new technological ideas as well. The result of this study was on opposite to that of Rahman & Umar, (2009).

Table 4: Tobit regression estimates for factors influencing technical efficiency

Variables	coefficient	standard-error	t-value
Intercept	0.4814***	0.1091	4.41
Farm size	-0.5102*	0.0311	-1.64
Farmer's age	-0.0013	0.0012	-1.06
Farmer's education level	-0.0019	0.0050	-0.39
Farmer's experience	0.0352**	0.0174	2.01
Farmer's gender	0.2658***	0.0621	4.28
Cooperative membership	0.0160	0.0735	0.22
Farmer's main occupation	0.0816**	0.034	2.40
Land ownership	-0.1349**	0.0612	-2.20
Sigma	0.1836	0.0107	

Note: *** significance at 1% level; ** significance at 5% level; * significance at 10% level
Source: field survey data (2015)

4. Conclusion and recommendations

This study has revealed that when it comes to the utilization of resources for the purpose of production, rice farmers in western Niger are technically inefficient. The result of Cobb Douglas function also ascertains the fact that an increase in fertilizer will give rise to an increase in paddy rice output. We hereby endorse that policies should aim at reducing the cost of productive inputs such as fertilizer, seed and chemicals to aid in efficiency. Farm size, farmer's experience, farmer's gender, farmer's main occupation, and land ownership were revealed to be vital determinants of technical efficiency. Improvement in farmer's efficiency in rice production has the possibility to intensify rice production in the region and in the country at large. This will culminate in a direct rippling effect on the output of local paddy rice, therefore food security, resulting in an upsurge in revenue among rice farmers and reduction of the supply and demand gap that will cut down rice importation which is on the ascendency in the country.

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