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Technical Efficiency in Rice Production Among Smallholder Farmers in Central Liberia: A Stochastic Production Frontier Analysis

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Abstract
Demand for rice remains high in Liberia with low farm-level productivity (1.2 t/ha). The ability of smallholder rice farmers to improve output levels and attain sustainable production depends on efficient farm practices, hence technical efficiency. A stochastic frontier production function was applied to examine the technical efficiency of rice production. A two stage random sampling with stratification was used to collect data from 400 rice farmers in Bein Garr and Panta Districts, Central Liberia. The study has revealed that technical efficiency among farmers range from 14% to 88%, with the mean of 55%; indicating that on average, the actual output can be increased by 45% in the study area with the available technology and resources. The determinants explaining efficiency variation in the study area were education, farming experience, household size, credit access, group membership and the type of seed used. The study recommends policies that target on increasing and improving farmers' access to credit so as to enable the farmers get the needed production inputs such as improved seeds and fertilizer on time. Furthermore, farmers should be encouraged to organize themselves into associations/cooperatives around major rice producing and processing hubs.
Keywords: smallholder farmers, rice, technical efficiency, stochastic frontier, Liberia

1.0 Introduction

Rice is one of the cereals most commonly consumed in the world, especially in Africa and Asia (Ogunniyi *et al.*, 2012). It is one of the world's major staple food, ranking third after wheat and maize on global production level and second in terms of cultivated area (Nwike and Ugwumba, 2015). Rice is the primary staple food crop for Liberia's 3.5 million people representing over 33% of their food consumption. It accounts for approximately 50% of adult caloric intake, with an annual per capital consumption estimated at 133kg (USAID-BEST, 2014). The crop is widely grown in almost every region in Liberia due to reliable and favorable climatic conditions (NRDS, 2012).

Despite being widely cultivated and the role it plays as a staple food crop in the country, a total annual rice output of about 290,600 metric ton has not kept pace with the growing demand of over 400,000 metric tons, largely due to low productivity and the large deficit is met through importation (NIC, 2015). The average yield in Liberia is just about 1.2 t/ha (USAID-BEST, 2014); which is low as compared to other West African countries with 2.7 t/ha in Ghana, 3.0 t/ha in Côte d'Ivoire, 3.4 t/ha in Mali and 4 t/ha in Benin (Donkoh and Awuni, 2011; Oladele *et al.*, 2011; Donkor and Owusu, 2014). The low productivity at the farm level is a pervasive problem, which impends not only the economic well-being of the farmers but also the efforts by the government to ensure food security. The implication is that if no special attention is given to reverse the situation, the country stands a chance of increasing its importation bills, facing severe food insecurity and negative outcomes from poverty reduction efforts by the government through the pro poor agenda for prosperity and development. Henceforth, it is essential to have clarity on questions like what is the level of efficiency of smallholder rice farmers in the study area? What are the output losses, what are the factors affecting rice production efficiency in the study area and how can these factors be mitigated? These are important policy issues that need to be understood by planners and policy makers.

In developing countries, available literature suggests that farmers fail to exploit the full potential of a technology (Ali and Flinn, 1989; Kalirajan and Shand, 1989; Thomas and Sundaresan, 2000; Narala and Zala, 2010; Djokoto, 2012; and Abdulai *et al.*, 2013). Hence, increasing the efficiency in production assumes greater significance in attaining potential output at the farm level. Improvement in technical efficiency is a potential source of further productivity growth. However, embarking on new technologies is meaningless unless the existing technology is used to its full potential, (Narala and Zala, 2010). Further, the analysis of variations between the potential and actual yields on the farm, given the technology and resource endowment of farmers, provide better understanding of the yield gap. Thus, technical efficiency is an indicator of the productivity of the farm and the variation in technical efficiency can reflect the productivity difference across farms. It helps for hunting the potentiality of the existing technology. Therefore, improvement in technical efficiency is the key for meeting the growing food grain demand in Liberia. This study provides an understanding of the aforementioned questions by analyzing smallholder rice farmers' level of technical efficiency, output loss in rice production and factors affecting rice production efficiency in Bein Garr and Panta Districts, Central Liberia.

Theoretical framework
Stochastic production frontier analysis has been widely used to study technical efficiency in various setting since its introduction by Aigner *et al*. (1977), and Meeusen and van den Broeck (1977). The approach has two components: a stochastic production frontier serving as benchmark against which firm efficiency is measured, and a one-sided error term which has an independent and identical distribution across observations and captures technical inefficiency across production units. In analyzing technical efficiency, it is not the average output, but the maximum possible output obtainable from a given bundle of inputs, is of importance. The frontier production function is defined as the maximum possible output that a farm can produce from a given level of inputs and technology. In stochastic frontier, the disturbance term is decomposed into two components: asymmetric component which captures randomness outside the control of the farmer and the other one-sided component capturing randomness under the control of the farmer (i.e., inefficiency).
The stochastic production frontier model was used to estimate the frontier for rice farmers in the study area. The model can be expressed as:

$$Y_i = f(X_i, \beta)e^{v-u} \quad (1)$$

In the logarithm terms the SPF is expressed as

$$lnY_i = lnf(X_i, \beta) + V_i - U_i \quad (2)$$

where Y_i is the output of the ith farm; X_i is the input vector; $f(X_i, \beta)$ is continuous differentiable quasi concave production function like Cobb Douglas or Translog; β is the coefficient vector of X_i; V_i is a two sided normally distributed random error ($V \sim N[0, \sigma_v^2]$) that represents the stochastic effects outside the farmer's control and U_i inefficiency error for farmer i assumed to be half normal and independently distributed ($U_i \sim N[0, \sigma_u^2]$). Equation (2) estimated by the maximum likelihood analysis creates consistent estimators for β, $\boldsymbol{\lambda}$, and σ, where β is a vector of unknown parameters, $\lambda = \sigma_u/\sigma_v$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$.

2.0 Methodology
2.1 Study area and sampling method
The study area is restricted to Bein Garr District of Nimba County and Panta District of Bong County. Nimba and Bong ranked the highest in rice production in 2011 with about 61 600 (21.2 %) and 60 900 (21.0 %) metric tons respectively. The combined estimates of these two counties accounted for 42.2 % of the total production and 41.2 % of area of rice harvested in Liberia (NRDS, 2012). Thus, these counties were appropriate for the study. The two stage random sampling with stratification was adopted. At the first stage, villages from each district were stratified into two, viz. upland and lowland rain-fed villages. Nine upland villages and six lowland villages in Bein Garr District and eight upland villages and seven lowland villages in Panta District were listed in the first stage frame. Five upland villages and three lowland villages in Bein Garr and four upland villages and four lowland villages in Panta were sampled from the frame with probability proportional to size. Using this method, larger villages were more likely to be included in the sample than smaller villages. In the second stage, twenty-five farmers were sampled from each village with simple random sampling. The total sample size was 400 rice farmers.

2.2 Method of analysis
The models in equations 3 and 4 were estimated by single step procedure using FRONTIER version 4.1. The single step procedure estimates in a single equation, the parameters for the efficiency model, technical efficiency scores, value of Gamma (γ) and sources of inefficiency in the production system. The value of Gamma indicates the level of inefficiency such that; $\gamma = 0$ implies that deviations from the frontier are entirely due to noise as there is no evidence for the presence of inefficiency effects. The value of $\gamma = 1$ indicates that all deviations from the frontier are due to inefficiency.

2.3 Empirical model
In an empirical study, the choice of functional form is very essential, since the functional form can significantly affect the results. Most importantly, it affects the identification of the factors affecting individual performance - the sources of technical inefficiency. A likelihood ratio (LR) test was performed to investigate the adequacy of the Cobb Douglas functional form relative to the less restrictive Translog[3]. In this test, if the second-order and interaction parameters of the Translog are zero, then the Cobb Douglas is considered as an adequate representation

[3] The LR test requires estimation of the model under the null (restricted) and alternative (unrestricted) hypotheses. The test statistic is calculated as LR = -2[lnL(H0) - lnL(HA)], where lnL(H0) and lnL(HA) are values of the log likelihood functions (LLF) under the null and alternative hypotheses respectively. The degrees of freedom for the chi-square statistic are given by the difference between the number of parameters estimated under HA and H0 (Coelli *et al.* 2005; Battese *et al.* 2004).

of the data. The LR test did not reject Ho, therefore the Cobb Douglas was chosen over the Translog production specification.

The stochastic frontier production of the Cobb Douglas type was specified for this study. The model is expressed as:

$\ln(Rice) = \beta_0 + \beta_1 \ln(Land_i) + \beta_2 \ln(Seed_i) + \beta_3 \ln(Fert_i) + \beta_4 \ln(Lab_i) + (V_i - U_i)\ldots$ (3)

Where, the subscript 'i' denotes the i^{th} farmer in the sample. The variables are defined as follows:

Rice = Output of rice in kg/ha
Land = Area planted under rice in ha
Seed = Quantity of seed planted in kg/ha
Fert = Quantity of fertilizer applied in kg/ha
$\beta_{0,}\ldots\beta_4$ = Parameters to be estimated
Ln = Denotes natural logarithms
V_i = Two sided random error
U_i = One sided half-normal error

The inefficiency model (U_i) is defined by the equation as follow:

$U_i = \delta_0 + \delta_1 Education_i + \delta_2 FarmExp_i + \delta_3 Hhsize_i + \delta_4 Credit_i + \delta_5 Extension_i + \delta_6 Group_i + \delta_7 Seedtype_i \ldots\ldots\ldots\ldots$ (4)

Education = Years of education
FarmExp = Years of experience in rice production
Hhsize = Number of household member
Credit = Dummy variable showing farmer access to credit; assuming 1 if access to credit and 0 if no access to credit.
Extension = Dummy variable indicating access to extension, 1 if access to extension services and 0 if no access to extension.
Group = Dummy variable showing farmer membership to group, 1 if membership to group and 0 if non membership to group.
Seedtype = Dummy for showing the type of rice seed planted by farmer, 1 if Improved seed and 0 if local seed.

Output loss is defined as the amount of rice that has been lost due to inefficiency in production given resources and technology and is calculated by multiplying maximum output by (1-TE). Maximum output per hectare is computed by dividing the actual output per hectare of individual farmers by its efficiency score.

$OL = maximum\ output(1 - TE)\ldots\ldots\ldots\ldots$ (5)

Where: OL = Output loss; TE = Technical efficiency

3.0 Results and Discussion

3.1 Estimation of frontier production function and factors explaining inefficiency

The parameters of the stochastic frontier production function were estimated using the maximum likelihood estimation (MLE) and the results are presented in Table 1. The estimated value of gamma ($\boldsymbol{\lambda}$) was 0.530 and highly significant at 1 % level of significance. This implies that 53 % of the variation of actual productivity from the frontier was due to technical inefficiency and was mainly farmers' practices rather than random variability.

Further, the estimates of the stochastic frontier have shown that the estimated value of the coefficient of land (area cultivated under rice) was negative and highly significant, indicating overuse of the input in rice production. The estimated value of fertilizer was positive and highly significant, indicating fertilizer to be productive input in enhancing rice productivity in the study area. Seed has shown positive impact on output, however, the coefficient was not statistically significant. The estimated coefficient for labor was negative, but was not statically significant. Positive and statistically significant value of the estimated coefficients indicate that producers could increase per unit area of output by applying more units of the inputs.

Table 1: Maximum likelihood estimates of stochastic frontier production function for sample rice farmers

Variables	Parameters	Coefficient	Standard error	t-ratio
Constant	β_0	7.782	0.765	10.167***
Area planted (land)	β_1	-0.172	0.052	-3.329***
Seed	β_2	0.015	0.065	0.234
Fertilizer	β_3	0.150	0.020	7.342***
Labor	β_4	-0.009	0.142	-0.060
Inefficiency effects				
Constant	δ_0	0.305	0.567	0.538
Education	δ_1	-0.050	0.034	-1.468*
Farming experience	δ_2	-0.272	0.073	-3.738***
Household size	δ_3	-0.153	0.105	-1.459*
Credit access	δ_4	-0.334	0.112	-2.988***
Extension services	δ_5	-0.137	0.141	-0.972
Group membership	δ_6	-0.210	0.107	-1.952*
Type of seed used	δ_7	-0.550	0.087	-6.3***
Diagnostic statistics				
Sigma square	σ^2	0.274	0.038	7.236***
Gamma	γ	0.530	0.207	2.557***

Number of observation = 400; Log likelihood function = -297.94; LR test = 66.87
***Significant at 1%; **Significant at 5%; *Significant at 10%

3.2 Distribution of technical efficiency estimates with actual output of rice production in the Bein Garr and Panta Districts

The mean technical efficiency estimate for the sampled rice farmers in Bein Garr and Panta District, Central Liberia was 55% with 14 and 88% as the minimum and maximum, respectively. The result is similar to the study of Alhassan (2008) in Northern Ghana, who found mean efficiencies of 51 and 53% of irrigated and non-irrigated rice production. The results as presented in Table 2 show that the lower the efficiency level of the farmers, the lower their actual output. The average output of the farmers in the study was about 2,200 kg/ha. Despite the observed variation in production efficiency, more than 60% of farmers have less than 60% efficiency level with output lesser than the mean output in the study area. However, the results indicate that there is a room for increasing production by improving technical and allocative efficiency for rice farmers in the study area.

Table 2: Distribution of sample rice farmers of Bein Garr and Panta Districts under different levels of technical efficiency with actual output

Efficiency range		Frequency	Relative efficiency (%)	Actual output (kg/ha)
0.10 - 0.20		2	0.5	341.15
0.21 – 0.30		18	4.5	689.18
0.31 – 0.40		49	12.3	1060.54
0.41 – 0.50		84	21.0	1473.03
0.51 – 0.60		88	22.0	1870.83
0.61 – 0.70		79	19.8	2609.28
0.71 – 0.80		67	16.8	3599.02
0.81 – 0.90		13	3.3	6796.45
0.91 – 1.00		0	0	0
Total		**400**	**100**	
Minimum	**0.14**			231.48
Maximum	**0.88**			10330.58
Mean	**0.55**			2222.61
Median	**0.55**			1851.85

3.3 Factors explaining inefficiency and output loss in rice production

In transforming physical input into output given a particular technology in the study area, some farmers were able to achieve higher technical efficiency than others. Some were found to be relatively inefficient. This divergence in the level of efficiency could be due to many factors. They are socio-economic and demographic factors. Significant factors explaining variation in efficiency among rice farmers in the study area are education, farming experience, household size, access to credit, group membership and type of seed used (Table 1). Output loss is an indication that there is still potential for enhancing technical efficiency by identifying the source of output loss. The results in Table 3 show that output loss is negatively related to farmer's actual productivity and output loss is higher at a lower efficiency level. The results (Table 1) revealed that the estimated coefficient on education is negative and statistically significant at 10% level, indicating a decrease in technical inefficiency. This implies that to an extent more education brings about decrease inefficiency (increase in efficiency) in rice production. This also indicates that farmers with more years of schooling incur significantly higher technical efficiency than farmers with less years of schooling. These results are consistent with Nganga *et al*., (2010), Oladeebo and Oluwaranti (2012) and Sadiq and Singh (2015). Farming experience also had a negative effect on technical inefficiency and was statistically significant at 1% (Table 1). Farmers with many years of rice farming experience were more technically efficient than those with few years. Farming experience provides better knowledge about the production environment in which decisions are made. It helps farmers to effectively and efficiently allocate resources, thereby allowing them to operate at higher level of efficiency. This is similar to the findings of Abdulai *et al.*, 2013, Sadiq and Singh (2015) and Saysay *et al.,* (2016b).The results (Table 3) show that farmers with high experience in rice farming achieved higher actual output, less output loss and higher efficiency level than experienced and low experienced farmers.

The estimated coefficient associated with household size was negative and statistically significant at 10 % level (Table 1). The result implies that farmers with more working members in the household increase technical efficiency. Smallholder farmer rice production is labor intensive, and as such farmers with increased household size have available labor for rice farming which could increase the quantity of rice produce. The result is in conformity with the findings of Kolawole (2006) and Saysay *et al.*, (2016a) but contrary to the findings of Narala and Zala, (2010) and Sadiq and Singh (2015). Furthermore, the results (Table 3) show that farmers who are fully involved into rice production performed better in terms of actual output in kg/ha and incurred less output loss and achieved higher efficiency than farmers who are formally employed but partly involved in rice production. Farmers that are engaged in non-farm employment could deprive the farm of valuable time to perform farming operations in a timely manner. This result is consistent with the findings of Rahman (2003) and Islam *et al*., (2011) who found that non-farm employment can lead to an increase in inefficiency, but contrary to Hyuha *et al.,* (2007) who found that access to off-farm income increases efficiency.

Extension services play essential role in increasing efficiency in rice production although it reached only a fewer (17%) of the total farming population in the study. Table 3 reveals that farmers who have access to extension services perform significantly better in terms of achieving actual output, incurring less output loss and operating at higher level of efficiency. The result shows a negative coefficient and strongly statistically significant effect of access to credit (Table 1). Access to credit reduces the problem of getting cash that usually affects farmers during the production period, and it enhances the use of agricultural inputs in production by ensuring that farmers secure the appropriate inputs in time. The results (Table 3) show that 61.3% of that farmers had access to credit and incurred less output loss and achieved higher efficiency and productivity than those with no access to credit (39.7%) in the study area. The findings is consistent with what other researchers have recently reported about the significance of credit support to the efficiency and success of smallholder farmers (Dwi *et al*., 2014; Rahman and Smolak, 2014; Sinyolo *et al*., 2016; Saysay *et al.*, 2016b). The estimated coefficient associated with group membership was negative and statistically significant at 10 % level (Table 1). Membership in farmers' group allows the farmers to have the opportunity of sharing information with other farmers and giving each other their experiences in rice production practices which can help reduce inefficiency among the farmers.

The dummy estimated coefficient for the type of seed used was negative and statistically significant at 1% level of significance. The results (Table 3) reveal a clear evidence with respect to the effect of improved variety in enhancing higher output, less output loss and higher efficiency level. Farmers that used improved seeds occurred less output loss and achieved higher rice output in kg/ha than those who used local (traditional) seeds in the study area. Hence, adopting improved (high yield) varieties in rice production will improve technical efficiency. This is in conformity with the study of Galawat and Yabe, (2012) and Baha, (2013). Furthermore, farmers who used fertilizer achieved higher rice output and efficiency, incurred less output loss than those who did not used the input.

Table 3: Output-loss in rice production and key determinants

Variables		n	Actual output (kg/ha)	Output loss (kg/ha)	Efficiency score
Level of experience					
	Low level (<5yrs)	116	1660.78	1782.26	0.45
	Experienced (5-10yrs)	105	2051.17	1571.56	0.53
	High experience (>10)	179	2687.26	1380.91	0.63
Involvement in rice farming					
	Full-time	382	2246.02	1543.15	0.56
	Part-time	18	1725.75	1636.64	0.47
Received extension services					
	Yes	67	2947.13	1541.46	0.61
	No	333	2076.83	1576.66	0.54
Credit access					
	Yes	245	2471.90	1405.70	0.60
	No	155	1828.56	1771.27	0.49
Variety used					
	Local	214	1652.18	1673.07	0.51
	Improved	186	2878.91	1438.09	0.60
Used of fertilizer					
	Yes	50	4003.05	1408.77	0.58
	No	350	1968.26	2517.45	0.54

4.0 Conclusion and Recommendation

It has been revealed that variation in output among rice farmers in Bein Garr and Panta Districts, Central Liberia is due to difference in their technical efficiency levels. Land and fertilizer have been found to be the main determinants of rice productivity in the study area. Technical efficiency varied widely among the farmers ranging from 14 to 88% with a mean of 55%. This indicates that on average, the actual output can be raised by about 45% without any additional resources in the study area. Hence, with proper management and allocation of the existing technology and resources, sufficient potential exists for improving rice productivity in the study area.

The determinants of technical efficiency of rice production included education, farming experience, household size, credit access, group membership and type of seed used. These are the influential factors shifting the production frontier. The policy implications in rice production are that inefficiency among the farmers can be reduced significantly by improving the level of both formal and informal education, creating programs for the highly experienced farmers to share their farming experiences with the less experienced ones. Policies should target on increasing and improving farmers' access to credit so as to enable them get the needed production inputs such as improved seeds and fertilizer on time. Hence, farmer's access to finance is essential in achieving the Liberia agricultural transformation agenda. Furthermore, research institutions should be supported to carry on innovative agricultural research thereby coming up with improved technologies to enhance productivity. Farmers should be encouraged to organize themselves into associations/cooperatives. Such organization of farmers should be in the form of contract farming around rice producing and processing hubs. Membership in farmers' group will allow the farmers to have the opportunity of sharing information with other farmers and their experiences in rice production practices which can help reduce inefficiency among them.

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