Efficiency analysis of rice producers: evidence from southern Ghana

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Abstract
In this study, we explored the factors that influence rice farmers' production efficiency in Ghana. This study investigates the rice farmers' technical efficiency (TE) using survey data

collected from the eastern region. The study also revealed that most farmers' production efficiency was below the production frontier, i.e., inefficient. Precisely, among the farms' production, only 13 (6.19%) were efficient under variable returns to scale (VRS), 3 (1.43%), and 4 (1.90%) were efficient under constant returns to scale (CRS) and scale efficiency, respectively. The results obtained show that the mean difference among some household and farm characteristics, including irrigation, access to extension services, credit and vehicle ownership variables, was significant, but the education level variable was insignificant. The Tobit model revealed that the rice producer's efficiency was mostly influenced by education, irrigation, access to extension, credit, and vehicle ownership. Our findings provide policy implications to enhance rice productivity.

Keywords: Technical efficiency. DEA. Rice Production. Ghana.

1. Introduction

During the early post-independence period, Ghana experienced a rapid dietary shift to rice. This trend was mainly due to increased income, favorable government pricing policies, good storability of rice, and ease of cooking (Nyanteng, 1987). Since then, rice has played an important role in ensuring food and nutrition security among rural and urban households in Ghana. It trades behind maize as the second most important cereal staple in Ghana and contributes significantly to consumer diets. With rice production being a major food source for most Ghanaians, a decline in rice production could threaten household food security. As a result, there is a crucial call for measures to be taken to improve productivity and aggregate production of rice so as to meet the unending demand for rice in Ghana and to ensure food security in general. Rice cultivation covers about 233,000 ha, with an annual average production of 641,000 metric tonnes (Statistics, 2016). There has been about 10 percent growth of rice output annually between 2008 and 2019, especially a sharp increase of 25 percent in 2019. Based on data available over the last decade, there is an indication that there has been an increase in rice production when compared to the area expansion cultivated to rice (Ministry of Food and Agriculture-MoFA, 2017).

However, domestic demand continues to be higher than supply, with the import share of rice consumed remaining above 50 percent (Statistics, 2016). This is as a result of several challenges confronting this sector. The sector is dominated by smallholder farmers, of which most of them cultivate less than 2 ha averagely. Again, challenges which include limited access to finance, irrigation facilities, processing facilities, improved productivity-enhancing, and output market often result in poor quality, low paddy yields, and uncompetitive rice likened to the imported ones. This large dependence on rice importation poses a great concern around foreign exchange imbalances and vulnerability to international rice price shocks.

Measures taken to combat these concerns include the National Rice Development Strategy of 2009 and the Planting for Food and Jobs (PFJ) campaign launched in 2017, which will not only prioritize rice but also set ambitious expansion targets for domestic rice production (Ministry of Food and Agriculture-MoFA, 2017). An example is the development of the National Rice Development Strategy (NRDS) to boost the rice sector by the Food and Agricultural Ministry in Ghana (MoFA) and was supported by Coalition for African Rice Development (CARD). This initiative is spearhead by the Japan International Cooperation Agency (JICA), New Partnership for Africa's Development (NEPAD), and Alliance for a Green Revolution in Africa (AGRA). The government's aim is to cut importation down under the flagship program by 10% (Ministry of Food and Agriculture-MoFA, 2017). The Ghana Commercial Agriculture Project (GCAP) has promoted rice cultivation in Northern Ghana under both rain-fed and irrigation systems by expanding irrigation access and matching investment grants for smallholder rice farmers (World Bank, 2017).

The significance of rice production to the nation's economic development and the role farmers play in rice production calls for a collective effort to improve the productivity and the efficiency of rice production in Ghana. It is, therefore, necessary to examine whether or not rice farmers in Ghana are making maximum use of the inputs available to them by assessing their technical efficiency. In doing so, there is the need to understand the current productive capacity of farmers regarding the factors affecting their efficiency. Although rice production's technical efficiency has been examined widely by some researchers, the studies on the efficiency of rice production in Ghana are limited. Those in Ghana also focus on the Northern sector of the nation (e.g., Abdulai & Huffman, 2000; Al-Hassan, 2008; Alhassan, 2012; Seidu, Sarpong, & Al-Hassan, 2004; Donkoh, Ayambila, & Abdulai, 2013; Yiadom-Boakye, Owusu-Sekyere, Nkegbe, & Ohene-Yankyera, 2013). We took a different direction in the study area by examining rice farmers' technical efficiency in their southern part. We used the Eastern region as a case study. No study has been done on the rice farmers' technical efficiency in the Eastern region. This study is very relevant because it gives policymakers insight into how the southern sector is also performing in terms of rice production. Every region may have different climatic conditions, soil quality, and many factors affecting rice production, so it is worth carrying out this study. We, therefore, used a nonparametric method data envelopment analysis to achieve our objective.

The rest of the paper follows as; section two takes some existing literature review; section three provides the methodology, while section four takes the results and discussion. The conclusion and policy implications are in section five.

2. Some Existing Literature Review

This study aims to identify the factors that affect the production efficiency of rice producers in Ghana. In terms of efficiency among crop farmers, many works have been carried out in many countries, including Ghana. Some of these scholars include Duy (2015) in Vietnam, Mekong Delta, Wagan et al. (2019) in Pakistan, Min et al. (2020) in China, Abdul-Rahaman et al. (2021) in Ghana. All these researchers revealed that householder/household characteristics (e.g., age, gender, education, household size, and many others), farm characteristics (e.g., farm size and herd size), and other social and institutional characteristics (e.g., cooperative member, farming experience, market information, income, off-farm income, access to credit, access to extension officers, etc.) influence technical efficiency. Concerning efficiency levels,

Duy (2015) used the Vietnam Living Standard Survey – VLSS 2008 to examine Vietnam's rice producer efficiency levels. The study revealed that the mean rice farmers' technical efficiency was 0.85. This means that there is still room for improvement to achieve efficiency. The study showed an underutilization of some production inputs such as fertilizer, herbicide, pesticide, seed, manure, and land, while labor and capital were over-utilized by the farmers. The results further showed that maize farmers in Ghana exhibit increasing returns to scale, indicating an increase in the use of the key resources available to them to improve their output.

In Pakistan, Wagan et al. (2019) used 350 rice farmers to find the technical efficiency of two region Kambar Shahdadkot and Badin. After using the DEA model, the study showed that farmers in Kambar Shahdadkot have high technical efficiency because they use more technology, and, machinery than the rice farmers in Badin.

Min et al. (2020) study in China also employed data collected in 2015 from a face-to-face interview survey of 450 households that cultivated 3096 plots located in the five major rice-producing provinces. The study showed that the average rice farmers production efficiency was 0.74. The study recommended that the Chinese government should help farmers to improve their farm efficiency to alleviate food insecurity. In Ghana, using 412 smallholder rice farmers in the Northern region, Abdul-Rahaman et al., (2021) explored the impact of rice variety adopters on rice production efficiency were also examined by . The study showed that adopted were 24% more efficient than non-adopted after using the sample selection stochastic production frontier model to deal with selection.

3. Methodology

3.1. Study area and Data Collection Procedure

The data include primary measurements collected through a household survey which was conducted between March 2019 and July 2019. A structured questionnaire was used to obtain information from the rice producers. This information includes key farm householders, including, for example, age, education, gender, and farm factors such farm size, fertilizer, chemical, seeds, labor, employed. The yield produced within the last 12 months was taken. Other information of institutional characteristics such as access to credit, extension services, and cooperative membership and relevant information based on the literature was also secured. Enumerators who speak the local language helped us offer a face-to-face interview to make the questions simple and easy for the farmers to understand.

A multistage sampling technique was employed to solicit representative farm/farmers for the study. In the first stage, we chose one district, Akyemansa, from the Eastern region of Ghana. The Eastern region is located in the southern part of the nation. The district under consideration is interesting. The reason is that about 87.2 percent of households in the Akyemansa district are engaged in agriculture. In the rural localities, nine out of ten households (90.7%) are agricultural households. Crop farming, including rice production, is dominant (98.2%) among households in the district. The district's relative humidity is about 55-59 percent throughout the year (Ghana Statistical Service, 2014). This climatic condition supports the cultivation of food crops (e.g., rice, maize, and vegetables) and tree crops such as oil palm and cocoa, which contributes significantly to household incomes in the districts (Ghana Statistical Service, 2014)

In stage two, three (3) communities were randomly selected from the district. Those three communities are Abenase, Anyinase, and Otwereso. At the final stage, we used simple random sampling techniques to capture 210 rice farm households. The farms were selected based on the community's size; thus, 80, 70, and 6 farms were selected from Anyinase, Abenase, and Otwereso, respectively.

3.2. Empirical model specification

The study’s objective is to assess the technical efficiency of rice production efficiency in Ghana. A two-stage analysis was employed in the study. In the first stage, data

envelopment analysis (DEA) was used to measure rice farmers' production efficiencies as an explicit function of unrestricted variables. We specified the model by using one output, i.e., the total production of rice harvested in kilograms per hectare (dependent variable) and five inputs, namely, farm size, fertilizer, seed, chemical, and labor cost (independent variables) (see Table 1 for detailed explanation). In contrast to one of the most parametric popular models, i.e., Stochastic Frontier Analysis (SFA), DEA, which is a non-parametric method, allows the analysis of the introduction of multiple inputs and outputs. The DEA method does not need a distributional form to be specified for the production function and the inefficiency term. Therefore, it was selected for our analysis. In the second stage, we explore how some relevant social, economic, and environmental variables, such as farm/farmer households, and institutional characteristics, can affect the rice production efficiency and using the Tobit model.

The constant returns to scale (CRS) and variable returns to scale (VRS) are known as the DEA method's two main models. Under the assumptions of CRS (where results of analyses remain constant) and VRS (where variations occur in the analyzed results), we estimated the rice productions efficiency scores, as well as the scale efficiency (SE) score in this study. Doing this analysis may help us differentiate the efficiency scores of CRS and VRS. Again, in DEA, the assumption that a producer's decision-making unit (DMU) can produce output (Y) with (X) inputs should hold for the producer with similar DMU. Thus, any new DMU generated should not differ in terms of the amount of output (Y) with the same inputs (X). Efficiency is achieved if this assumption holds. Every rice producer in Ghana's aim is to maximize its yield using variable inputs. Thus, using the Tobit model, socio-economic and institutional factors influencing rice producers' efficiency were regressed based on an output-oriented DEA VRS assumption in the final stage of the analysis, as specified below (Coelli, Prasada Rao, O'Donnell, & Battese, 2005).

$$
\begin{aligned}
&min_{\theta,\lambda}\theta \\
&subject\ to \\
&-y_i + Y\lambda \geq 0 \\
&\theta x_i - X\lambda \geq 0 \\
&N1'\lambda = 1 \\
&\lambda \geq 0
\end{aligned}
\qquad (1)
$$

where θ refers to the scalar representing efficiency score of ith decision-making unit; λ refers to a $(N \times 1)$vector of a constant. Here, there is satisfaction in the condition $\lambda \leq 1$,

with the value of 1 indicating a point on the frontier, i.e., production efficient farmer (Farrell, 1957).

In stage two, after the production efficiency scores have been generated using the DEA, a two-tailed Tobit model to identify sources of inefficiencies is utilized. This is because efficiency scores range between 0 and 1, i.e., a continuous variable. Previous studies (Dagistan, Koc, Gul, Parlakay, & Goksel Akpinar, 2009; Gül, Demircan, Yilmaz, & Yilmaz, 2016; Koc, Gul, & Parlakay, 2011; M., M., M., L., & B., 2019; Mitra, Khan, & Nielsen, 2019; Unakıtan & Kumbar, 2018) have used the Tobit model to find inefficiencies.

4. Results and Discussions

4.1. Descriptive analysis

The descriptive statistics of the variables used in the study are presented in table 1. The results show that a 745 kg/ha average total output of rice was produced among the total respondents with a farm size of 1.2 hectares and labor of 3.17 person-days per hectare. The rice farmers spent an average of GH 44.56 and GH 89.39 annually on seeds and fertilizers, respectively, with a total average of 34.11 liters of agrochemicals used. Out of the total respondents, 61% were males and an average age of 39.78 years. The average number of years spent in school was 7.76 years and a family size of 5.62 people. While 39% of the farmers had access to irrigation, only 22% had access to extension services. 41% of the respondents had access to credit, and 22% were cooperative members. Finally, about 11% own a vehicle.

Table 1: Description of variables, means, and standard deviations (SD)

Variables	Descriptions	Mean	SD
Rice output	Total output of rice harvested (Kg/ha)	745.13	602.39
Farmland size	Land area of cultivation (hectares)	1.20	0.78
Labor	Person-days/Ha	3.12	1.02
Fertilizer	Total fertilizer expenses incurred for one production year (in GH¢)	44.56	24.98
Seed	Total seed expenses incurred for one-year production (in GH¢)	89.39	73.02
Agrochemical	Total agrochemical used in liters	34.11	17.33
Gender	1 if the farmer is a male; 0 otherwise	0.61	0.45
Age	The age of the farmer (Number of years)	39.78	14.94
Education	Number of years spent in school by a farmer	7.76	5.34
Family size	Number of family members	5.62	2.91

Irrigation	1 if the farmer have access to irrigation; 0 otherwise	0.39	0.54
Extension	1 if the farmer has access to extension service; 0 otherwise	0.22	0.41
Membership	1 if the farmer is an association member; 0 otherwise	0.22	0.42
Access to credit	1 if the farmer has borrowed from formal/informal lenders or both; 0 otherwise	0.41	0.47
Vehicle ownership	1 if the farmer owns a vehicle; 0 otherwise	0.11	35.32

Source: survey results, 2019. Note during the study period, USD1= GH¢5.4

The frequency distribution scores of the sampled rice farm for VRS, CRS, and SE are presented in Table 2. The results show that the rice farm's mean production efficiency level is about 72.4% for VRS, 33.7% for CRS, and 55.2% for SE. This implies that an efficient farm should reduce its production input units by 27.6%, 66.3%, and 44.8% under VRS, CRS, and, SE respectively, to maintain the same level of output. Again, out of the 210 rice producers, only 13 (6.19%) were efficient under VRS, 3 (1.43%), and 4 (1.90%) were efficient under CRS and SE, respectively.

Table 2. Frequency distribution of technical efficiency scores

Efficiency Score	VRS	CRS	SE
0.00-0.09	0	3	0
0.10-0.19	15	30	0
0.20-0.29	7	33	13
0.30-0.39	11	74	29
0.40-0.49	23	23	37
0.50-0.59	21	18	69
0.60-0.69	66	12	21
0.70-0.79	38	7	19
0.80-0.89	11	5	13
0.90-0.99	5	2	5
1	13	3	4
Total DMUs	210	210	210
Min.	0.124	0.071	0.232
Max.	1	1	1
Mean	0.724	0.337	0.552
SD	0.203	0.211	0.307

Source: survey results, 2019

The mean production efficiency scores from key characteristics of the rice producer are shown in Table 3. The difference among the characteristics are significant for irrigation,

access to extension services, credit, and vehicle ownership variables, but the education level variable is insignificant. For example, the results revealed that farms with irrigation accessibility are 7.6% more efficient than farms without irrigation access. Also, farmers with extension services access are 5.4% more efficient than their counterparts without access to extension services.

Table 3: Summary results of the VRS production efficiency scores by some key characteristics

Characteristics	Mean	Std. Dev	P-value
Education			
High	0.729	0.108	0.2347
Low	0.719	0.090	
Irrigation			
Access to irrigation	0.762	0.147	0.0011
Non-access to irrigation	0.686	0.117	
Access to extension services			
Have access to extension services	0.751	0.104	0.0461
Do not have access to extension services	0.697	0.071	
Membership status			
Member	0.730	0.228	0.6382
Non-member	0.718	0.290	
Access to credit			
Have access to credit	0.815	0.202	0.0085
Do not have access to credit	0.633	0.334	
Vehicle ownership			
Owns a vehicle	0.771	0.072	0.0012
Do not owns a vehicle	0.677	0.180	

Source: survey results, 2019. Note: We divide the sample into two groups based on education level with the median in the sample as the breakpoint

4.2. Determinants of rice production efficiency

To further estimate the determinants of efficiency, this study employed the Tobit model. Here, the production efficiency scores were regressed on the household and farm characteristics. The results revealed that education, irrigation, access to extension, credit and vehicle ownership affects efficiency. The coefficient value of education is positive and significant, implying that educated farmer are more efficient that uneducated one. Education gives farms ideas and skills to improve productivity. The result confirms the findings of Min et al., (2020) study in China.

Also, farm with irrigation access are more likely to be efficient. In a season there are variations in climate change, which affect weather behavior, irrigation becomes a better way

to enhance rice productivity. Our findings agree with Abdul-Rahaman et al., (2021) and Twumasi et al., (2020) study in Ghana. There is a positive and significant relationship between the extension variable and production efficiency. This means that relative to farmers without access to extension services, those with gets extension officers visit are likely to be more efficient. This finding is consistent with the study of Siaw et al. (2020) and Danquah et al. (2019), which showed that extension officers help farmers to learn new skills and technologies to improve productivity.

Access to credit coefficient is also positive and significant, suggesting that farmers with access to credit probability of being efficient is higher than those without access to credit. Credit helps farmers to purchase needed inputs for production; hence, boosting farm income. The finding is in line with (Chandio & Jiang, 2018; Twumasi, Jiang, & Acheampong, 2018; Twumasi, Jiang, & Danquah, 2019) results, who argued that access to credit helps the farmer to increase their productivity as well as making farmers more efficient.

Finally, the vehicle ownership variable has a positive and significant coefficient, suggesting that the farmers who owns vehicle are more efficient. This finding is consistent with the study of Ma and Abdulai, (2019) who argued that farmers economic performance (e.g., yield and net returns) rises if they secure vehicle for their farm activities.

Table 4. IV-Tobit model results of the determinants of technical efficiency

Variables		VRS	
	Coefficient	Std. Dev.	P-Value
Gender	0.007	0.001	0.2728
Age	-0.063	0.012	0.4911
Education	0.401	0.116	0.0047**
Family size	-0.029	0.020	0.1677
Irrigation	0.018	0.044	0.0161**
Extension	0.010	0.005	0.0739*
Membership	-0.061	0.031	0.2677
Access to credit	0.106	0.103	0.0175**
Vehicle ownership	0.042	0.021	0.0039***
Constant	0.624	0.1877	0.0000***
Log-likelihood	-1642.453		

Source: survey results, 2019. Asterisks *, ** and *** represent significant levels at 10%, 5% and 1% respectively. Standard errors in parentheses

5. Conclusions and Policy Implications

Using household survey data from the eastern region of Ghana, we assessed the production efficiency level of rice farms. Based on the above analysis, the research mainly draws the following conclusions:

The results obtained shows that the mean difference among some household and farm characteristics, including irrigation, access to extension services, credit and vehicle ownership variables were significant but education level variable was insignificant. The Tobit model revealed that efficiency among the rice producer was mostly influenced by education, irrigation, access to extension, credit and vehicle ownership affects efficiency. The study also revealed that most farmers' production efficiency was below the production frontier, i.e., inefficient. Precisely, among the farms' production, only 13 (6.19%) were efficient under VRS, 3 (1.43%) and 4 (1.90%) were efficient under CRS and SE respectively

From the above results, this study offered several implications. First, the results reveal that policy designs towards access to credit should be priority. Thus, the government can intensify trade credit, where farmers can get production inputs on credit and bay back later. Also, extension services variable was a key impact in the production efficiency growth, suggesting that stakeholders and government should train more extension officers to support the farmers to achieve high production. to bring all the farmers under one union is essential. Irrigation programs are also needed by the farmers to maximize their efficiency; therefore, policies towards such programs should be enhanced by the poly maker.

The limitation of the study is that we could not cover a wild geographical area. We only focused on one region. Future researchers can consider a more regions to see if their conclusion concurs with this study.

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