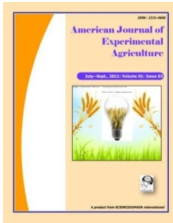

*American Journal of Experimental Agriculture*
*4(3): 244-262, 2014*

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# NERICA Adoption and Impacts on Technical Efficiency of Rice Producing Households in Ghana: Implications for Research and Development

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*This work was carried out in with the contribution from all listedauthors. Author BOA and author ANW designed the study, performed the statistical analysis, and wrote the first draft of the manuscript. Author EM was in charge of the collection and management of the data. Author DBS managed and streamlined the analyses of the study and author AMB managed the literature searches and edited the manuscript. All authors read and approved the final manuscript*

***Original Research Article***

***Received 30th September 2013***
***Accepted 3rd November 2013***
***Published 26th November 2013***

## ABSTRACT

In an effort to enhance agricultural development in Ghana, rice producers have witnessed myriads of improved agricultural technology development and dissemination. Notably among them is the Multi-national NERICA Rice Dissemination Project (MNRDP). However the empirical evidence linking these technologies to productivity indicators is limited. This paper uses cross sectional data which were collected from 200 smallholder rice producers from major rice growing districts in Ghana, to examine whether adoption of NERICA rice varieties have impacted on technical efficiency. Taking into account the endogeneity of technology adoption and assuming that impact is heterogeneous across the population,

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The propensity score matching approach was usedto estimate average treatment effect (ATE) on technical efficiency. Theanalyses revealed an adoption rate of 68 per cent among sample rice farmers. The data further suggest an average technical efficiency of 69.1 per cent. In addition, adoption of NERICA rice varieties was found to have a positive and significant impact on technical efficiency of rice producing households in the country. Besides NERICA adoption, other factors that significantly influenced technical efficiency include; education, household size, gender and non-farm income. The result also highlighted a positive influence of institutions such as NGOs and extension services on technical efficiency. The findings suggest that access to improved varieties is an essential factor to consider in promoting interventions aimed at improving technical efficiency of smallholder rice producers. Further, continuous provision of training through establishing and strengthening linkages between farmers and these institutions is recommended to enhance the smooth transformation of adoption efforts into efficient rice production among smallholder rice farmers in Ghana.

*Keywords: Impact; adoption; NERICA varieties; technical efficiency; average treatment effect (ATE).*

## ABBREVIATIONS

*AfricaRice: Africa Rice Centre; ARI: Africa Rice Initiative; ATE: Average Treatment Effect; CSIR: Council for Scientific and Industrial Research; DEA:Data Envelopment Analysis; FBO: Farmer Based Organizations; MNRDP: NERICA Rice Dissemination Project; NERICA: New Rice for Africa; NGO: Non-Governmental Organizations; OLS: Ordinary Least Squares; PSM:Propensity Score Matching; TE: Technical Efficiency; USD: United States Dollar.*

## 1. INTRODUCTION

Rice is one of the world's most important foods and is the main source of nutrition for more than half of the world population [46]. In Africa, rice has increasingly become a popular food as it is tasty and quick to cook. It competes effectively with traditional coarse grains and roots and tuber crops. Besides being an important food staple for both rural and urban communities across Ghana, it is the most important cash crop in the communities in which it is produced [6].

In Ghana, domestic demand for rice has not been adequately met by growth in local production. To meet this gap, the country currently imports about 70per cent of domestic rice requirement accounting for about USD 600 million per annum [24]. Apparently, rice is a key economic commodity in Ghana. It is one of the crops with a high potential to improve self-sufficiency hence have received reasonable attention by policy makers in the country lately.

Against this background, there have been myriads of development interventions aimed at promoting local rice production and consumption including the Multi-national NERICA Rice Dissemination Project (MNRDP). With the support from the Government of Ghana the project promoted the New Rice for Africa (NERICA) varieties together with complementary agronomic technologies under the Africa Rice Initiative (ARI), throughout Africa.

Amidst declining land holdings in sub-Saharan Africa, productivity gains has been projected to come from investment in technologies with higher levels of output given the current size of land while ensuring environmental sustainability [30,37]. In view of this, strategies towards improving productivity and efficiency must include, among others, accelerated adoption of improved crop varieties, increased restoration of soil nutrients through the use of organic and inorganic fertilizers and adoption of improved soil and water conservation technologies in order to reduce erosion and improve soil moisture content [37].Adoption of improved varieties in particular have been one of the key ways through which increased in productivity and efficiency among small scale farmers in Ghana can be achieved.

Literatures on the positive impacts of agricultural development interventions on the livelihoods of farm households in Ghana have been documented. These interventions have promoted improved technologies including high yielding crop varieties as well as best-bet agronomic practices. The impacts of these interventions have been channeled through the adoption decision making processes. These adoption decision processes have been analysed extensively with various forms of binary choice and censored regression models [1,3,4,18,23]. Least squares estimates have also revealed significantly higher efficiency and productivity among farmers who adopt and use improved agricultural technologies [36,45].

In most of these studies however, the status of sampled respondents in terms of their participation in the intervention is assumed to be random which in reality is not the case. Parameter estimates from such approach are characterised by selection and endogeneity biases [21,26,28]. In addition, there is scanty evidence on the impact of adoption of NERICA rice varieties on efficiency and productivity of rice producing households.

Approaches to minimize the bias associated with selection and endogeneity are deeply rooted in the concept of counterfactual outcome framework. These methodologies produce consistent estimates of the effect of an intervention/adoption on a randomly selected population, also known as average treatment effect (ATE). This approach has been employed to estimate the actual and potential impacts of the interventions [7,20,21,22,38].

The measurement of efficiency draws on the seminal works of Farrell [25] who suggested the efficiency of a firm consisting of two main components as technical efficiency and allocative efficiency. Technical efficiency is a measure of the ability of a firm to obtain maximum output from a set of inputs given the best available technology. Efficiency scores are performance measures or indicators used in evaluating production units including farm households. There are two main approaches for estimating efficiency, parametric and nonparametric [8,17,39,47]. The parametric can broadly be classified into two categories, namely, deterministic frontier models and stochastic frontier models. The most common nonparametric method is data envelopment analysis (DEA).

The parametric method of estimation involves econometric modelling of production frontiers. This has been widely applied in the literature [8,16,43,13]. This approach accounts for measurement error in both the output and the stochastic element of production, thereby decomposing the effect of noise from the inefficiency effect. In addition, it allows conventional statistical tests to be carried out. However it is unable to measure efficiency of multi-output cases [8,9,17]. The nonparametric DEA does not require a functional form to specify the relationship between the inputs and outputs, and also it has the ability to accommodate multiple-input and multiple-output technologies [9,17].

This paper employed the counterfactual outcome framework and estimated the impact of adoption of the NERICA varieties on technical efficiency of rice farmers in Ghana. It aims at quantifying the impact of adoption of NERICA varieties developed and disseminated to rice farmers on technical efficiency of smallholder farmers in Ghana. In addition, we explore whether establishing and strengthening institutional linkages among farmers to improve technical efficiency of smallholder farmers.

The remaining sections of this paper are presented as follows. Following this section is description of the methodology and the study area. It includes a brief overview of the MNRDP in Ghana, data collection methods and the empirical framework. The ensuing two sections present the results of analysis of the empirical findings and the implications of the result. The final section presents some concluding remarks and policy recommendations.

## 2. METHODOLOGY

### 2.1 The NERICA Rice Dissemination Project in Ghana

The Multi-national NERICA Rice Dissemination Project (MNRDP) was one of the numerous development interventions that received huge support from the Government of Ghana [35]. The MNRDP was part of an overall initiative to promote the New Rice for Africa (NERICA) varieties together with complementary agronomic technologies throughout Africa, the Africa Rice Initiative (ARI). The project was intended to ultimately contribute to poverty reduction and food security among rice producers in the country. The NERICA varieties distributed through the project are mainly NERICA 1 and NERICA 2. For the study, a farmer is said to be an adopter if he/she uses any of these varieties. The NERICA rice varieties combine their high yielding potential, disease resistance and early maturity traits together with a new potential for upland rice cultivation in Ghana [2].

In Ghana the project was implemented in 3 pilot rice producing districts namely, Ejura-Sekyeredumase and Hohoe in southern Ghana and Tolon-Kumbungu in northern Ghana. Ejura-Sekyeredumase is located on latitude 070 23’ 00.00’’ N and longitude 010 22’ 00.00’’ W. Hohoe is located on latitude 070 08’ 56.54’’ N and longitude 000 28’ 28.56’’ E. Tolon-Kumbungu is located on latitude 090 25’ 51.41’’ and 010 03’ 52.56’’ W.

The project included 3 main components, namely, technology transfer, production support and capacity building. Under technology transfer was participatory evaluation, adaptation and selection of appropriate technology mix. The identified technology mixes were designed to meet the needs of the respective agro-ecological of the targeted districts [35].

Production support was in the form of rice production infrastructure such as roads and postharvest facilities, human resource development and inputs and seed supply. While roads and postharvest facilities were to ensure effective market participation, the latter were expected to improved farm level performance. The production and distribution of certified seeds of the NERICA varieties among beneficiary farmers was very crucial for the success of the project. The creation of access to NERICA seeds bythe project facilitated the adoption of the NERICA varieties. The component on capacity building focused on market integration. It involved sensitization and training of key stakeholders to facilitate the process of market integration.

After 5 years of selection, promotions and capacity building, the MNRDP ended in 2010 [35]. The success of the MNRDP like all agricultural technology dissemination interventions can be measured by the observed changes in adoption decisions which are further translated into improved farm level performance and the overall wellbeing of beneficiaries [45]. For the

MNRDP, adoption of the NERICA rice varieties was assured through the facilitation of access to the seeds. Adoption of the NERICA rice varieties was in turn expected to impact positively on efficiency and productivity among targeted rice producing households in the country.

## 2.2 Data and Sampling Technique

The basic information for the analysis was obtained from primary data collected with the aid of objective oriented structured questionnaire. The data described rice producer and production characteristics and access to information.The study was conducted within the project districts in Ghana. A total of 200 rice producing households, 10 per community were systematically selected and interviewed. The selection of the households followed a two-stage systematic random sampling procedure. In the first stage, communities were randomly selected from a list of rice producing communities in the project districts. The second stage involved a random selection of farm households from a list of households from the selected communities.

## 2.3 Empirical Framework and Estimation Technique

In this paper, a two-stage impact estimation methodwas employed. The first stage, involves the use the stochastic frontier estimation analysis to generate technical efficiency scores following Battese and Coelli [10]. Secondly, the estimated technical efficiency scores wereregressed on NERICA adoption alongside other socio-economic, institutional and farm level covariates, which are hypothesised to affect technical efficiency. To accounts for endogeneity in the choice of variety and selection bias, the propensity score matching approachwas used[5,12,19,33] to estimate the impact of adoption on technical efficiency.

### 2.3.1 Estimating technical efficiency

This study applied the parametric approach because the rice producing environment is largely influenced by external factors. This approach specifies some functional form to represent the relationship between output and inputs. A preferred functional form has the properties identified by Coelli, et al. [17]. Both the Cobb-Douglas and the transcendental logarithmic (translog) function developed by Christensen et al. [15] satisfies these properties and are widely used in econometric estimation. Both functional forms were considered torepresent the rice production model. However, a hypothesis test result suggested that translog functional form is not an adequate representation of the data given the assumptions of the translog stochastic frontier model and was therefore not employed in the analyses.

Following Battese and Coelli [10], Cobb-Douglas production function can be specified as follows:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{5} \beta_j \ln X_{ji} + V_i - U_i \quad (1)$$

, i=1,2,3,…..,N

Where the subscript i indicate the i-th farmer in the sample:

$Y$ represents the quantity of rice harvested for the sampled farmer (in kilograms)

$X_1$ is the total area of land (in hectares) planted to rice;

$X_2$ is the total labour (in man days) used in rice cultivation;

$X_3$ is the quantity of seeds(in kilograms) used in rice cultivation;

$X_4$ is the quantity of herbicides (in kilograms)used in rice cultivation;

$X_5$ is the quantity of fertilizers (in kilograms) used in rice cultivation;

The $V_i^s$ are the random errors, assumed to be independent and identically distributed as $N(0,\sigma^2)$

The $U_i^s$ are the non-negative technical inefficiency effects assumed to be independently distributed among themselves and between the $V_i^s$, such that $U_i^s$ is defined by the truncation of the $N(\mu_i,\sigma^2)$ distribution, where is defined by a set of other explanatory variables that are hypothesized to influence technical efficiency. The magnitude of the effect of these factors will then be explored when analyzing the determinants of technical efficiency.

The variables included in the technical efficiency model are area, labour, seeds, fertilizer and herbicide. These variables are major inputs used in rice cultivation in Ghana and have been widely applied in several previous studies on technical efficiency [9,11,41,42,43].

The technical efficiency of the i-th farmer is defined by

$$TE_i = e^{-U_i} \tag{2}$$

Where is the inefficiency effects component of the model.

The parameters of the stochastic frontier production function model, defined by equation (1) are estimated by the maximum-likelihood method using the program, FRONTIER 4.1 [16].

Tests of several null hypotheses for the parameters in the frontier production function are performed using the generalized likelihood-ratio test statistic defined by

$$\lambda = -2\{\ln[L(H_0)/L(H_1)]\} \tag{3}$$

Where $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null $(H_0)$ and alternative $(H_1)$ hypotheses, respectively. If the null hypothesis is true, the test statistic has approximately a chi-squared or a mixed chi-squared distribution with degrees of freedom equal to the difference between the numbers of the parameters involved in the alternative and null hypotheses. If the inefficiency effects are absent from the model, as specified by the null hypothesis, $H_0:\delta_0=\delta_{01}=\delta_{02}=\delta_1=...=\delta_6=\gamma=0$ ,where $\gamma=\sigma^2/\sigma_S^2$ and $\sigma_S^2=\sigma_V^2+\sigma^2$, then $\lambda$ is approximately distributed according to a mixed chi-squared distribution with at least 10 degrees of freedom. In this case, critical values for the generalized likelihood ratio test are obtained from Table 1 of Kodde and Palm [32].

### 2.3.2 Estimating the impact and determinants of technical efficiency

The determinants of technical efficiency were estimated by regressing the technical efficiency scores on NERICA adoption together with other socio economic covariates such as age, gender, education, household size, non-farm income, farm level covariates such as fertilizer and herbicide use as well as other institutional covariates like access to roads, distance to market, access to agricultural development projects, access to FBOs, access to NGOs, and access to extension services using ordinary least squares regression(OLS) procedure.

The OLS regression model is explicitly expressed as:

$$TE_{Si} = \alpha_0 + \alpha_a A + \sum_{k=1}^{5} \alpha_{Hk} H_{ki} + \sum_{k=1}^{2} \alpha_{Gk} G_{ki} + \sum_{k=1}^{6} \alpha_{Ek} E_{ki} + e_i \quad (4)$$

Where $\alpha_a$ , $\alpha_{Hk}$ , $\alpha_{Gk}$ and are parameters of the $A$ , $H$ , $G$ and $E$ variables, respectively; $A$ denote NERICA adoption, $H_1$ denotes the age of the household head; $H_2$ denotes the gender of the household head; $H_3$ denotes the number of years of formal education of the household head; $H_4$ denotes the size of the household and $H_5$ denotes the nom-farm income of the household head; $G_1$ represents the use of fertilizer in rice production and $G_2$ is the use of herbicide in rice production; $E_1$ is represents access to roads; $E_2$ is the distance to market; $E_3$ denotes access to extension services; $E_4$ denotes access to agricultural development projects; $E_5$ denotes access to FBOs; $E_6$ denotes access to NGOs; and $e_i$ is the random error term in the model.

In estimating the impact of NERICA adoption on technical efficiency, it was expected that the adoption of NERICA varietieswas likely to result in two potential outcomes for any farmer selected at random. Assuming that the potential outcome for adopting NERICA verities is $y_1$ and that for not adopting is $y_0$ , then the average treatment effect which represents the expected population impact of adoption can be derived as follows:

$$TE_i = y_{i,1} - y_{i,0} \quad (5)$$

$$ATE = E\left(y_1 - y_0\right) \quad (6)$$

Where $TE_i$ denotes 'treatment effect' and represents the effect of adoption on farmer $i$ , $y_{i,1}$ the potential impact for adopters, and $y_{i,0}$ as the potential impact for non-adopters of NERICA verities.

In reality, an outcome and its counterfactual cannot be observed and so $y_1 - y_0$ is undefined for farmer $i$ . Since adoption is a necessary condition for impact, then $y_0 = 0$ for a randomly sampled farmer. This implies that the impact on farmer $i$ is $y_{i,1}$ and the average adoption impact $ATE = E(y_i)$. This in reality underestimates the true population impact because $y_1$ is observed only for adopting, a situation that may result in the problem of selection bias. If $N_A = 1$ denotes adoption and $N_A = 0$, denotes non-adoption, the average impact on the adopting sub-population, ATT, was more relevant for this study. This was derived as:

$$ATT = E(Y_1 | N_A = 1) \quad (7)$$

Where $Y_1$ = the outcome variable (technical efficiency)

Two broad approaches have been used in the quest to deal with selection bias associated with endogenous treatment variable [29]. One of the approaches is based on the assumption of conditional independence [21], which postulates the existence of a set of observed covariates k, which, when controlled for, renders the treatment status independent of the two potential outcomes. This approach also referred to as Propensity score matching was used in this study. Different matching procedures were explored and the best results were selected for the discussion.

## 3. RESULTS AND DISCUSSION

This section describes the results of the estimation of the stochastic frontier production for rice. Furthermore, the determinants of technical efficiency as well as the population impact parameters estimated for using OLS and PSM methods are presented and discussed.

### 3.1 Descriptive Statistics and Household Characteristics

Table 1 presents descriptive statistics of the sample households. Overall, 68 per cent of the farmers have adopted and cultivating the NERICA rice varieties. The average age of the heads of sample was 51 years old with males accounting for about 81 per cent. On the average, more than half of the sampled rice producers had formal education. With an almost equal gender distribution, the typical household includes an average of about 7 members.The data on institutional variables suggest that about 67 per cent of the rice producers have access to extension services. Access to Non-governmental organizations (NGOs) and farmer based organizations (FBOs) accounted for about 15 per cent and 6 per cent, respectively (Table 1). Averagely, the rice producers travelled a distance of 3.87 km to participate in markets (Table 1).

Farm level characteristics reveal that, rice producers planted an average of about 173.74 kilograms of seeds per hectare. For every hectare of rice cultivated, an average of 366.57 kilograms of fertilizer and 44 liters of herbicide were applied per household. The average production of rice was approximately 2934.53 kg per household. The average labour use was approximately 197.25 man-days per hectare. Although rice was the dominant source of household income as well as income from agriculture in general, income from non-farm activities was approximately US$107 accounting for almost 12 per cent of the total household income (Table 1).

**Table 1. Descriptive statistics of the variables in the stochastic frontier production model**

| Characteristics | Mean | Standard dev. |
|---|---|---|
| Adoption | 0.68 | |
| Average Technical efficiency | 0.69[a] | 0.14 |
| **Household covariates** | | |
| Household size (N) | 6.75 | 3.44 |
| Male producers (%) | 80.61 | |
| Female producers (%) | 19.39 | |
| Age of producer (years) | 50.88 | 12.61 |
| Educated producers (%) | 60.62 | |
| **Institutional covariates (%)** | | |
| Extension | 67.01 | |
| NGOs | 14.52 | |
| FBOs | 5.63 | |
| **Infrastructural covariates** | | |
| Existence of market (%) | 29.9 | |
| Av. distance to market (km) | 3.87 | 4.14 |
| **Farm level covariates** | | |
| Output (kg) | 2934.53 | 4600.79 |
| Area (ha) | 0.86 | 1.01 |
| Labour (man-days/ha) | 197.25 | 213.73 |
| Seed (kg/ha) | 173.74 | 183.38 |
| Fertilizer (kg/ha) | 366.57 | 1006.55 |
| Herbicides (lit/ha) | 44.88 | 454.26 |
| Agric income (USD) | 825.90 | 2004.75 |
| Nonfarm income (USD) | 107.40 | 305.65 |

[a]*significant at the 1 per cent level*

## 3.2 Empirical Results on Technical Efficiency

The maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic frontier production function are presented in Table 2. The values of the explanatory variables in the Cobb-Douglas stochastic frontier model were mean-corrected by subtracting the means of the variables so that their averages were zero. This approach indicates that the first-order parameters are estimates of output elasticities for the individual inputs at the mean values.

All estimated first-order coefficients in the production function fall between zero and one, except that for fertilizer. The negative estimate contradicts the monotonicity condition that all marginal products are positive at the mean input levels. The results indicate that seed, land, labour, fertilizer and herbicides are essential factors for rice production and the impacts of these variables on the mean rice outputs are significant. However, all these factors had a negative effect on rice output. For the reason that the technical efficiency model was used as a step in the analyses, its estimation comprised of purely production input variables.

The results further suggest that except fertilizer, all the other variables had a positive significant effect on technical efficiency. This indicates that rice producers are operating below the maximum allowable level of production given the technology available to them. Consequently, increasing the levels of land labour and quantity of seed are likely to increase their level of rice output.

**Table 2. Maximum-likelihood estimates for parameters of the Cobb-Douglas stochastic frontier production models for rice farmers in Ghana**

| Variable | Parameter | Coefficient | SE |
|---|---|---|---|
| Constant | $\beta_0$ | 0.419 | 0.047 |
| Land | $\beta_1$ | 0.015[a] | 0.099 |
| Labour | $\beta_2$ | 0.0095[a] | 0.070 |
| Seeds | $\beta_3$ | 0.039[b] | 0.038 |
| Herbicide | $\beta_4$ | 0.028[a] | 0.083 |
| Fertilizer | $\beta_5$ | -0.059[a] | 0.075 |
| Gamma | $\gamma$ | 0.367[a] | 0.054 |
| Variance parameters | $\sigma^2$ | 0.797 | 0.061 |
| Log likelihood function | | 105.19 | |

*[a]significant at the 1 per cent level, [b]significant at the 5 per cent level*

The $\gamma$-parameter associated with the variance of the technical inefficiency effects in the stochastic frontiers is estimated to be very high and was highly significant at 1 per cent. This indicates that the technical inefficiency effects are a significant component of the total variability of rice output.

This result is supported by the second hypothesis test in which the null hypothesis, $H_0 : \gamma = 0$, where $\gamma = \sigma^2 /(\sigma_V^2 + \sigma^2)$ is the ratio of the variance associated with inefficiency effects and its sum with the variance of the random errors in the rice production. The results indicated that the null hypothesis of no technical inefficiencies of rice production should be strongly rejected (Table 3). This suggests that the traditional production function is not an adequate representation of the data given the assumptions of the stochastic frontier model.

The first null hypothesis, $H_0 : \beta_{ij} = 0 \text{ for all } i \le j = 1,2,...,5$, states that the second-order coefficients in the translog production function have zero values and so, if this hypothesis is true, then the Cobb-Douglas production function applies. This null hypothesis is not rejected at 5 per cent level of significance (Table 3), implying that the Cobb-Douglas production function is an adequate representation of the data given the assumptions of the stochastic frontier model.

**Table 3. Tests of null hypotheses for parameters in the stochastic frontier production function for rice producers in Ghana**

| Null hypothesis | $\lambda$ | Critical value[a] | Decision |
|---|---|---|---|
| $H_0 : \beta_{ij} = 0 \text{ for all } i \le j = 1,2,...,7$ | 15.92 | 32.1 | Do not reject $H_0$ |
| $H_0 : \gamma = 0$ | 19.21 | 16.3 | Reject $H_0$ |

*[a] Taken from table 1 of Kodde and Palm [32] using 5 per cent level of significance.*

### 3.3 Elasticities and Returns to Scale

The estimates of the elasticities of output with respect to inputs of production are presented in Table 4. Because the variables of the Cobb-Douglas model were mean-corrected to zero, the first-order coefficients are the estimates of elasticities at the mean input levels. For the Cobb-Douglas model, the elasticities of mean rice output with respect to the different inputs depend on several parameters and values of the inputs. The elasticity of mean rice output with respect to the *j*-th input variable is defined by the following expression [9]:

$$\frac{\partial \ln E(Y_i)}{\partial \ln X_{ji}} = \{\beta_j + \sum_{k=1}^{5} \beta_{jk} \ln X_{ki}\} - C_i\left(\frac{\partial \mu_i}{\partial \ln X_{ji}}\right) \quad (9)$$

Where $\mu_i$ is the inefficiency in the model; $C_i = 1 - \frac{1}{\sigma}\left\{\frac{\phi\left(\frac{\mu_i}{\sigma} - \sigma\right)}{\Phi\left(\frac{\mu_i}{\sigma} - \sigma\right)} - \frac{\phi\left(\frac{\mu_i}{\sigma}\right)}{\Phi\left(\frac{\mu_i}{\sigma}\right)}\right\}$; $\phi$ and $\Phi$ represent the density and distribution functions of the standard normal random variable, respectively.

The empirical results show that, from the estimates of the Cobb-Douglas production function model, the estimated elasticities of mean rice output with respect to land, labour, seeds, herbicides and fertilizer, at mean input values, were 0.015, 0.0095, 0.039, 0.028 and -0.059, respectively. This indicates that, if land under rice, with the required quantities of labour, seeds, herbicides and fertilizer were to be individually increased by 1 per cent, then the mean production of rice is estimated to increase by 0.015, 0.0095, 0.039 and 0.028 per cent, and decrease by 0.059 per cent respectively. This is because the estimated output elasticity with respect to land, labour seeds and herbicides were found to be positive whiles that for fertilizer was found to be negative and was all statistically significant.

The returns to scale estimates, evaluated at the mean input a value is 0.130 (Table 4). This value is significantly less than one, indicating that rice producers in Ghana are operating under increasing returns to scale.

**Table 4. Elasticities of mean rice output with respect to inputs in the stochastic frontier production functions**

| Input | Estimated output elasticity |
|---|---|
| Land | 0.015(0.099)* |
| Labour | 0.0095(0.070) |
| Seeds | 0.039(0.038) |
| Herbicide | 0.028(0.083) |
| fertilizer | -0.059(0.075) |
| Returns to scale | 0.130 (0.365) |

**Standard errors are in parenthesis*

## 3.4 Technical Efficiency Indexes

Table 5 shows the distribution of the predicted technical efficiencies of the sample rice producers. The mean technical efficiency was estimated to be 0.691, with the maximum of 0.937and the minimum of 0.127. This implies that, on the average, the rice farmers were producing riceat about 69 per cent of the potential (stochastic) frontier production levels, given the technology currently being used. Thus, in the short run, there is capacity for increasing technical efficiency in rice production by 31 per cent without necessarily varying the existing input levels.

In the present study, in general, more than half of the producers had a mean technical efficiency in the range of 0.71–0.99. The remaining proportion of the rice producers had mean technical efficiency ranging from 0.51-0.70. This means that in general, most of the sample rice producers on the average are technically efficient in the allocation and use of inputs.

**Table 5. Percentages of technical efficiencies of rice farmers in Ghana within decile ranges**

| Interval | Percentage |
|---|---|
| <0.5 | 7.2 |
| 0.51–0.60 | 13.9 |
| 0.61–0.70 | 24.2 |
| 0.71–0.80 | 35.1 |
| 0.81–0.90 | 19.1 |
| 0.91–1.00 | 0.5 |
| N | 194 |
| Mean | 0.691 |
| SD | 0.139 |
| Maximum | 0.937 |
| Minimum | 0.127 |

## 3.5 Determinants of Technical Efficiency

A summary of the empirical results of the coefficient estimates for the determinants of technical efficiency is provided in Table 6. The result suggested that significant factors influencing technical efficiency in rice production include NERICA Adoption, Gender, Education, Access to road, Household size, NGOs, Extension and the use of Herbicide. Except for household size which had a negative effect, all the other factors positively influenced technical efficiency.

The positive significant relationships between NERICA adoption and technical efficiency levels of rice producers suggest that producers who adopted and planted NERICA varieties tended to have smaller technical inefficiencies in rice production than non-adopters, other things being equal. The results further indicated that holding other factors constant under the assumption of homogeneous impact, adoption of the NERICA rice varieties is associated with an increase of about 11 per cent in technical efficiencies on smallholder rice farms in Ghana.

The positive significant effect of the education variableimplies thateducated farmers are more technically efficient in their rice production. It is therefore an important factor to be considered in improving rice production in the country. Education augments the capacity of farmers to obtain and optimize the use of information in relation to production inputs, consequently improving their use of inputs efficiently [40,44]. In addition, improvement in resource use and hence productivity could result from enhanced human capital through increased access to educational training.

**Table 6. Determinants of technical efficiency of rice producing households in Ghana**

| Variable | Estimate | Std. error |
|---|---|---|
| NERICA Adoption | 0.114[a] | 0.0169 |
| Gender | 0.042[b] | 0.0176 |
| Age | -0.000527 | 0.000578 |
| Education | 0.00552[a] | 0.00169 |
| Access to road | 0.0351[b] | 0.0169 |
| Distance to markets | -0.00151 | 0.00176 |
| Nonfarm income | 0.0000655[b] | 0.0000256 |
| Household size | -0.00631[a] | 0.00209 |
| Agric. Projects | -0.0138 | 0.0189 |
| FBOs | 0.00394 | 0.0195 |
| NGOs | 0.0338[c] | 0.0167 |
| Fertilizer use | 0.00821 | 0.0156 |
| Herbicide use | 0.0301[c] | 0.0155 |
| Extension | 0.043[b] | 0.0187 |
| Constant | 0.555[a] | 0.0414 |
| F–stat. | 19.17[a] | |
| Adjusted $R^2$ | 0.6154 | |
| N | 194 | |

*[a]significant at the 1 per cent level, [b]significant at the 5 per cent level, [c]significant at the 10 per cent level*

In addition, non-farm income from off farm activities accruing to the household has a positive significant relationship with technical efficiency. This result suggests that the more income obtained by farmers from other non-farm activities, the more technically efficient they become. Similar results were obtained by Villano and Fleming [43] who found that non-farm income enhances farmers' ability to timely acquire the right amount of basic inputs necessary for efficient rice production hence becoming more efficient in their farming operations.

The negative effect of household size on technical efficiency suggests that farmers with small family sizes tend to be more technically efficient than those with larger farm sizes. Large household size normally place a huge demand on food requirement. With larger household size, there is the possibility of some of the household members snagging in other non-farm activities hence reducing the attention directed into rice production, this may result in lower technical efficiency. This corroborates the positive effect of non-farm income on technical efficiency (Table 6). Similar results were obtained by Oduol, et al. [37] in the Democratic Republic of Congo. The empirical result further depicts a positive effect of gender on the technical efficiency. This suggests that male farmers were more likely to be technically efficient in rice production than their female counterparts. The largely male dominated rice producers in the country could account for this.Females have limited access to production resources.

The use of herbicides was positively related with technical efficiency signifying that rice production could be improved by increasing the use of herbicides. This could be as a result of the fact that weeds control in rice production is very essential hence ability to manage and keep them in very low intensity has a significant influence on production. Rice producers in Ghana are generally financially constrained in the acquisition of inputs such as herbicides; promoting access to such inputs therefore has the potential of improving efficient rice production.

The results also suggest that institutional variables such as the existence of roads used in the transport of both inputs and produce and access to organisations that provide agricultural extension and financial services such asNGOs and access to extension are significant determinants of technical efficiency. The existence of such organisations enhances farmers' access to vital extension, financial and market information which when utilised effectively is likely to improve technical efficiency. This result is further sustained by the high proportion of farmers with access to extension (Table 1). It also signifies the significant role played by NGOs in agriculture in the country since regardless of the low proportion of farmers having access to NGOs, yet its influence on technical efficiency is significant. Positive effects have been found between such institutions and technical efficiency [14,41,42]. Development interventions aim at enhancing technical efficiency in the country could establish and strengthen linkages with these institutions and also between these institutions and farmers.

## 3.6 Impact of NERICA Adoption of on Technical Efficiency

The estimated population impact parameters for the PSM are presented in Table 7. The table shows results from three matching methods namely kernel matching, nearest neighbor matching, and stratified matching. Comparing the standard errors of the methods, the nearest neighbor matching methods were more efficient and were therefore discussed in the study.

The results suggests that adoption of NERICA varieties has had a positive and significant impact on technical efficiency of smallholder rice producers in Ghana. The estimated average impact of adoptionofNERICA varieties on technical efficiency of sample farmers was denoted by ATT. Consequently, the impact parameter suggested that adoption of NERICA rice varieties is likely to increase technical efficiency by 2.1 per centfor the semi-parametric estimates and 3.6 percent for the pure parametric estimates. This however coincides with the expectations of all stakeholders in the rice sector including development partners. Similar findings have been reported by Chaovanapoonphol, et al., [14] where impact of impact of agricultural loans was found to significantly increase technical efficiency of rice farmers in the Upper North of Thailand. In addition, Mouelhi [34] also found a positive significant impact of adoption of impact of on technical efficiency in the Tunisian manufacturing sector.

On the contrary, conflicting findings have been reported by Oduol, et al. [37] where the impact of adoption of soil and water conservation technologies were found to significantly reduce technical efficiency of small holder farmers in sub-Saharan Africa. Holden, et al. [27] and Kassie [31] also found significantly lower returns on plots with improved technologies. For this study, the inability of the treatment variable (adoption) to capture cost of adoption as well as other corresponding packages that comes with it could account for the minimal impact of NERICA on technical efficiency. Consequently, Future projects that seek to ensure access to seeds and other critical inputs should also include strategies to ensure that the cost of adoption of the varieties and that of other corresponding packages that comes with it is well thought-out.

**Table 7.Estimated population impact parameters**

| | Treated | contr. | ATT | Std. Err. | t-test |
|---|---|---|---|---|---|
| Kernel | | | | | |
| Semi parametric | 112 | 82 | 0.031 | . | . |
| Parametric | 112 | 82 | 0.035 | . | . |
| Nearest neighbor | | | | | |
| Semi parametric | 112 | 82 | 0.031[a] | 0.021 | 1.520 |
| Parametric | 112 | 67 | 0.053[b] | 0.036 | 1.492 |
| Stratification | | | | | |
| Semi parametric | 112 | 97 | 0.031[b] | 0.021 | 1.520 |
| Parametric | 112 | 97 | 0.031[b] | 0.021 | 1.520 |

*[a]significant at the 1 per cent level, [b]significant at the 5 per cent level.*

## 4. CONCLUSION

The aim of this paper was to examine whether the adoption of NERICA rice varieties introduced and disseminated among rice farmers has had an impact on technical efficiency of smallholder rice producers in Ghana. In addition, the paper focused on estimating the technical efficiency and examining its determinants among smallholder rice producers. It also explored the effectives of institutional linkages among farmers to improve technical efficiency of smallholder farmers.

The Cobb-Douglas stochastic production frontier was used to generate the technical efficiency scores. The estimated technical efficiency scores were regressed on NERICA adoption besides other socio-economic, institutional and farm level covariates, which are hypothesized to affect technical efficiency and finally to estimate the impact of adoption of NERICA varieties on technical efficiency, propensity score matching and ordinary least squares regression procedure to consistently estimate the average treatment effect.

The analyses alsorevealed a high adoption rate of 68 per cent among sample farmers. It was further established that the estimated technical efficiency ranged from 12.7 per cent to 93.7 per cent with an average of 69.1 per cent suggesting that rice farmers in Ghana could increase technical efficiency in rice production by 31 per cent without necessarily varying the existing input levels.Our findings further revealed that, adoption of NERICA rice varieties has been found to have a positive and significant impact on technical efficiency of rice producing households in the country, suggesting that the benefits of adoption of the NERICA varieties have been translated into improved technical efficiency. This suggests that access to improved varieties is an essential factor to target among others in the promoting interventions aimed at improving technical efficiency.

The result highlights institutions such as NGOs and extension services to have a positive influence on technical efficiency. This implies that continuous provision of training through the establishing and strengthening linkages between farmers and these institutions is recommended to enhance the smooth transformation of adoption efforts into efficient rice production among smallholder rice farmers in the country.

In this study, the impact of adoption on technical efficiency was examined using cross sectional dataset. A panel dataset could be obtained by conducting a complementary survey that presents the adoption and impact variables over time could allow for a more thorough analysis of the impact of the NERICA on technical efficiency over time. In addition, future research that seeks to examine the costs associated with adoption and that of other corresponding packages that come with it is essential.

## ACKNOWLEDGEMENTS

The authors of this paper wish to acknowledge the contribution of Africa Rice Center (AfricaRice) for the financial and technical support for the generation of the data. The contribution of Council for Scientific and Industrial Research (CSIR) of Ghana for the administrative support and for serving as the host for this study is also acknowledged. All technicians of who worked on this study are appreciated. The usual disclaimer applies.

## COMPETING INTERESTS

Authors declare that no competing interests exists

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