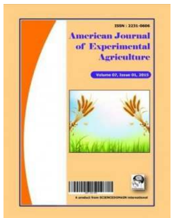

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Cost Efficiency of NERICA Producing Households in Ghana: A Modified Non-neutral Stochastic Frontier Analysis

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Authors' contributions

This work was carried out in collaboration between both authors. Author SA designed the study, was in charge of collection and management of the data, performed the statistical analysis and wrote the first draft of the manuscript. Author EEO reviewed the statistical analysis and all drafts of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: To investigate cost efficiency and its determinants on New Rice for Africa (NERICA) farms in Ghana whilst accounting for the non-usage of fertilizer and herbicides by some farmers.
Study Design: Cross sectional.
Place and Duration of Study: Kpando, Hohoe and Kadjebi Districts in the Volta Region of Ghana in the 2010/2011 cropping season.
Methodology: Single-stage maximum likelihood estimation of a modified Cobb-Douglas stochastic cost frontier and inefficiency model. The inefficiency model is extended to also account for the interactive effect of some farm specific factors on efficiency and uses a cross-sectional data on 159 farm households.
Results: The results reveal that the cost function monotonically increases in all the input prices and output. The scale economies analysis indicates that economies of scale prevail in the production of

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NERICA rice in the study area. The combined effects of farm specific factors and some interactions were found to have significant influence on cost efficiency. Estimated mean cost efficiency is 107% indicating that on average NERICA farmers incur costs about 7% above the minimum obtainable cost. Level of education is found to improve cost efficiency.

Conclusion: On the average NERICA farmers are fairly cost efficient and expanding their current scale of production will result in a decrease in per unit cost of output. Education programs designed for uneducated farmers should be introduced. The youth who are more educated should be encouraged to venture into NERICA farming. Farmers in remote districts should be provided with agricultural information and also given ready access to inputs such as fertilizer and seed.

Keywords: Stochastic frontier; cost efficiency; modified Cobb-Douglas; economies of scale.

1. INTRODUCTION

Rice is the second most important staple food after maize in Ghana and its consumption continues to increase due to population growth and changes in consumer habits [1]. The per capita consumption of rice in Ghana has risen from 12.4 kg/person/year in 1984 to an estimated 24 kg/person/year in 2009 [2] whilst the total supply of rice for 2009/2010 amounted to about 587,860 metric tons with only 34.7% of this produced locally, making Ghana a net importer of rice. Ghana depends largely on imported rice to make up for the supply deficit and such dependence on rice imports has adverse implications for food security, income generation and the fight against poverty. Considering the high level of rice consumption in Ghana, an increase in local production will make rice available at affordable prices and also raise the income of farmers [3].

Rice production in Ghana has recorded a marginal increase over the last ten years from 1999 to 2009 but the increase is attributed mainly to land area expansion [1]. Over the last three decades local production of rice in Ghana has not been able to meet local demand, calling for large imports to augment supply. Recognizing the above challenge, the government has pursued policies over the years to increase local production by employing specific measures such as increased mechanization, increased cultivation of inland valleys, varietal improvement, increased seed production and utilization.

In spite of the government efforts, considerable shortfalls in the domestic rice supply still exist. Devising means of ensuring increased and sustainable domestic production of rice for food security, import substitution and savings in foreign exchange becomes important. To contribute to increase in domestic rice production, improved production and post-harvest technologies including the release of new rice varieties such as the (New Rice for Africa) NERICA by West Africa Rice Development Association (WARDA) in collaboration with national partners was introduced in Ghana. NERICA is a new high-yielding rice variety of the upland type, developed to suite the African environment by combining the resistance of African rice (*Oryza glaberima*) to pest, disease, and water stress with the higher yielding potential of the Asian species. This was achieved through the use of complex embryo rescue techniques to cross the Asian *Oryza sativa* with the African *Oryza glaberima* rice. The first NERICA variety was developed in 1994 by researchers at WARDA. The average yield of upland rice in Ghana is 1 ton ha^{-1}, however NERICA has a potential average yield of 4.5 tons ha^{-1} when improved crop management practices are employed [1].

The development of technological innovation to improve farm income and productivity has been of prime concern for research and policy formulation over the years [4]. Growth in output is however not only determined by technological innovation and its subsequent adoption but also the efficient application of such technology. In order to investigate and improve efficiency in production, most studies on efficiency have concentrated on technical efficiency. However, it is the improvement in overall economic efficiency that will result in major gains in output [5]. Therefore the investigation of NERICA farms to ensure maximum output at the best input combinations given relative input prices is paramount. Some studies have been conducted on rice farms in Ghana to assess their performance [6-8]. However, no study has considered the investigation of cost efficiency in NERICA production in Ghana. It is against this backdrop that this study is designed to examine the cost efficiency of NERICA farms using the

Stochastic Frontier Approach (SFA). The study also explicitly models the non-usage of some input variables by farmers. This problem has been dealt with in many studies by concentrating on farmers with only positive observation for all the input variables; a method that may not be appropriate and results in biased estimates [9].

The two frontier construction techniques employed in the investigation of farm level efficiency are the non-parametric (linear programming) method generally referred to as the Data Envelopment Analysis (DEA) and the parametric (stochastic frontier approach). Reviews of both methods can be found in [10-14]. The main advantage of the stochastic frontier is its ability to account for random noise beyond the control of the farmer, a feature not found in the DEA which attributes all deviations from the frontier to inefficiency. While the DEA imposes no restrictions, the stochastic frontier has the disadvantage of specifying functional forms and imposing distributional assumptions on the error terms in the econometric estimation process thereby imposing restrictions on the data. In any case the approach to use depends on the application and for farm level data where random noise due to measurement error, missing variable and weather are likely to interfere, the SFA provides a better option [11]. Many studies in the developing world have applied the SFA to the investigation of farm level efficiency [15-17] with a number of them focusing on efficiency in rice production [6,18-22]. The rest of this paper is organised into the following sections; section 2 on materials and method describes the data on the farmers and the proposed stochastic frontier approach used, section 3 discusses the empirical results and section 4 outlines the conclusions and some recommendations.

2. MATERIALS AND METHODS

2.1 Data, Study Area and Sampling Procedure

The study is based on farm household data on NERICA rice cultivation in the Volta Region. Cross-sectional data were collected from 159 NERICA rice farmers from three districts in the Volta region namely Kpando, Hohoe and Kadjebi Districts in the 2010/2011 cropping season. A multistage stratified sampling technique was adopted for the selection of samples. First the three districts were purposively selected because they are the pilot districts for the NERICA rice dissemination project in the Region. The second stage involved a simple random selection of NERICA rice farmers from the list of farmers provided by the technical officers at the MOFA offices in the districts. A sample of 60 farmers were selected each from Hohoe and Kadjebi Districts and 39 farmers from Kpando Disrict. A smaller number of farmers were drawn from the Kpando District because it was the third district to benefit from the NERICA dissemination project and therefore has a relatively smaller number of farmers. All input costs are on a per hectare basis. This is due to large variability in land size under cultivation by the sampled farms.

Data were collected through the use of structured questionnaires. The Data collected was on relevant socioeconomic information, inputs and output of the farmers as well as price information. Summary statistics on the variables of interest are provided in Table 1. Farmers and sampled farms were located through the help of agricultural extension officers in the various districts.

2.2 Data Analysis

The stochastic frontier model to efficiency measurement is the most popularly used parametric frontier estimation method due to its stochasticity and it can fit three economic models: production, cost and profit frontiers. The stochastic frontier production function model takes the form [23-25].

$$Y_i = f(x_i;\beta).\exp(v_i - u_i) \qquad (1)$$

The stochastic frontier model (1) specifies output variability by two convoluted error terms: A symmetric random error term v_i to capture the effect of exogenous factors beyond the control of the decision making unit such as weather condition, measurement error and an asymmetric error term u_i to capture technical inefficiency. The components of the convoluted error term $(v_i - u_i)$ are independent of each other. The stochastic production frontier has a dual cost frontier that can be stated as [26]

$$C_i = f(P_i, q, \alpha).\exp(v_i + u_i) \qquad (2)$$

Where C_i is the level of total cost for observation i , $f(P_i, q; \alpha)$ represents a suitable functional form (Cobb–Douglas or transcendental logarithmic) of a row vector of input prices P_i, total output q and a vector α of unknown parameters. In the above stochastic cost frontier the u_i points out how far the farm operates above the cost frontier [27].

Table 1. Summary of variables in stochastic frontier cost function and inefficiency model

Variable	Description/Unit	Minimum	Mean	Maximum	Std. dev.
Total cost/ha	Total cost of production in GHS	514.375	1524.205	9655	948.893
Output/ha	Total output in KG	250	1850.740	5880	952.036
Cost of fertilizer/ha	Amount spent on fertilizer in GHS	0	134.314	350	77.420
Cost of herbicide/ha	Amount spent on herbicides in GHS	0	71.928	715	77.420
Cost of labour/ha	Amount spent on labour in GHS	225	1128.337	9025	897.714
Cost of seed/ha	Amount spent on seed in GHS	25	66.018	175	25.772
Other cost/ha	Depreciated value on the amount spent on hoe, sickle and cutlass in GHS	5.75	57.058	825	82.051
DF (dummy for fertilizer)	Dummy for use of fertilizer (1=yes, 0=no)	0	0.792	1	0.407
DH (dummy for herbicides)	Dummy for use of herbicides (1=yes, 0=no)	0	0.849	1	0.359
Gender	Dummy (1=male, 0=female)	0	0.723	1	0.449
Edulevel	Highest education level of main decision maker None=1 Primary Sch.=2 Junior high sch.=3 Senior high Sch.=4 Post-senior high Sch.=5 Tertiary Sch.=6	1	2.855	6	1.107
Exp	Experience in farming NERICA in years	1	2.560	5	1.204
Kadjabi	Dummy if farm is located in Kadjabi District (1=yes, 0=no)	0	0.371	1	0.485
Kpando	Dummy if farm is located in Kpando District (1=yes, 0=no)	0	0.258	1	0.439
EduExt	Interaction between education and extension visits (Number)	2	27.025	144	23.259
EduLand	Interaction between education and land area cultivated (number)	0.04	1.474	12	1.514
AgeLand	Interaction between age of household head and land are cultivated (number)	1.16	24.005	248	27.011
Land (ha)	Land area cultivated in hectares	0.04	0.497	4	0.460

Exchange rate for Ghana Cedi to US Dollar is GHS 1.43 = 1 USD (World Bank average for 2010).
Source: Field survey data, 2011

Estimation of the parameters in the stochastic frontier model is underpinned by distributional assumptions concerning the two error terms. The v_i is assumed to be independently, identically and normally distributed with mean zero and a constant variance, σ_v^2, $[v_i \sim N(0, \sigma_v^2)]$. However in the frontier literature, different distributional assumptions with various specifications have been assigned to the u_i.

Given appropriate distributional assumptions associated with cross-sectional data on the sample firms [28-30] proposed models for the technical inefficiency effects in stochastic frontier functions, and estimated the parameters of both the stochastic frontier and the inefficiency model simultaneously. A stochastic frontier model similar to that of [30] and specified for a panel data context was formulated by [31]. This study adopts the [31] model but specifies for cross-sectional data context and also incorporates a modification of the model by [30]. The stochastic frontier cost function is specified as in equation (2), where C_i, P_i, α and v_i are as defined earlier. The u_i is assumed to be independently distributed as truncation (at zero) of the normal distribution with mean $Z_i\delta$ and variance σ_u^2 such that the cost inefficiency effect, u_i in the stochastic frontier model can be specified as

$$u_i = Z_i\delta + W_i \quad (3)$$

Where W_i, is defined by the truncation of the normal distribution with mean zero and variance, σ^2 such that the point of truncation is $-Z_i\delta$, i.e. $W_i \geq -Z_i\delta$. These assumptions according to [31] are consistent with u_i being a non-negative truncation of the $N(Z_i\delta, \sigma^2)$ distribution. Z_i is a (1 x m) vector of explanatory variables associated with cost inefficiency in production which may include management, socioeconomic and demographic characteristics. δ is a (m x 1) vector of unknown parameters to be estimated.

The cost efficiency of the ith farm, denoted by CE_i, is given as the ratio of the observed cost of production of a given farm to the minimum cost. Thus the cost efficiency of the ith farm is given by model (4) [27].

$$CE_i = \frac{E(C_i/P_i, u_i = 0)}{E(C_i/P_i, u_i)} = \exp(u_i) \quad (4)$$

The CE_i estimates lie between the values of one and infinity, where CE value of one denotes a fully efficient farm and a value greater than one denotes an inefficient farm. The study employs the single–stage maximum likelihood estimation procedure to estimate the parameters of the stochastic cost frontier and the inefficiency models simultaneously[1] [31]. The farm specific cost efficiencies are estimated in terms of the parameterization $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \frac{\sigma_u^2}{\sigma^2} = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$ [25]. The parameter γ is viewed to be bounded between zero and one and for 0< γ <1, then total cost variability is characterized by both the presence of inefficiency and stochastic errors. γ taking a value of 1 is an indication that all the deviations from the frontier are due to the cost inefficiency effect, hence the stochastic frontier model collapses to the deterministic frontier model. Whereas γ taking on a value of zero means the deviations from the frontier are entirely one of random noise, hence the stochastic frontier becomes an average response function.

2.3 Model Specification

The choice of functional form in an empirical study is of particular importance. In this study, the stochastic frontier cost model of the first-order flexible Cobb-Douglas functional form is employed to estimate the farm level cost efficiency of the sample farms in the study area. The superiority of the Cobb-Douglas functional form over the others in this context is as a result of its self-dual property [26]. The Cobb-Douglas functional form is widely used in frontier studies [15,31-33]. In this study the Cobb-Douglas model for the cost function is modified to capture cases of zero observation for cost of fertilizer and cost of herbicide. This is important because using the conventional Cobb-Douglas function without it being modified to capture cases of zero observation for some of the input costs imply that attention will be paid to only farms with positive observation for all the input variables, or an arbitrarily small value greater than zero will have to be assigned to those input variables. This may result in seriously biased estimates for the parameters of the model if the number of 'zero cases' for some input cost is significant compared to the total number of sample observation [9,34].

The modified Cobb-Douglas cost frontier function for the estimation of cost efficiency of the NERICA rice farms is defined as follows.

[1] The likelihood function and its partial derivatives with respect to the parameters of the model are obtained minor alterations of the technical efficiency expressions minor alterations of the technical efficiency expressions [35].

$$LnC_i = \alpha_0 + \alpha_1 DH_i + \alpha_2 Ln[Min(CHerb_i, 1 - DH_i)] + \alpha_3 DF_i + \alpha_4 Ln[Min(CFert_i, 1 - DF_i)] + \alpha_5 Ln(CSeed_i) + \alpha_6 Ln(CLabour_i) + \alpha_7 Ln(Other\ cost_i) + \alpha_8 Ln(Output_i) + v_i + u_i \quad (5)$$

Where i and Ln are the ith farmer and the natural logarithm respectively. C_i denotes the total cost of production of the i th farmer in GH¢/ha, DF is a dummy variable for cost of fertilizer and has the value of one if fertilizer was used and zero if otherwise, CFert represent the cost of fertilizer in GH¢/ha, DH is a dummy variable for cost of herbicide and is one if herbicide was used and zero if otherwise, CHerb, represent the cost of herbicides in GH¢/ha. CSeed represents the cost of seed planted in GH¢/ha. CLabour represents the cost of labour in GH¢/ha. Output refers to the total amount of NERICA rice produced in kg/ha. Other costs refers to the total amount spent on simple farm tools such as hoe, cutlass and sickle in Ghana Cedis. The depreciated values of these items were derived using the straight line depreciation method.

The expressions: $Ln[Min(CHerb_i, 1 - DH_i)]$ and $Ln[Min(CFert_i, 1 - DF_i)]$ account for zero usage of fertilizer and herbicides respectively by some of the farmers, and the dummies DH and DF account for intercept change. If the dummy variables DH and DF were not included in the model to account for intercept change, then the estimator for the responsiveness of total cost of NERICA rice production to changes in the cost of fertilizer and herbicide will be biased [9]. The v_i and u_i are error terms defined earlier. The study assumes the marginal cost and elasticity of total cost associated with other input costs (apart from cost of fertilizer and cost of herbicides) are the same for farmers who did not use either fertilizer or herbicides as for those who did use fertilizer and herbicides.

2.4 Cost Inefficiency Source Model

The non-neutral stochastic frontier model proposed by [30] allows for the interaction between farm specific factors and input variables. Their model is defined as:

$$\mu_i = Z_i\delta + Z_i^*\delta^* \quad (6)$$

Where $Z_i\delta$ is as defined earlier, Z_i^* is the product of input variables in the frontier function and various farm specific factors (Z_i), δ^* is a vector of unknown parameters. The inefficiency effects defined by (6) is an implication that variations in the level of efficiency for each farm depends also on the level of input variables whilst the marginal products and elasticities of mean cost also depend on the respective farm specific factors specified in the inefficiency model [34]. Following [36,37] this study specifies μ_i as

$$\mu_i = Z_i^*\delta \quad (7)$$

Where Z_i^* involves operational and farm specific factors Z_i and appropriate interactions I_i and some input variables L_i. This study specifies the various operational and farm specific factors hypothesized to influence cost inefficiency of NERICA farms as:

$$u_i = \varphi_0 + \sum_{m=1}^{5} Z_{mi}\delta_m + \sum_{n=1}^{3} I_{ni}\omega_n + \tau L_i + W_i \quad (8)$$

Where W_i is as defined earlier, $\varphi_0, \delta, \omega\ and\ \tau$ are parameters to be estimated. Gender Z_1 is a dummy variable which has the value of one if the farmer is a male and zero if otherwise. Edulevel Z_2 represents the highest level of education (formal schooling) ever attained by the farmer[2]. Experience Z_3 represents the number of years the farmer has been engaged in farming NERICA rice. D_d is dummy variable for district d (d= Kpando District (KPD), Kadjebi District (KD), with Hohoe District (HD) as the base. EduExt I_1 , represents the interaction of maximum level of formal schooling and extension visit. EduL and I_2 represents the interaction of maximum level of formal schooling and land size. AgeLand I_3 represents the interaction of age of the farmer and land size under cultivation. Land (L) represent the total land size under cultivation by each farmer used to capture size effect.

2.5 Scale Economies

Considering a cost frontier model, the overall scale economies is equivalent to the reciprocal of the sum of all cost elasticity with respect to all output. Mathematically this is expressed as

$$\varepsilon_r = \left[\sum_{m=1}^{M} \frac{\partial lnC(P_i, q, \alpha)}{\partial ln q_m}\right]^{-1} \quad (9)$$

[2] *The levels of formal education is ranked as follows; None ⟹ 1, Primary level ⟹ 2, J.S.S/Middle school ⟹ 3, secondary/vocational/technical level ⟹ 4, Post-secondary level ⟹ 5, tertiary level ⟹ 6.*

Where $C(P_i, q, \alpha)$ is as defined earlier, and q_m is the mth output. The scale effect for NERICA farms is analyzed by computing returns to scale value. This is computed as the inverse of the coefficient of cost elasticity with respect to NERICA output in kg/ha as the only output in the analysis. Economies of scale (increasing returns to scale) prevail if $\varepsilon_r > 1$ and diseconomies of scale (decreasing returns to scale) prevail if $\varepsilon_r < 1$. $\varepsilon_r = 1$, implies neither economies of scale nor diseconomies of scale prevail (constant returns to scale). Economies of scale and returns to scale are equivalent measures if and only if the product is homothetic an assumption that is implicitly inherent in the Cobb-Douglas functional form [38]. All the parameters of the stochastic frontier cost function together with the inefficiency model parameters are estimated simultaneously in a single-stage maximum likelihood estimation procedure using the computer software FRONTIER version 4.l [27].

The formulation and estimation of the stochastic production frontier and the inefficiency models are based on assumptions underlying the u_i and the functional form employed; hence it is important to conduct a test of hypothesis to ascertain the adequacy of the specified models, presence of inefficiency and whether exogenous factors influence efficiency. These hypotheses are tested using the generalized likelihood ratio statistic λ, which is defined as.

$$\lambda = -2[ln\{L(H_0)\} - ln\{L(H_1)\}] \tag{10}$$

Where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the specifications of the null and alternate hypothesis respectively. The likelihood ratio test statistic λ, has approximately a chi-square (or mixed chi-square) distribution with degree of freedom equal to the number of parameters assumed to be zero in the null hypothesis provided the null hypothesis is true. According to [11], all critical values can be obtained from the appropriate chi-square distribution, but if the null hypothesis involves $\boldsymbol{\gamma}$ = 0, then λ has a mixed chi-square distribution and so the critical values for such a test are obtained from Table 1 of [39].

3. RESULTS AND DISCUSSION

Table 2 shows that most of the farmers apart from growing NERICA which is upland rice also grow rice under rain fed lowland conditions. Out of the total number of farmers who cultivate rice under other systems apart from upland rice cultivation, (69%) cultivate rice under rain fed lowland conditions. None of the sampled farms cultivated rice under irrigated conditions. The table also shows that the main source of labour on NERICA farms in the study area is hired labour representing about 50% of the labour force employed on NERICA farms. Family members provide 43% of labour and equally represent an important source of labour. The dominant mode of land preparation is through manual means i.e. the use of simple farm tool such as hoe and cutlass.

This shows the need for increased mechanization in NERICA rice farming. From the table, 70% of the farmers use manual means to prepare land and 30% use tractor services. This however may be attributed to the hilly nature of the topography that makes it difficult for the use of tractor services. On land preparation for NERICA cultivation, a large number of farmers also use herbicides, mainly glyphosate to kill the

Table 2. Distribution of farmers by production information

Production information	Item	Frequency	Percentage
Rice growing systems*	Valley bottom	26	31
	Rain fed lowland	58	69
Main source of labour	Hired labour	80	50
	Friends	11	7
	Family labour	68	43
Mode of land preparation	Manual	112	70
	Mechanized	47	30
Farm size(ha)	<0.2 ha	10	6
	0.2 - 0.4ha	108	68
	>0.4 ha	41	26

**Rice cultivation by farmers under other rice farming systems apart from upland rice*
Source: Field survey data, 2011

weeds and then planting is carried out. On farm size (68%) of the farms visited had sizes ranging from 0.2 hectares to 0.4 hectares.

The analysis of the contribution of the various input costs to the total cost incurred by the farmers in NERICA production shows that, on the average labour accounts for 72% of total cost incurred, cost of fertilizer accounts for 10%, cost of herbicides accounts for 5%, cost of seed planted accounts for 5%, cost of land accounts for 5% and cost of intermediate inputs (cutlass, hoe, sickle, knife etc.) accounts for 3%.

3.1 Hypotheses Test

The test of hypothesis for the specified model and statistical assumptions are provided in Table 3. The first null hypothesis which specifies that inefficiency effects are absent from the model at all levels is strongly rejected. Likewise the second null hypothesis which specifies that the inefficiency effects are non-stochastic is also rejected. The above two results are confirmed by the high and significant value of gamma (γ = 0.99) which is close to one, and gives an indication that the inefficiency effects are likely to be very significant in analysing the value of total cost of the farmers.

The third null hypothesis that the farm specific factors including the intercept of the cost inefficiency model are zero (i.e. the cost inefficiency effects have a simpler half-normal distribution with a mean of zero) is also strongly rejected. The fourth null hypothesis which specifies that the cost inefficiency effects are not a linear function of the various socioeconomic and farm specific factors (i.e. the cost inefficiency effects have the same truncated normal distribution with mean being the constant φ_0) is also rejected. This indicates that the joint effects of explanatory variables in the inefficiency model including their interactions are significant in explaining the variability in cost of production of the farmers, although some variables were not statistically significant. The cost inefficiencies are clearly stochastic and are related to the farm specific factors. The fifth null hypothesis that inclusion of the interaction between some farm specific factors and input variables are not important in explaining the cost inefficiency of NERICA farms in Ghana is also rejected. This implies that model (5) is an adequate representation of the data and that the interaction between education and land size; education and extension visits, age and land size are important in explaining the variability in cost efficiency. The sixth null hypothesis that specifies that the location of farms according to districts may not affect cost inefficiency is rejected. Thus there is a district effect in cost inefficiency in the region which implies that the level of efficiency of the farmers may vary depending on the district within which a farm is located. The seventh hypothesis which specify that there is no intercept change is also rejected indicating that the estimates in the frontier model would have been bias if these dummies were not included.

3.2 Frontier Model Estimates

Maximum-likelihood estimates of the parameters of the stochastic frontier cost function are presented in Table 4. Conforming to the a priori expectations, all parameter estimates of the cost of labour, fertilizer, herbicides, seed, other costs and output are positive, which agrees with the property of cost functions monotonically increasing with the prices of inputs. All parameter estimates are highly significant at 1%. This implies that the cost of labour, seed, fertilizer, herbicides, and other costs have significant influence on NERICA rice production.

Table 3. Hypotheses test for model specification and statistical assumptions

Null hypothesis	Log-likelihood value	Test statistic (λ)	Critical value ($\lambda^2_{0.001}$)	Decision
1. $H_0: \gamma = \varphi_0 = \delta_i = 0$		201.61	30.54	Reject H_O
2. $H_0: \gamma = 0$	209.23	82.45	9.5	Reject H_O
3. $H_0: \varphi_0 = \delta_i = \omega_i = \tau = 0$	250.45	119.16	29.59	Reject H_O
4. $H_0: \delta_i = \omega_i = \tau = 0$	276.31	67.46	27.88	Reject H_O
5. $H_0: \alpha_1 = \alpha_2 = \alpha_3 = \tau = 0$	284.91	50.26	18.47	Reject H_O
6. $H_0: \delta_4 = \delta_5 = 0$	288.98	42.12	13.82	Reject H_O
7. $H_0: \alpha_7 = \alpha_8 = 0$	250.83	118.42	13.82	Reject H_O

The correct critical value for the hypotheses involving $\gamma = 0$ are obtained from Table 1 in [39]

Table 4. Estimates of the stochastic cost frontier function and inefficiency model

Variables	Parameters	Estimates	t-ratios
Constant	α_0	-0.103	-68.294
Output	α_1	0.014	5.530
Cost of fertilizer	α_2	0.072	24.663
Cost of herbicides	α_3	0.043	91.515
Cost of labour	α_4	0.788	297.871
Cost of seed	α_5	0.048	30.787
Other costs	α_6	0.030	13.062
DF	α_7	0.035	21.943
DH	α_8	0.088	43.956
Inefficiency model			
Constant	φ_0	-0.712	-6.701
Gender	δ_1	-0.144	-5.170
Education level	δ_2	-0.108	-5.437
Experience	δ_3	-0.056	-3.980
Kadjabi	δ_4	1.017	10.374
Kpando	δ_5	0.686	9.010
EduExt	ω_1	0.006	4.909
EduLand	ω_2	0.092	3.496
AgeLand	ω_3	0.002*	1.400
Land	τ	-0.131*	-1.167
Variance parameters			
sigma-square	σ^2	0.023	12.566
Gamma	γ	0.999	
Llf value		310.038	

***** *Not statistically significant at any conventional level. All other estimates are significant at 0.01*

The cost elasticity with respect to all the input prices reveals that cost of labour have the highest elasticity of 0.79, indicating that a 1% increase in the cost of labour will increase total cost of production by 0.79%. 1% increase in the cost of fertilizer will increase the total cost of production by 0.07% and 1% increase in the cost of seed, herbicides and other costs will increase total production cost by 0.05%, 0.04% and 0.03% respectively. Similar results for the estimated parameters of the various input costs were found by [40,41] when investigating cost efficiency in maize production in Nepal and Nigeria respectively.

There will also be a 0.014% increase in total cost of production by a 1% increase in NERICA rice output. The parameter estimates for the intercept coefficient for fertilizer (DF) and Herbicides (DH) are both found to be positive and highly significant. This implies that the parameter estimates of the stochastic cost frontier model would have been bias if these dummies were not included. Using dummies to account for the non usage of hired and/or family labour by some farmers in fish farming in Ghana, [42] also found positive and significant estimates for the intercept terms. This revelation is further emphasized by the rejection of the seventh null hypotheses. ($H_o: \alpha_7 = \alpha_8 = 0$). The percentage of variation between total cost of production observed by farmers and minimum cost (frontier cost) that is attributed to inefficiency is given by the value of gamma. $\gamma = 0.99$ implying that inefficiency dominates random error in explaining the variation between observed cost and the frontier cost.

3.3 Scale Economies

Economies of scale exist in NERICA production since the computed value 71.43 (1/0.014) is greater than one. This result is not unexpected given the small scale nature of NERICA farms with an average size of 0.5 hectares. This result further indicates that on the average the farmers experience a decrease in total cost of production irrespective of their farm size, and given the product specification (functional form). The above derivation is an indication that NERICA farmers are experiencing increasing returns to scale, and therefore are in stage I of the production surface, implying that a proportionate increase in all inputs will results in more that proportionate increase in output (i.e. doubling all inputs by farmers will results in more that double as much output). Effort should be directed at assisting farmers to expand their present scope of production, enabling them take advantage of economies of scale, i.e. more variable inputs should be employed to increase output.

3.4 Cost Inefficiency Analysis

The estimated parameters for the cost inefficiency model are presented in Table 4. The results reveal that the coefficient for gender dummy is estimated to be negative and highly significant.

This indicates that male farmers are more cost efficient than their female counterparts. Rice cultivation is a laborious exercise considering the traditional and rudimentary nature of cultivation, and this has left most of the work in the hands of males with females doing the less laborious work such as threshing, bird scaring, and harvesting. Thus female farmers are more likely to employ a lot of hired labour which leads to incurring high cost in production. The negative coefficient estimate for education implies that farmers with higher level of education tend to be more efficient. This is in consonance with the findings of [5], who reviewed findings of the frontier literature in developing world agriculture and found education to be efficiency enhancing. Education may enhance knowledge and the ability to adopt new and improved methods of farming which eventually culminate in efficient resource allocation. The coefficient for experience is negative and significant which indicate that the farmers who have spent more years in NERICA cultivation are more cost efficient. The locational dummies to capture the effect of locational differences on efficiency were found to be positive and significant. This implies that there is district effect in production. Estimated coefficient for Kadjabi and Kpando Districts are positive and implies that farms located in these districts may be less cost efficient relative to farms located in Hohoe the base district. This result is similar to the findings of [6] who investigated the profit efficiency of rice farmers in the Northern Region of Ghana. Interaction between education and extension visits however is found to have a positive and significant coefficient estimate. This indicates that formal education tend to be more relevant in improving efficiency of farmers relative to visits by extension officers to these farms given the negative and significant coefficient estimate for education. The results again reveal that farmers with higher education who cultivate larger farms are more cost inefficient, however the relationship is statistically insignificant. Further analysis on farm size by incorporating area cultivated into the inefficiency model gives a negative coefficient estimate which indicates that as the area under cultivation expands, the cost efficiency of the average NERICA farm increases. This result only reemphasizes the results that economies of scale exist in NERICA production and that the unit cost of output eventually decreases. However the coefficient estimate in the inefficiency model is statistically insignificant.

3.5 Cost Efficiency

The efficiency analysis reveals that there is the presence of inefficiency in production and this is further confirmed by the significant gamma value of 0.99. This reveals that about 99% of the variation between the frontier cost and observed cost among the farmers is attributable to differences in their cost efficiencies. Cost efficiency is estimated as $C_{EE} = \exp(u_i)$ and the scores for all the farmers is summarized in Table 5.

Table 5. Estimated cost efficiency scores of NERICA producing households

Efficiency score	Frequency
1.0 - 1.1	132
1.2 - 1.3	24
1.4 - 1.5	2
1.6 - 1.7	0
1.8 - 1.9	1
Total	159
Mean	1.073
Minimum	1.000
Maximum	1.892
Std. deviation	0.099

The higher C_{EE} is the more cost inefficient is the farmer. The estimated cost efficiencies range from 1.0 to 1.89. The study finds that 132 farms have cost efficiency scores ranging from 1.0 to 1.1, representing about 83% of the farms. This implies that majority of farms are fairly efficient in producing a given level of output using cost minimizing input ratios which is an indication of the willingness on the part of farmers to minimize resource wastage from the perspective of cost. The above result thus reemphasizes the hypothesis by [4], that smallholder farmers are resource poor but allocative efficient.

The mean cost efficiency is estimated to be 1.07 in the production year. This estimated mean cost efficiency is slightly greater that the estimate of 1.04 found in [43]. It is however smaller compared to the estimate of 1.634 found in [40] and 1.161 in [41]. This indicates that on average NERICA farms incurred costs about 7% above the minimum cost defined by the frontier. Alternatively about 7% of the cost incurred during NERICA production is wasted in comparison to the best practice farm producing the same output given the same technology.

4. CONCLUSIONS AND POLICY IMPLICATIONS

The study adopts the stochastic cost frontier technique with a modified Cobb-Douglas functional form to assess cost efficiency and its determinants among NERICA farm households in Ghana using the single stage maximum likelihood estimation procedure. This model is extended to investigate the influence on cost efficiency of interactions between some farm specific factors and input variables. The estimated elasticity of cost with respect to the various input prices (labour, fertilizer, herbicides, seed, other costs and output) are positive and significant. The estimated returns to scale is greater than one implying that economies of scale prevail in NERICA production in the study area. On the average, cost of labour among the various input costs account for the highest share of the total cost of production (72.07%) and a 1% increase in its cost will increase the total cost of production by 0.79%. The study finds that the combined effect of operational and farm specific factors are found to influence cost efficiency. Also it is found that the inclusion of interaction between various farm specific factors and input variables incorporated into the inefficiency model are found to influence cost efficiency, and increase in the land area under cultivation is also found to enhance cost efficiency. The mean cost efficiency is estimated to be 107% indicating that on average about 7% of total cost is wasted relative to the adoption of the best practices given the level of technology. Results from the efficiency analysis indicate that majority of farmers (about 83%) are fairly efficient in producing a given output at minimum cost. However 99% of the variation between observed cost and minimum achievable cost among farmers is due to their inefficiency. The study also found that the location of farms according to districts have a significant influence on cost efficiency in the study area.

Findings of the study give the indication that although the farmers are small-scale farmers, they are fairly efficient in the use of their resources and that expanding their current scale of production will result in a decrease in the per unit cost of output, given the prevailing economies of scale obtained. Since the level of education is found to improve cost efficiency, education programs designed for uneducated farmers should be introduced to enable them improve upon their efficiency. Also the provision of education facilities and enticing the younger generation who are more educated into NERICA farming will help improve cost efficiency significantly. The results for district effect in production gives the suggestion that farmers in remote areas should be provided with agricultural information and also given ready access to capital inputs such as fertilizer and other farm inputs. Again the formation of rice grower association should be encouraged and supported to create a platform for interaction between experienced farmers and the less experienced ones.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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