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2 **TECHNICAL EFFICIENCY OF RICE**

3 **PRODUCTION AT THE TONO IRRIGATION**

4 **SCHEME IN NORTHERN GHANA**

5

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16 **ABSTRACT**

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Aim: To investigate the determinants of technical efficiency of rice farmers at Tono Irrigation
Project

Study Design: Cross sectional

Place and Duration: The Kassena-Nankana District of Upper East Region of Ghana in the
2007/2008 cropping season

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Methodology: One-step estimation of the Stochastic Frontier Model

Results: The technical efficiency estimates ranged from 0.41 to 1.00 with a mean value of 0.81. The factors that determined farmers' technical efficiency included education and the adoption of modern inputs such as seeds and chemical fertilizers.

Conclusion: The sustainability of the farmers' high efficiency will be dependent on the continuous support they receive in the areas of input supply and education, among others.

Keywords: *Rice, Stochastic Frontier Model, Technical Efficiency, Tono Irrigation Scheme, Translog Production Function.*

1. INTRODUCTION

Ironically, while we approach the deadline for the Millennium development goals (MDGs), the number of food insecure people in Africa is increasing (FAO, 2006). The FAO (2006) stresses that the continent accounts for 50 percent of the 12 million children under five, who suffer chronic hunger. This is because food production falls short of demand, implying that per capita food production is on the decline. One of the reasons that explain the precarious situation with respect to food supply in Africa is the fact that the region missed out of the Green revolution. The Green revolution combined improved seeds, inorganic fertilizers, plant protection products and irrigation, resulting in significant increases in food supply, especially in Asia (Bationo and Waswa, 2011)). Notable among the crops that the revolution targeted, was rice, which is now an important staple for almost every nation.

The cereal has become so important that at its 21st session in 2006, the International Centre for rice (IRC) chose as its theme "Rice is life" (FAO, 2006). The FAO (2006) reveals that rice supplies consumers with more calories than other staples. Against this backdrop the organization suggests that it should be an important staple for many poor people, who may

39 not be able to buy a variety of food crops in order to get the needed calories. It is along
40 these lines that stakeholders think that Africa could benefit a lot from this crop.
41 Unfortunately, while at the world level, rice supply is, at least, enough to cover consumption,
42 in Sub-Saharan Africa, supply falls short of demand, resulting in rice import bills of about 1
43 billion US Dollars annually in the region (FAO, 2006)

44

45 Rice is an important food crop in Ghana and its consumption is growing, particularly among
46 urban dwellers. The strategic nature of rice has long drawn the attention of policy makers
47 who view promoting domestic production as a means of reducing dependency on imports
48 and generating employment and income for rice growers (Randolph, 1995). For instance, it
49 is estimated that Ghana spends about US\$100 million annually to import the rice needed to
50 meet more than half of Ghana's rice requirements.

51

52 In 2005, the agricultural policy of the government was to modernize agricultural and
53 encourage agro-based industry. Also, under the US Millennium Challenge Account (MCA)
54 Aid Package, the theme for the Ghana's programme was "Reducing Poverty through
55 Agricultural Transformation." The specific objectives were to increase productivity as well as
56 competitiveness of agricultural products in regional and international markets (ISSER, 2007).

57

58 Northern Ghana accounts for the bulk of the total rice production in the country. For
59 instance, before irrigation projects gradually transformed the Accra coastal plain into a major
60 area of rice production, the Northern region alone accounted for an average of 63% of rice
61 production between 1977 and 1987. Similarly, in 1998, the three Northern Regions together
62 produced about 67% of the total rice produced in the country. The Upper East Region was
63 the largest producer of rice in the whole country in 1998 contributing about 46% of the total
64 rice produced. Over the years governments of Ghana have attempted to boost rice
65 production locally. One of such is the establishment of several irrigation projects including

66 the Ve, Afife, Kpong, Tanoso, Ashaiman, Tono, Dawhenya, Weija, Bontanga, and Aveyime,
67 among others.

68

69 **1.1 The Tono Irrigation Project**

70

71 The Tono irrigation project was constructed by the Ghana government through a state
72 company known as the Irrigation Company of the Upper Region (ICOUR). The construction
73 of the dam began in 1975 and was not completed until 1985 (ICOUR, 1989). The Tono
74 irrigation Project was proposed as part of Nkrumah's agricultural development policies to
75 "provide the north with a large share of the national development fund than ever had been
76 the case during the colonial administration." The government of Ghana funded the project
77 with loans obtained from the Canadian and British governments. The project consists of an
78 embankment across the Tono River to form a 2,490-hectare reservoir capable of providing
79 about 37 million cubic meters of water for irrigation purpose. The gross project area is about
80 3,860 hectares. However, the area developed for irrigation is about 2,490 hectares. The
81 catchment area is 650 km². The maximum surface area is 1,860 hectares and a maximum
82 storage capacity of 93x10⁶ m³. The project is demarcated into 24 zones, and belongs to
83 eight villages along the periphery of the irrigated land behind the main land. The villages
84 include Biu, Bonia, Wuru, Yagbania, Yigbwan, Korania, Gaani, and Chuchuliga. Appendix
85 1 is the map of Ghana showing the Upper East region, while Appendix 2 is a layout of the
86 Tono Irrigation project showing the communities.

87

88 Tono rice farmers enjoy some assistance from the Irrigation Company of Upper Region Ltd
89 (ICOUR) in the form of input supplies such as fertilizers, seeds and pesticides, and paying
90 back after harvest. Also, farm machinery like tractors, combine harvesters and other farm
91 implements are usually leased to farmers for a fee. Apart from these, there are advantages
92 such as fairly flat and gentle sloping lands and abundant labour supply usually during the dry

93 season when there are no rain-fed agricultural activities. The soils are also typical of the
94 savannah ochrosols, quite conducive for the cultivation of rice.

95

96 However, despite the fact that these facilities are available to almost all the farmers, it is not
97 every farmer who will necessarily take advantage and manage his or her farm well for
98 maximum output. Efficiency is dependent on farm and farmer characteristics, which
99 obviously vary across farm-firms. Thus, the objective of this study was to find out how the
100 differences in farmers' socio economic indicators as well as management practices affect the
101 efficiency levels in the Tono Irrigation sites.

102

103 **2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY**

104

105 **2.1 Stochastic frontier Model**

106 Technical Efficiency (TE) is defined as the ability to achieve a higher level of output, given
107 similar levels of inputs. In order to estimate and analyze the technical efficiency of rice
108 farmers, the Stochastic Frontier Analysis (SFA) is used. The stochastic frontier approach,
109 unlike the other parametric frontier measures, makes allowance for stochastic errors due to
110 measurement errors. The stochastic frontier model decomposes the error term into a two-
111 sided random error that captures the random effects outside the control of the firm (farmer)
112 and the one-sided inefficiency component. The level of TE is measured by the distance a
113 particular firm is from the production frontier. Thus, a firm that sits on the production frontier
114 is said to be technically efficient. TE is measured as a ratio of actual to potential output
115 (Aigner et al. 1977; Meeusen and Van den Broeck 1977). In analyzing farm level data where
116 measurement errors are substantial and weather is likely to have a significant effect, the
117 stochastic frontier method is usually recommended (Coelli 1995a).

118

119 Forsund et al. (1980) argue that inefficiency is typically related to factors that are associated
 120 with farm management practices. Such factors include education, farm size, quality of seed,
 121 labour cost, experience and sex.

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124

$$125 \quad Y_i = f(X_i\beta) \exp(V_i - U_i) \quad (1)$$

126

127 Where Y_i is the output of the i th farmer; X_i is a $(1 \times K)$ vector of farm inputs; β is a $(1 \times K)$
 128 vector of parameters to be estimated; while V_i measure the random variation in output (V_i)
 129 due to factors outside the control of the farm, U_i are factors within the control of the farm
 130 responsible for its inefficiency, V is assumed to be identically and independently distributed
 131 as $N(0, \sigma_v^2)$ and independent of U_i which is distributed as a truncated normal (at zero) of the
 132 $N(0, \sigma_u^2)$ distributions. U_i is independently, but not identically distributed.

133

134 The composed error term, ε_i is defined as

$$135 \quad \varepsilon_i = V_i - U_i \quad (2)$$

136 Also,

$$137 \quad TE = \frac{Y_i}{f(X_i\beta) \exp(V_i)} = \frac{f(X_i\beta) \exp(V_i - U_i)}{f(X_i\beta) \exp(V_i)} = \exp(-U_i) \quad (3)$$

138

139 In equation 3 the numerator is the observed output of the i -th farm, while the denominator is
 140 the output that could be produced by a fully-efficient firm using the same input vector. The
 141 measure is an output-oriented Farell (1957) measure of technical efficiency, which takes a
 142 value between zero and one. TE can be obtained by estimating β by maximum likelihood.

143

144 Battese and Coelli's (1995) model of TE effects is defined by:

145

146
$$U_i = Z_i\delta + \varepsilon_i$$

147

(4)

148 Where Z_i is a $(1 \times m)$ vector of explanatory variables associated with the TE effects; δ is a
149 $(m \times 1)$ vector of unknown parameters to be estimated; and ε_i is an unobservable two-
150 sided random variable with mean zero and constant variance. The parameters indicate the
151 impacts of variables in Z on TE. A negative value suggests a positive influence on TE and
152 vice versa. The log-likelihood function for the this stochastic frontier and inefficiency model in
153 addition to the first partial derivatives of the log-likelihood function with respect to the
154 different parameters of the model is presented in the Appendix in Battese and Coelli (1993).

155

156 In terms of the functional form of the Stochastic Frontier Model, the two commonly used are
157 Cobb Douglas and the Translog. The main advantage of the latter is that it is flexible, which
158 implies that it does not impose assumptions about constant elasticity of production nor
159 elasticities of substitutions between inputs. However, it can cause multicollinearity problems.
160 A case in point is Dawson et al. 1991. The Cobb-Douglas functional form however is not only
161 simple but it is self-dual and has been applied widely in agricultural production technologies
162 in many developing countries (Bravo-Ureta and Pinheiro, 1993). However, it has been
163 criticized for its restrictiveness. A number of studies have estimated both the Cobb-Douglas
164 and the translog functional forms and then tested the null hypothesis that the former is an
165 adequate representation of the data, given the specification of the translog functional form.
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 179 the data, given the specification of the translog functional form. The test is conducted using
 180 the generalized likelihood-ratio test (Griffiths et al. 1993).

181 The generalised likelihood- ratio test statistic is of the form:

$$182 \quad \lambda = -2\{\ln[L(H_0)] / L(H_1)\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\}$$

183

(5)

184 Where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null and
 185 alternative hypothesis H_0 and H_1 respectively. If the given null hypothesis is true then λ
 186 has approximately a chi-square (χ^2) (or a mixed chi-square distribution). On the other
 187 hand, if the null hypothesis involves $\gamma = 0$, then the asymptotic distribution involves a mixed
 188 Chi-square distribution (see Coelli, 1995a). Note that the generalized likelihood-ratio can as
 189 well be used to conduct other tests such as whether the model contains the technical
 190 efficiency term u and whether the inefficiency-effect variables are significant in determining
 191 technical efficiency. These tests are conducted in the present study.

192

193 2.2 Empirical model

194

195 In this study, the translog stochastic frontier model to be estimated is defined by

$$196 \ln y_i = \beta_0 + \sum_{j=1}^5 \beta_j \ln x_j + \sum_{j=1}^5 \sum_{k=1}^5 \beta_{jk} \ln x_{ji} \ln x_{ki} + v_i - u_i \quad (6)$$

197 Where i indicates an observation for the i-th farmer, i=1, 2, 3, .85.

198 $\ln$ represents logarithm to base e ; Y is output of rice (in kg); X_1 is land (in acres); X_2 is the
 199 quantity of seed used for planting (in kg); X_3 is quantity of solid fertilizer (in kg); X_4 is the
 200 labour hours; and X_5 is other expenditures, including liquid fertilizers and tractor services.
 201 Ideally 'other expenditure' should have been disaggregated so that the respective elasticities
 202 of the variables can be determined. However, this was not done because some of the
 203 farmers recorded zero values for some of the variables, hence the decision to use the
 204 composite variable 'other expenditure' for which there are positive values for each farmer. A
 205 similar approach has been used by Coelli and Battese (1996). All the variables are in their
 206 natural logarithm. The V_{is} are assumed to be independent and identically distributed at mean
 207 zero and constant variance, and independent of the U_{is} . on the other hand the U_{is} are non-
 208 negative assumed to be independently distributed, such that U_i is obtained by truncation (at
 209 zero) of the $N(m_i, \sigma^2)$ distribution.

210 The mean is defined by

$$211 m_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \epsilon_i \quad (7)$$

213 Where Z_1 is the number of years the farmer has been cultivating rice; Z_2 is number of years
 214 in school; Z_3 is the sex of the farmer (categorized as 1 for males and 0 for females); ϵ_i is the
 215 two-sided error term and δ_{is} is a vector of parameters to be estimated.

216 Equations 6 and 7 are estimated by Maximum Likelihood, using the computer program,
 217 FRONTIER version 4.1 (Coelli, 1996b) by Battese and Coelli's (1993, 1995) one-

218 step/simultaneous estimation procedure. The Maximum Likelihood estimation yields
219 consistent estimators for β, δ, γ and σ_{ε}^2 , where

220 $\gamma = \sigma^2 / \sigma_{\varepsilon}^2$ and $\sigma_{\varepsilon}^2 = \sigma_v^2 / \sigma^2$. Note that the γ - parameter has a value between zero and one.

221

222 **2.3 Sampling and Data collection methods**

223 Data was collected in during the 2007/2008 farming season at the Tono Irrigation Project
224 located in the Kassena-Nankana District of Upper East Region of Ghana. The choice of the
225 study area was purposive. Stratified sampling technique was used to divide the population
226 into males and females. Simple random sampling was then used to select the final
227 respondents based on their availability as at the time of data collection. In all, 85 farmers
228 involving 51 (60%) males and 34 (40%) females were interviewed. Semi-structured
229 questionnaire was the main tool used for the data collection.

230 **2.4 Descriptive statistics of variables**

231 It can be observed from Table 1 that the mean age of the sample farmers was 38.3 years.
232 This shows a youthful adult population, who when well motivated, can give off their best to
233 raise rice productivity in the study area in particular and the nation as a whole. In Ghana, the
234 years of formal education range from approximately 6 years to 19 years as follows:
235 primary=6; junior High school (JHS)=9;Senior high school (SHS)=12; and tertiary=19. The
236 mean years of formal education of 11.1 indicates that on a whole the majority of the farmers
237 had completed SHS. Also, on average the farmers had been in rice cultivation for about 11
238 years. Over 92% of farmers in Ghana farm on a small scale. The situation is not different in
239 the case of our sample farmers, considering the fact that even the maximum farm size is 5.5
240 acres. As indicated earlier land at the Tono Irrigation Dam is very scarce and with an
241 increasing population the situation keeps worsening. The mean total output of rice in kg was
242 2,420, which is about 48 mini (50kg) bags. This is quite high, considering the fact that land

holdings are generally small. Seed density is the amount of seed planted per acre of a plot. From the table, the mean quantity of rice seed planted was 94.76 kg, which is almost twice the 50kg bag. Fertilizer was 164 kg, which is also high, considering the generally low fertilizer application in Ghana. For instance, in 2008, the average inorganic fertilizer use in Ghana was 8kg/ha (MoFA, 2008). The mean labour hours was 130.38.

Table 1. Descriptive statistics of variables

Variable	Minimum	Maximum	Mean	Std.
				Deviation
Age of farmer	19.00	55.00	38.23	10.47
Years of Education	0.00	15.00	11.14	4.34
Experience	2.00	26.00	10.86	6.63
Farm size (in acres)	1.00	5.50	2.49	1.32
Total Output (in kg)	600.00	6325.00	2420.71	1310.54
Qty of seed (in kg)	40.00	190.00	94.76	43.35
Other costs				
(Expenditure)	7.00	40.00	20.57	10.36
Qty of fertilizer (in kg)	50.00	450.00	164.29	112.18
Total labour hours	69.00	649.00	226.96	130.83

Current Exchange rate: \$1= GH¢1.98

3. RESULTS AND DISCUSSION

3.1 Tests of Hypotheses

255

256 It must be recalled that the study sought to test three hypotheses. The first hypothesis was
 257 that the cob-Douglas functional form was an adequate representation of the data, given the
 258 specification of the translog functional form. That is to say that the sum of the coefficients of
 259 the squared values of the conventional inputs (land, seed, fertilizer, labour and expenditure)
 260 as well as the interaction terms are equal to zero. The second was that there were no
 261 inefficiency effects in our model. That is to say that the inefficiency term u_i is absent and
 262 that the model is an ordinary average response model with v_i as the only error term. The
 263 last test says that the variables in the inefficiency effects model (socio-economic indicators)
 264 do not explain the inefficiency term u_i . All the three null hypotheses are rejected, implying
 265 (1) the translog functional form is a better representation of the data, (2) the presence of the
 266 inefficiency term u_i and (3) the explanatory variables determine u_i respectively.

267

268 **Table 1. Tests of hypotheses for appropriate function form of stochastic frontier**
 269 **model and coefficients of the explanatory variables for the inefficiency models**

Null Hypothesis	Log-likelihood function (H_0)	Test statistic λ	Critical value	Decision
Test1	20.64	39.44	10.38 (5)	Reject H_0

$$\begin{aligned}
H_0 : \beta_{LL} + \beta_{SS} + \beta_{FF} + \beta_{BB} + \beta_{EE} = \\
\beta_{LS} + \beta_{LF} + \beta_{LB} + \beta_{LE} + \beta_{SF} = \\
\beta_{SL} + \beta_{SE} + \beta_{FL} + \beta_{FE} + \beta_{LE} = 0
\end{aligned}$$

Test 2

$H_0 : \gamma = \gamma_0 = \dots \gamma_3 = \delta = 0$	31.59	17.54	10.38 (5)	Reject H_0
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Test 3

$H_0 : \delta_1 = \dots \delta_3 = 0$	31.36	18.4	10.38(5)	Reject H_0
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270 Critical values are at 5% significant level and obtained from Table 1 of Kodde and Palm

271 (1986, P.1246).

272 Figures in Brackets are the number of restrictions.

273

274 3.2 Determinants of Output

275 The Maximum Likelihood (ML) estimates of the stochastic frontier translog and cobb-

276 Douglas production parameters for rice are presented in Table 3. In the case of the translog

277 specification, the first term variables were all significant, with the exception of fertilizer.

278 However, even though labour was significant, it had a negative sign, meaning that as the

279 variable is increased output falls. The only variable that was significant, in the case of the

280 Cobb-Douglas specification was labour. The fact that only one variable was significant in the

281 case of the latter goes to confirm the rejection of the null hypothesis that the Cobb-Douglas

282 specification was an adequate specification of the data. Notice that in the inefficiency effect

283 model also, only sex, was significant in explaining technical efficiency (in the Cobb-Douglas

284 specification).

In the case of the squared values also all the variables were significant, maintaining a negative sign. Fertilizer however maintained a positive sign. The interaction parameters were also all significant, with the exception of β_{SE} and β_{FL} for the translog specification.

The squared values in a translog model help us to know the long term effects of the variables on the dependent variable. For instance, the fact that both β_L and β_{LL} are negative means that a continuous increase in the quantity of land would lead to a reduction of output, both in the short and long run. However, since β_F is positive but β_{FF} is negative, it can be said that in the short run, increasing the quantity of fertilizer will lead to increased output but in the long run the quantity must be reduced for output to continue to increase. The same applies to the rest of the variables.

The interaction terms tell us the substitutability or complementarity of the variables. A parameter with a positive sign implies that the two variables are complementary, while a parameter with a negative sign means that the variables are substitutes. From Table 3, the significant parameters with a positive sign are β_{LS} , β_{LE} , β_{SE} and β_{SE} . The ones with a negative sign are β_{LF} , β_{LF} , β_{FE} and β_{EE} . This means that while land is complementary to seed and other expenditure, it is substitute to fertilizer and labour. Seed is also complementary to fertilizer and labour. However, expenditure is substitute to fertilizer and labour.

Table 3. Tests of hypotheses for appropriate function form of stochastic frontier model and coefficients of the explanatory variables for the inefficiency models

Variable	Parameter	Coefficient	std error	t-ratio	Coefficient	std err	t-ratio
----------	-----------	-------------	-----------	---------	-------------	---------	---------

Constant	β_0	-136.5	1.0	-133.7	1.1	1.2	0.9
Land	β_L	-28.5	1.3	-22.2***	0.5	0.7	0.7
Seed	β_S	33.0	1.2	28.2***	0.3	1.3	0.3
Fertilizer	β_F	1.0	1.1	0.9	0.1	0.2	0.8
Labour	β_B	3.2	1.4	2.3**	0.1	0.1	2.1**
Expenditure	β_E	10.8	0.9	12.3***	0.0	0.5	0.0
Land sqd	β_{LL}	-2.5	0.5	-5.2***			
Seed sqd	β_{SS}	-5.7	0.8	-7.1***			
Fertilizer sqd	β_{FF}	0.5	0.1	3.4**			
Labour sqd	β_{BB}	-0.4	0.2	-2.8**			
Exp sqd	β_{EE}	-0.4	0.1	-2.6**			
Land*Seed	β_{LS}	7.1	1.1	6.3***			
Land* Fert	β_{LF}	-1.1	0.5	-2.4**			
Land*labour	β_{LB}	-1.1	0.3	-3.3**			
Land* Exp	β_{LE}	0.7	0.4	1.7*			
Seed* Fert	β_{SF}	1.4	0.5	2.7**			
Seed*Labour	β_{SB}	1.8	0.4	4.4***			

Seed* Exp	β_{SE}	0.1	0.6	0.2			
Fert*Labour	β_{FL}	0.0	0.1	-0.2			
Fert* Exp	β_{FE}	-0.6	0.2	-2.9**			
Labour*Exp	β_{LE}	-0.4	0.2	-2.5**			
Inefficiency							
Constant	δ_0	-0.7	0.3	-2.7**	0.3	0.3	0.8
Experience	δ_1	0.0	0.0	-0.6	0.0	0.0	0.1
Education	δ_2	0.1	0.0	3.1**	0.0	0.1	-0.4
Sex	δ_3	-0.4	0.1	-5.7**	-0.3	0.2	-1.9*
sigma-sq	σ_u^2	0.04	0.0	4.8**	0.1	0.2	0.6
Gamma	γ	0.99	0.0	31.7***	1.0	0.0	611.0
Log-likelihood	-	40.36	-	-	20.64	-	-

308

309 3.3 Frequency Distribution of Technical Efficiency Scores

310

311 The technical efficiency estimates ranged from 40% to 100% with a mean value of 81%,
 312 which is comparable with other similar studies (Seidu, 2008; Bhasin 2002). The estimated
 313 gamma (γ) parameter of 0.99 in the study area indicates that 99% of the total variation in
 314 rice output is due to technical inefficiency. This can also be interpreted to mean that the
 315 differences between actual (observed) and frontier output are dominated by technical

inefficiency (i.e. factors within the control of the farmers rather than outside their control).
The result suggests that 99% of the variation in output among rice farmers is due to
differences in technical efficiency (Coelli, et al. 1998).

319

Table 4. Frequency distribution of technical efficiency scores

Class interval	Frequency	Percentage
0.41-0.50	3	3.6
0.51-0.60	0	0.0
0.61-0.70	17	20.0
0.71-0.80	17	20.0
0.81-0.90	24	28.2
0.91-1.00	24	28.2
Total	85	100

Mean value=0.81; Minimum value=0.40; maximum value=1.00; standard deviation=0.14

322

3.4 The sources of inefficiency

The sources of inefficiency are discussed using the estimated (5) coefficients associated
with the inefficiency effects in Table 3. Variables with negative coefficients have negative
relations with inefficiency. The opposite is the case for variables with positive coefficients.

The determinants of inefficiency were sex and the level of education of rice farmers.

328

329 The negative sign of the education variable means that farmers with more years of formal
330 education tended to be more technically efficient or were less technically inefficient, and the
331 negative coefficient of the sex variable also means that male farmers were more technically
332 efficient (or less technically inefficient) than their female counterparts. Figures 1 to 4 below
333 give a pictorial explanation of the sources of technical efficiency of farmers in the study area.
334 The average efficiency of male farmers was just 1% greater than that of female farmers. In
335 the case of education, clearly, there was only 1% difference between the technical
336 efficiencies of secondary/technical school leavers and tertiary school leavers in favour of the
337 latter. The technical efficiency of the latter, however, is greater by 10% than that of those with
338 little or no formal education. Contrary to our *a priori expectation*, farmers with a greater
339 number of years of experience in rice cultivation tended to have lower efficiency levels
340 compared with their 'inexperienced' counterparts. Sometimes, the reason for inefficiency on
341 the part of farmers with long years of experience, is complacency, leading to the refusal to
342 adopt innovative ways of farming. Figure 4 also depicts the fact technical efficiency is higher
343 for smaller farms than bigger farms.

344

345

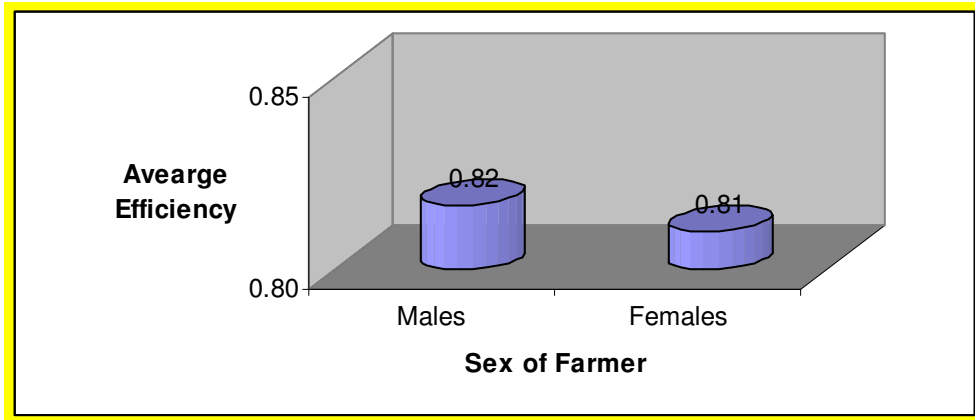
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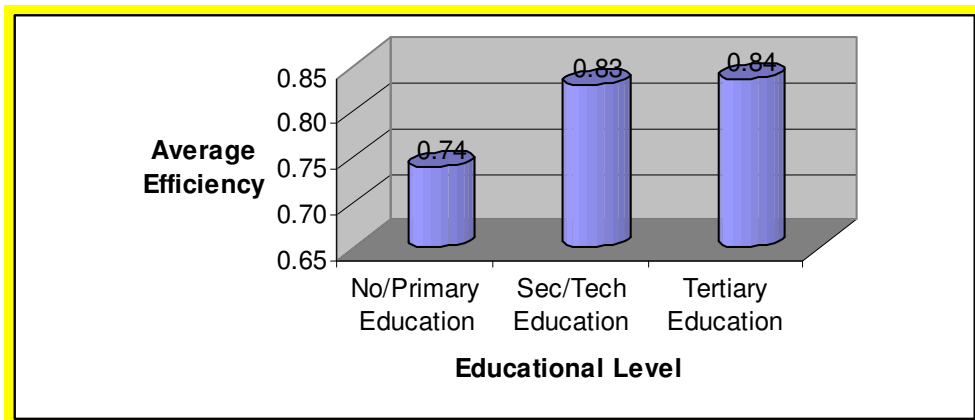
350 Figure 1: Sex of Farmers and Technical Efficiency



351

352 **Figure 2: Educational level of farmers and technical efficiency**

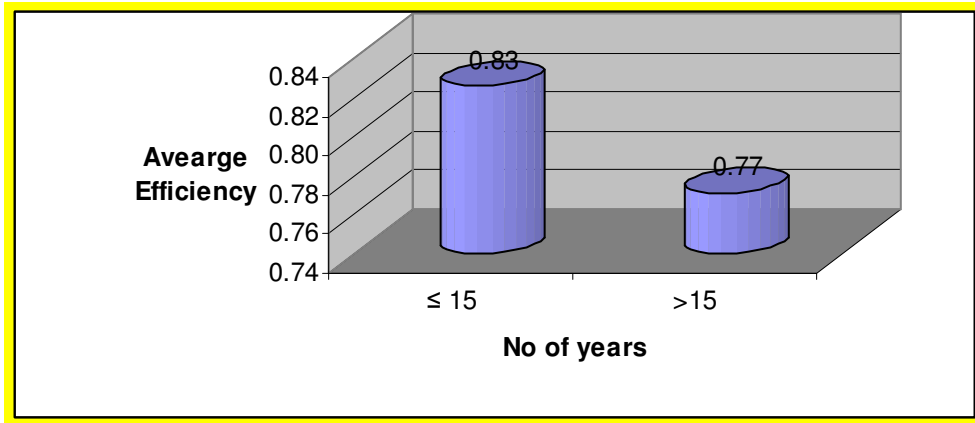
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356 **Figure 3: Experience of Farmers and Technical Efficiency**



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361 **Figure 4: Farm size and technical efficiency**

362



363

364

365 As shown earlier, the average technical efficiency of Tono rice farmers in this present study

366 is very high (81%). Also, the estimated gamma (γ) parameter of 0.99, suggests that 99% of

367 the inefficiency of the farmers is due to factors within the control of the farmers. This means

368 that the relative contribution of noise or factors outside the control of farmers is very minimal.

369 From theory, factors outside the control of farmers include drought, floods or bushfires. The

370 high average efficiency and gamma parameter in this present study do not come as a
371 surprise, considering the intensive nature of the farming that goes on at Tono. Unlike rain-
372 fed agriculture which is exposed to the vagaries of the weather, farming at the Tono Dam is
373 a dry season one, where farmers do not only have water supply (from the dam), but do also
374 have supply of inputs such as fertilizer, seeds, and pesticides, sometimes on credit. Farm
375 machinery like tractors, combine harvesters and other farm implements are also usually
376 available for hiring. However, since these inputs are generally for sale, the quantities that
377 would be bought by the individual farmers depend on their financial statuses and the
378 expected returns, among others. For policy formulation, it is important to note that
379 agricultural intensification, made possible by the availability of irrigation water and the timely
380 supply of other inputs, goes a long way to reduce farmers' dependence on natural factors,
381 resulting in high technical efficiency.

382

383 From the results presented, the four main variables that emerged as the determinants of
384 technical efficiency in rice production in the study area were land, seed, fertilizer, education
385 and gender. These may be targeted for specific policy formulation. The "Supply of the right
386 agricultural inputs in adequate quantities and at affordable price is key to overcoming the
387 problem of low productivity in Ghana's agriculture" (ISSER, 2007). With respect to land, the
388 average plot size in the Tono irrigation site is 0.99 hectares, which is likely to reduce with
389 time, as a result of population pressures. The situation will be worse for women, considering
390 the fact that they are already disadvantaged. It was observed that not only were women
391 fewer than men, but their landholdings were also in general, smaller than that of men.

392

393 Similarly, more land must be brought under irrigation. ISSER (2010) recognizes that
394 improvement of irrigation systems is one of the most important areas that need heavy
395 investment in the country to ensure all-year round production. It stresses that this facilitates
396 full employment of the other factors of agricultural production, especially labour. In Ghana,

397 the policy objective for irrigation development is to raise productivity of irrigation water from
398 30% to 80% within a decade, starting from 2007 (MoFA, 2007). Consequently, by the end of
399 2010, there had been a first phase rehabilitation of the Tono dam, making available 1,874
400 hectares of land for cultivation. This was aside the rehabilitation of 70 dams in the three
401 northern regions within that same period (ISSER, 2010).

402

403 With respect to seed, ISSER (2005) notes that during the 2005 farming season, 20 farmers
404 and 18 seed inspectors were trained in hybrid seed maize production while 2.5 hectares of
405 Nerica (New rice for Africa) was harvested as seed base to be distributed to farmers for
406 planting. In addition, about 9.2 tonnes of (other) rice seed were produced and distributed to
407 farmers. However, these were woefully inadequate. Consequently, at the beginning of 2007
408 the government's plans were to develop and crop about 500 hectares of valley bottom sites
409 for the production of 2,500 tonnes of rice under the Inland Valley Development Project. In
410 addition, the Nerica Rice Dissemination Project planned to produce 200 tonnes of certified
411 rice seeds and further contract the production of 150 tonnes of certified seeds during the off-
412 season. Furthermore, in order to facilitate technology dissemination in Nerica rice cultivation,
413 2400 farmers were to be mobilized for training. ISSER (2010) also reports that the Savannah
414 Agricultural Research Institute (SARI) and Crop Research Institute (CRI) have developed
415 and approved the release of four improved seed varieties.

416

417 "A major component of production cost in Ghana's agriculture is the cost of inputs which are
418 very high, thus making it difficult for the many poor smallholders who dominate the sector to
419 afford them" (ISSER, 2008, P133). As reported in ISSER (2008) the price of Urea went up by
420 about 11.76% from Gh ₵ 21.57 in 2005 to Gh ₵ 24.10 in 2006. The price of NPK-15-15-15
421 also rose slightly from Gh ₵ 20.22 per 50 kg in 2005 to Gh ₵ 20.24 in 2006. However, the

price of NPK-20-20-20 fell from Gh ₵ 20.42 per 50 kg in 2005 to Gh ₵ 19.92 in 2006¹. In the case of insecticides and pesticides the prices were lower in 2006, with Actielic and Atrazine falling by as much as 26% and 23% respectively. Against the backdrop of the difficulty associated with the fertilizer subsidization, in 2010, the fertilizer programme was reviewed and a more efficient waybill system introduced to replace the existing coupon system. This was to enhance the delivery of the programme and ensure a more transparent distribution system (ISSER, 2010). Consequently, in 2010 the government subsidized 60,000 metric tonnes of fertilizer at an average cost of Gh ₵ 16.00 per bag of 50kg as part of efforts to increase productivity.

431

The role of education in the development of a country cannot be over-emphasized. Seini (2002) argues that investment in people, especially the poor and women, is key to the accelerated growth and development of Ghana. He stresses that education increases people's ability to understand issues related to the adoption of technology, thereby raising their productivity. Along similar lines Nankani (2007) argues that basic education is critical for small farmers who need to adopt new technologies, seeds and crops. The result for the present study is consistent with the findings by Abdulai and Huffman (2000), Seyoum, et al. (2000) and Seidu (2008). Seyoum, et al. (1998) find that farmers with more education respond more readily to new technology and produce closer to the frontier output. Also, Ajibefun and Daramola (2003) conclude that education is an important policy variable, which can be targeted to improve both technical and allocative efficiency. However, Kalirajan and Shand (1985) argue that even though the number of years of schooling is a productive factor, farmers' education is not necessarily related significantly to their yield achievement. Illiterate farmers, without the training to read and write, can understand a modern production technology as well as their educated counterparts, provided the technology is communicated properly. In Ghana, the implementation of new educational reforms for basic education

The Exchange rate during this period was about 1.50 Gh ₵ to 1.00 US\$. 1

448 began in 2007. The main components included teacher upgrading and deployment,
449 attainment of gender parity, the active promotion of science, technology and research; and
450 the incorporation of pre-schools into the basic education system. However, while Nankani
451 (2007) acknowledges that Ghana has made major strides in expanding gross enrolments in
452 primary education, he laments over the relative neglect of programs of adult literacy that will
453 help current farmers to absorb new methods of agriculture. He concludes that the most
454 important thing to do, if a nation is to have quality education, is to involve local government,
455 communities and parents in the running of schools.

456

457 Like our present study, Donkoh (2011), Binam et al. (2008) find male farmers to be more
458 efficient than their female counterparts. However, Doss and Morris (2001) argue that the
459 reason for lower efficiency on the part of female-headed households is their engagement in
460 non-farm activities more than their male counterparts. In Seidu (2008), the gender variable
461 was not significant. Women continue to produce and manage a large share of goods and
462 services, yet their efforts have often been hidden in the tasks associated with domestic and
463 conjugal roles (Adepoju and Oppong, 1994). Also, Ellis (1993) states that because of the
464 domestic roles (such as cooking, clearing and mending) and the biological roles of child
465 bearing and caring for children, women do not have enough time to perform other tasks
466 adequately. Farmers, especially women can be supported to rely on group assistance as an
467 alternative source of affordable human labour supply.

468

469 **4. CONCLUSION**

470

471 The study aimed at finding out the technical efficiency levels of rice farmers at the Tono
472 Irrigation Project in the Upper east region of Ghana. The method of analysis involved one-
473 step estimation of the stochastic frontier model. The mean technical efficiency was 0.81 with
474 the majority of the farmers recording efficiency levels above 0.60. The conventional inputs

that were significant in determining output were land, seed, labour and crop expenditure, most of them maintaining their expected signs. Technical efficiency was also influenced by gender and education. In terms of methodology, the translog specification of the model performed better than the cobb-Douglas specification. The former was also advantageous in helping to know the effects of the squared values as well as their interaction terms. The high average technical efficiency level of the farmers at the Tono Irrigation is largely due to the intensification nature of the farming, made possible by the supply of the dam water and other inputs for which they receive support. The sustainability of the high efficiency will be dependent on the continuous support the farmers receive in the areas of input supply and education, among others. It is recommended that a panel study is carried out to better understand the long term implications of the determinants of technical efficiency in the study area.

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609

610 **ABBREVIATIONS**

611 CRI Crop Research Institute

612 FAO Food and Agriculture Organisation

613 ICOUR Irrigation Company of the Upper Region

614 IRC International Centre for rice

615 JHS Junior High School

616 MDG Millennium Development Goals

617 MoFA Ministry of Agriculture

618 ISSER Institute of Statistical, Social and Economic Research

619 SARI Savannah Agricultural Research Institute

620 SFA Stochastic Frontier Analysis

621 SHS Senior High School

622 TE Technical Efficiency

623

624

625 **APPENDIX**

626

627 **Appendix 1: A map of Ghana showing the major irrigation schemes**

