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Technical Efficiency in Smallholder Paddy Farms in Ghana: an Analysis Based on Different Farming Systems and Gender

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Abstract
One way of achieving sustained increase in food production in developing countries is to ensure efficient utilisation of scarce agricultural resources. The present study examined farm-specific technical efficiency of smallholder rice farmers in the Upper East region of Ghana. Data were collected from a random sample of 440 smallholder rice farmers (220 irrigators and 220 non-irrigators), which comprised of 306 male farmers and 134 female rice farmers. Farm-specific technical efficiency was calculated using a transcendental logarithmic (translog) stochastic production frontier function and estimated by the maximum likelihood estimation method. The results showed that smallholder rice farmers are technically inefficient because they produce, on average, at 34% below maximum output. There is significant difference between mean technical efficiency for irrigators (48%) and non-irrigators (45%) as well as male (58%) and female (34%) farmers. Credit availability, family size and non-farm employment significantly determine technical efficiency of smallholders. A programme to accelerate provision of education and credit is needed in order to improve technical efficiency of rice farmers. The right kind, quantity and timely provision of credit should be emphasized. Lastly, the maintenance of existing irrigation projects and the provision of community-managed smallholder irrigation projects and rural infrastructure should be emphasized.
Key words: Technical efficiency, smallholder farms, gender, Upper East Region of Ghana.

1. Introduction

The stochastic frontier approach has gained popularity in farm-specific efficiency studies. In the frontier approach, the production function is estimated as the most efficient set of points in input-output space so that deviations from this frontier are used as the measure of technical inefficiency. When production processes of a sample of farms are represented in output-input space, with a given level of technology, production theory emphasizes that all observations lie on a single production function. In reality, however, this does not occur because first, random disturbances which are beyond the control of the farms, and second, real farm-specific differences in technical efficiency (Kalirajan 1981). Differences in technical efficiency imply that some farms are more successful than others in using technology efficiently.

Random disturbances beyond farmers' control are less important in explaining productivity differences because they merely reflect efficiency differences among farms as random events. However, when deviations from the frontier are as a result of differences in technical efficiency, they allow a more realistic way of measuring productivity differences between observations. This is because such deviations reflect farm-specific variability associated with decision making as individual farms seek to use the available technology efficiently. If farms use their technology efficiently, then the observations will lie on the estimated function; if they do not, the observations will lie below the function.

The agricultural sector dominates the Ghanaian economy, contributing about 40% to the Gross Domestic Product (GDP) and employing more than 60% of the labour force, mostly women (World Bank 2002). The agricultural sector is also characterised by traditional small-scale farming. Over 85% of Ghanaian farmers are smallholder operators, accounting for over 80% of total agricultural production in Ghana (Ministry of Food and Agriculture (MOFA), 2000). Economic policy in Ghana has largely been concerned with the efficiency of agricultural production and agrarian organizations. A country like Ghana, which has shortage of all factors of production except labour, obviously cannot afford to make an inefficient use of resources. It is therefore important to estimate the level of technical efficiency at the farm-level, and to identify the sources of such inefficiency. Such information is important for formulating appropriate policies for reducing the level of technical inefficiency. Measurement of technical efficiency could also help decide whether to improve efficiency first or develop a new technology in the short run.

Farm efficiency is a broad area, which can be examined by comparing the economic efficiencies of various types of farm groups (small, medium and large), or farming systems (irrigated and non-irrigated) or ecological zones. Gender and farmers' experience in crop cultivation can also be considered in economic efficiency studies. The analyses have often involved the application of primal (production function) approach or dual approaches (the use of profit and cost functions). However, recent studies of technical efficiency have used the stochastic frontier approach (involving the use of stochastic production frontier, stochastic profit frontier and stochastic cost frontier models) or the panel data approach (Kumbhakar & Heshimati 1995; Parikh & Shah 1995 and Xu & Jeffrey 1998). Each approach, however, has its advantages and disadvantages. Thus, the application of primal or dual approaches has produced varying results and conclusions partly because of differences in study location, sample size, agricultural systems or environment as well as model specification.

Rice in the Upper East region is cultivated for consumption and income purposes. The ability of smallholder rice farmers such as those in the Upper East region of Ghana to adopt new technology or to achieve sustainable small-scale production depends upon their level of technical efficiency. High technical efficiency will not only enable farmers to increase the employment of productive resources, but it will also give a direction of adjustments required in the long run to increase food production. There is strong evidence in Africa of the efficiency of smallholder farmers from Kenya, Sierra Leone, Cote d'Ivoire, Nigeria, Ethiopia and Malawi (Dittoh 1991; Phiri 1991; Olagoke 1991; Bindish & Evenson 1993; Udry 1993; Adesina & Djato 1996; Byiringiro & Reardon 1996 & Chirwa 2001).

However, no study has been done to estimate the level of technical efficiency across different rice farming systems or between male and female rice farmers in the region. There is therefore a gap in knowledge of technical efficiency of farmers growing rice in the Upper East region of Ghana. The critical questions to be answered are: What is the level of technical efficiency in resource use across smallholder rice farming systems? What socio-economic and institutional factors affect farmer technical efficiency in rice production? How do farmers' social, economic and demographic features relate to technical efficiency? To what extent does gender influence technical efficiency in the region? This present paper examines farm-specific technical efficiency with emphasis on smallholder rice farmers (irrigators, non-irrigators, males and females) in the Upper East region of Ghana in order to suggest ways to increase the levels of rice production in Ghana. Another objective is to derive farm-specific technical efficiency associated with input use and to relate the derived measure to farmer social, economic and demographic characteristics. The rest of the paper is presented as follows. Section 2 gives an overview of efficiency and stochastic production frontier. This is followed by the methodology. Section 4 contains the empirical results whereas conclusion and recommendations are in the last Section.

2. Efficiency and Stochastic Production Frontier

Statistical estimation of production frontiers can be stochastic or deterministic. The deterministic frontier takes the following general form:

$$Y = f(X)\, e^{u}, \qquad (1)$$

where Y and X are defined as above and u is a non-negative error term representing technical inefficiency. The deterministic frontier is estimated without consideration of the possibility of measurement error, statistical noise or random exogenous variations. This method permits ready calculation of the degree of inefficiency for each farm in terms of the divergence of output from the production frontier. However, it is unsatisfactory from an econometric point of view because random variations in output across farms, and even measurement error, will be wrongly attributed to inefficiency within the farm's control (Ali and

Byerlee 1991). Deterministic frontiers are also criticized on the grounds of imposing a particular functional form upon the technology (Coelli 1995).

Following the inadequacies of deterministic frontier estimation, three sets of researchers (Aigner Lovell & Schmidt 1977; Meeusen & van den Broeck 1977; and Battese & Corra 1977) simultaneously and independently developed the stochastic production frontier methodology. The stochastic frontier estimation involves the specification of the disturbance term that causes actual production to deviate from this frontier by decomposing it into two parts as follows:

$$Y = f(X_a,\beta)e^{v-u}, \qquad (2)$$

where v is a symmetric, normally distributed ($v \sim N(0, \sigma_v^2)$) component representing the random effect of measurement error and stochastic events or exogenous shocks beyond the control of the producing unit (for example, environmental factors such as bush fire, temperature and moisture), and u is a one-sided component representing technical inefficiency (TI). If $u = 0$, production lies on the stochastic frontier and production is technically efficient; if $u > 0$, production lies below the frontier and is inefficient. The general form is:

$$\ln \text{Output} = \beta_0 + \Sigma_i \beta_i \ln X_i + \Sigma_j \beta_j Z_j + \frac{1}{2}\Sigma_i \Sigma_i \beta_{ii} (\ln X_i)^2 + \frac{1}{2}\Sigma_j \Sigma_j \beta_{jj} (\ln Z_j)^2 + \Sigma_i \Sigma_j \beta_{ij} \ln X_i Z_j + \beta_k D_k + e \qquad (3)$$

where ln is the natural logarithm; X_i's are inputs; Z_j's are conditioning factors; D is a dummy variable representing farmer and farm characteristics; β_I's are the parameters for the conventional inputs; β_j' s are the parameters for the conditioning factors; β_{ii}'s are the parameters for the interactive terms of the conventional inputs; β_{ij}'s are the parameters for the interactive terms between the conventional inputs and the conditioning factors; β_k's are the parameters for the dummies; and e is the error term defined as $e = v + u$.

The decomposition of the error term into two components allows the deterministic frontier to vary across farms or over time for the same farm and therefore, the production frontier, $f(X_a,\beta)e^v$, is itself stochastic. The technical efficiency relative to the stochastic production frontier $e^{-u} = Y / [\, f(X_a,\beta)e^v \,]$ is captured by the one-sided error component $u \geq 0$. Assuming that the symmetric error is identically and normally distributed as $N(0, \sigma_v^2)$ and the non-negative error u distributed as the absolute value of a normal distribution , $N(0, \sigma_u^2)$, that is half-normal, the population average technical efficiency can be calculated as:

$$E(e^{-u}) = 2e^{\sigma u2/2}(1 - F^*(\sigma_u)), \qquad (4)$$

where F* is the standard normal distribution function. The log likelihood function for this system can be written as

$$\text{Ln } L(Y|\beta, \lambda, \sigma^2) = \frac{N}{2}\ln(2\pi) - N \ln \sigma + \sum_{i=1}^{N} \ln[1 - F(e_i\lambda\sigma^{-1})] - 1/2\sigma^2 \left(\sum_{i=1}^{N} e_i^2\right), \quad (5)$$

where $e = u_i + v_i$, and F is the standard normal cumulative distributive function.

Initial applications of the stochastic frontier model allowed average technical efficiency (inefficiency) to be estimated for the sample, but did not allow for the estimation of firm-specific technical inefficiency. This was because individual residuals could not be decomposed into the two components, v_i and u_i.

Jondrow et al. (1982), however, specified a decomposition method from the conditional distribution of u given e. Given the normal distribution of v, and the half-normal distribution of u, the conditional mean of u given e is shown to be

$$E(u \mid e) = \sigma_*^2 \{f^*(e\lambda/\sigma) / [1 - F^*(e\lambda/\sigma)] - e\lambda/\sigma\}, \tag{6}$$

where f* and F* represent the standard normal density and distribution functions, respectively, and $\sigma_*^2 = \frac{\sigma_v^2 \sigma_u^2}{\sigma^2}$, where σ_u^2 and σ_v^2 represent the variances of the parameters one-sided (u) and systematic (v), respectively. Therefore, total variance of output, σ^2, can be expressed as $\sigma^2 = \sigma_v^2 + \sigma_u^2$ or $\sigma = (\sigma_v^2 + \sigma_u^2)^{1/2}$.

The ratio of the two standard errors as used by Jondrow et al. (1982) is expressed as

$$\lambda = \sigma_u / \sigma_v \tag{7}$$

which measures total variation of output from the frontier which can be attributed to technical efficiency. The specification also enables the estimation of γ, the ratio of the variance of u to the total variances, $\gamma = \sigma_u^2/\sigma^2$, so as to determine, on the basis of the size of γ, whether the differences between the best and actual practices were actual or accidental (Kalirajan & Shand 1985). The smaller the ratio, the higher is the probability that the differences are accidental.

3. Methodology

3.1 Data

Farm-level data were collected on 440 irrigated and non-irrigated rice farms in the Upper East Region (UER) of Ghana. The data covered the social, economic and demographic characteristics of the survey sample. These include the gender and age of the farmer, family size, total number of years of schooling, off-farm work, extension service contact, access to credit and distance of farm from farmer's residence. The data were used to identify important characteristics influencing efficiency of rice production under the two production systems. Data on farm features included farm size, location, input and output totals, farming method, farming system, yield and use of agro-chemicals were collected. Further, data on production risks involving the type of risks, seasonality, source of risk and effects and coping strategies were also collected with the aim of measuring how farmers cope with these risks. Other important areas covered include agricultural development related programmes of the UER, rice specific policies and projects of the UER, production costs of farmers (nature, magnitude and type), input and output prices and availability and accessibility of farm resources. Finally, data were obtained on employment with specific reference to total and hired labour, number of labourers and their gender, labour use and wage rate.

3.2 Empirical model

3.2.1 Technical efficiency

The variable inputs used for irrigated and non-irrigated agriculture in the Upper East region include labour, seed, chemical fertilizer, pesticides, animal power (bullock), machine power (tractor), manure and irrigation expenses. However, variable inputs like seed, pesticides, machine power and manure are excluded from the analysis for various reasons. Seed is excluded in the analysis because the amount of seed used per hectare is technically fixed, and it might not be reasonable to use seed as an argument of a production function. Pesticides and manure were excluded because a large number of farmers did not use them and where they were used it was difficult quantifying them. The majority of the farmers could not also use machine power or tractor services because of high fees and sometimes unavailability of the services, hence, the exclusion of machine power from the analysis. Considering the general formulation of the translog production function as shown in equation 3, a translog stochastic frontier production is estimated using data from 440 farms in Upper East region of Ghana, for the 2002-03 agricultural year. The translog stochastic frontier production is specified as:

$$\begin{aligned}\ln \text{Output} = {} & \beta_0 + \beta_1 \ln Lab + \beta_2 \ln Land + \beta_3 \ln Animp + \beta_4 \ln Fert + \beta_5 \ln Cap \\ & + \delta_1(0.5 \ln Lab)^2 + \delta_2(0.5 \ln Land)^2 + \delta_3(0.5 \ln Animp)^2 + \delta_4(0.5 \ln Fert)^2 \\ & + \delta_5 (0.5 \ln Cap)^2 + \phi_1 \ln Lab * \ln Land + \phi_2 \ln Lab * \ln Animp \\ & + \phi_3 \ln Lab * \ln Fert + \phi_4 \ln Lab * \ln Cap + \phi_5 \ln Land * \ln Animp \\ & + \phi_6 \ln Land * \ln Fert + \phi_7 \ln Land * \ln Cap + \phi_8 \ln Animp * \ln Fert \\ & + \phi_9 \ln Animp * \ln Cap + \phi_{10} \ln Fert * \ln Cap + e, \end{aligned} \qquad (8)$$

where, ln = natural logarithm; Output = rice output (kg/ha); Lab = amount of labour (man-days/ha); Land = land (farm size) in hectares; Animp = animal power expressed by bullock days per hectare; Fert = chemical Fertilizer input in kg/ha; Cap = capital input in cedis (¢) per hectare. Capital input includes all cash expenditures for transporting and storing, fertilizer, seed, machine hire and irrigation facilities. βs are parameters of the linear terms, δs are parameters of the quadratic terms, and ϕs are parameters of the cross-product or interactive terms and e is a disturbance term, defined as

$$e = v - u. \qquad (9)$$

The a priori signs of the parameters are as follows: $\beta_i > 0$; $\delta_j > 0$; and $\phi_m > 0$, where $i = 1, 2,\ldots,5$; $j = 1,2,\ldots,5$; and $m = 1,2,\ldots,10$.

The parameters of the transformed translog production frontier as specified in equation 15 were estimated separately for each farm group using maximum likelihood method in the LIMDEP econometric software. Given a flexible and interactive production frontier for which the translog production frontier is specified, the farm-specific technical efficiency (TE) of the j^{th} farmer was estimated by using the expectation of u_j conditional on the random variable e_j as shown by Battese (1992). That is,

$$TE = \exp(-u_j) = e^{-uj}, \qquad (10)$$

so that $0 \le TE \le 1$. Farm-specific technical inefficiency index (TI) was computed by using the following expression:

$$TI = (1 - \exp[-u_j]) \qquad (11)$$

The parameters of the translog production frontier were estimated using maximum likelihood method in the LIMDEP econometric software. The advantage of this approach is that, it produces better results than OLS and COLS in sample sizes larger than 400 (Olson, Schmidt & Waldman, 1980). Given the distributional assumptions for v and u, that is $v_i \sim N(0, \sigma_v^2)$ and $u_i \sim |N(0, \sigma_u^2)|$, the maximum likelihood estimation also provides sufficient information to calculate a conditional mean for u (Jondrow et al. 1982). Estimation of the production function by maximum likelihood yields unbiased, consistent and asymptotically efficient parameters (Kirkley, Squires & Strand, 1995).

The use of the stochastic frontier is not without limitations. An important drawback of the stochastic translog production function is the lack of a priori justification for the selection of a particular distributional form for the one-sided inefficiency term (Thiam et al. 2001). Also, unlike the Cobb-Douglas, the translog function does not always generate elasticity of substitution of one, and the isoquants and marginal products derived from the translog depend on the coefficients of the interaction terms (Debertin 1986). Further, the estimated parameters of the translog production function do not have any direct economic meaning unless they are used to calculate some elasticities (Kumbhakar & Heshmati 1995). Nevertheless, the translog production frontier is flexible and allows an interaction of the variables. In addition, the implementation and interpretation of the technical inefficiency measures derived from the stochastic approach are straightforward.

4. Results

The estimates of the stochastic frontier[i], which shows the best practice performance, that is, efficient use of the available technology, are presented in Table 1. The ratio of the standard error of u to that of v, λ, exceeded one in value (1.7256) and was statistically different from zero at the 1% level of significance. The null hypothesis, H_0: $\lambda = 0$, is rejected in favour of the alternative. The value of λ and the fact that it is significantly different from zero, imply a good fit and the correctness of the specified distributional assumption.

Moreover, the estimate of γ, which is the ratio of the variance of farm-specific technical efficiency, u, to the total variance of output, σ^2, is 0.749. This can be interpreted to mean that the differences between observed and frontier output is dominated by technical inefficiency. Thus, about 75% of the variation in output among the farms is due to the differences in technical efficiency. The COLS approach was tried but it produced negative standard error for the symmetric term, v[ii]. Since about 75% of the variation in output among the farms is due to the differences in technical efficiency, the interpretation is that about 25% of the variation in rice output among farms was due to random shocks outside the farmers' control. Examples of such random shocks include weather, topography, machine performance, bushfires and diseases as well as statistical errors in measuring data (Aigner et al. 1977; Huang & Bagi 1984; Kalirajan & Shand 1985; Dawson & Lingard 1989; Dawson et al., 1991 and Apezteguia & Garate 1997).

To get an idea of the overall technical efficiency of sampled rice farms, the overall technical efficiency index was computed. We do not present the individual technical efficiencies for all 440 farms, but the frequency distribution of these efficiencies is contained in Table 2[iii]. The mean level of technical efficiency (47%) is low compared to 83%, 96%, 75% and 89% which were found by Huang & Bagi (1984), Parikh & Shah (1994), Kumbhakar (1994) and Tadesse & Krishnamoorthy (1997), respectively. The mean, maximum and minimum technical efficiencies for different categories of rice farms are presented in Table 2. The table shows that irrigated rice farmers had a 48% mean level of technical efficiency compared with 45% for non-irrigators, whereas male and female farmers achieved 58% and 34% levels of technical efficiency. Technical efficiency ranges between 10% and 97% for irrigators and 10% to 89% for non-irrigators (Table 2). On the other hand, technical efficiency ranges between 10% and 85% for male farmers and 10% and 90% for female farmers. Difference-of-mean test show that, at the 0.05 percent level of significance, irrigators are more technically efficient than non-irrigators, whereas male farmers performed better than female farmers under the given technology. The null hypothesis, which states that technical efficiency is the same for irrigators and non-irrigators is rejected. Similarly, the null hypothesis, which states that technical efficiency is the same for male and female farmers is also rejected.

The results indicate that, on average, male-irrigators are more technically efficient than male-non-irrigators whereas female-irrigators are more technically efficient than female-non-irrigators. This finding confirms our earlier results that irrigated rice farmers achieve high levels of technical efficiency. Overall, with an average level of technical efficiency of about 47%, smallholder rice farmers produce considerably far below the frontier. The low levels of technical efficiency among smallholders suggest that the presence of random shocks (production risks) is negatively affecting the use of the technology available to farmers. A possible explanation of the relatively low technical efficiency for non-irrigators is that these farmers depend on rainfall, which is a major cause of low agricultural production in the country. Field observation further revealed that rainfed agriculture is prone to bushfires. Low technical efficiency also signifies allocative inefficiency resulting from farmers mistakes.

4.1 Determinants of Technical Inefficiency

After deriving farm-specific estimates of technical inefficiency the derived measures were then related to the characteristics of farmers and their environment. The variables used to explain technical inefficiency in the study area include credit, education, farmers' experience, distance and contact with extension personnel. Additional variables are sex, off-farm work and family size. The inclusion of credit, education, experience, extension contact and family size in the model derives from the findings of earlier studies (Kalirajan 1981; Kalirajan & Flinn, 1983; Lingard et al. 1983; Flinn & Ali, 1986; Bindlish & Evenson 1993; Adesina & Djato 1995; Croppenstedt & Demeke 1996; Abdulai & Huffman 1998). These factors are negatively related to technical inefficiency. Inclusion of the land title variable is warranted because land owners and tenants have different levels of land use thereby making it difficult to generalise its effect on technical inefficiency. Whereas some researchers (Kalirajan 1981; Kalirajan & Shand 1986; Flinn & Ali 1986) found a positive relationship between land title and technical inefficiency, others (Kalirajan & Flinn 1981; Lingard et al. 1983) reported a negative relationship between the two variables. Croppenstedt &

Demeke (1996) also showed that the distance of the farm from the farmer's home is negatively related to technical inefficiency. The present study, therefore, includes distance of farm from farmer's residence in order to know the direction of the relationship between this variable and technical inefficiency in the study area. In fitting the relationship between technical inefficiency (TI) and farmer and farm attributes, the following specification was used:

$$\ln TI = \alpha_0 + \alpha_1 CRED + \alpha_2 EDUC + \alpha_3 EXTCON + \alpha_4 LANDTITLE + \alpha_5 FAM + \alpha_6 DIST + \alpha_7 OFF + \varepsilon, \quad (12)$$

where, CRED = amount of farm credit received during farming season (cedis); EDUC = farmer's years of education; DIST = distance of farm from farmer's residence in number of minutes; EXTCON = contact with extension personnel (1 = contacted by an extension agent, 0 = otherwise); LANDTITLE = land title (1 = owner; 0 = tenant); OFF = Number of man-hours spent off-farm; FAM = farm size (hectares); α_i = parameters and ε = Error term. The a priori expectations on the signs of the parameters are $\alpha_6 > 0$; $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5 < 0$; and α_7 ?.

The parameter estimates of the relationship between technical inefficiency and farm and farmer characteristics using the ordinary least squares (OLS) estimator are presented in Table 4. A negative and statistically significant relationship is found between availability of credit and technical inefficiency, suggesting that farmers lacking credit to purchase fertilizer or engage additional labour tend to experience higher technical inefficiency. The estimate of the education variable is negative (but not significant), suggesting that higher level of education increases technical efficiency. The role of education toward improving farmers' efficiency is now widely accepted, in that it enables them to understand the socio-economic conditions governing their farming activities and learn how to collect, retrieve, analyse and disseminate information. Moreover, with higher levels of education, farmers are able to organize themselves into farmer groups or associations thereby enabling them to source funding from lending institutions, especially from NGOs engaged in micro credit delivery. Education also enhances farmers' understanding of extension recommendations.

The coefficient of extension contact, although not significant, is found to have a negative relationship with technical inefficiency. Farmers who have adequate extension contact avail themselves with modern agricultural technology regarding input mobilization, input use and disease control which enable them to reduce technical inefficiency.

The negative and significant coefficient of the non-farm employment variable shows that farmers engagement in non-farm activities tend to increase technical inefficiency. Discussions revealed that majority of the young farmers earn additional income by way of participating in non-farm activities such as fishing, handicrafts, commercial driving and bicycle reparing. The negative relationship suggests that increases in non-farm work reduce financial constraints, particularly for resource-poor farmers, enabling them to purchase productivity enhancing inputs. This finding does not agree with the conclusions of Abdulai (1998) for Northern region of Ghana that farmers engaged in non-farm activities tend to exhibit higher levels of inefficiency.

The estimate of the parameter for family size variable is negative and significant. The production of rice is labour intensive, and as such the negative relationship between family size and technical inefficiency suggests that larger families have labour (children, young, men and women) to meet the labour requirements of rice production. Thus, farm households who have larger families engage in division of labour and specialisation thereby reducing technical inefficiency. The significance of the family size variable seems plausible because in an environment such as the Upper East region where nine out of ten are poor, larger family sizes put extra pressure on the family to work hard for an additional income from non-farm employment.

5. Conclusion and recommendations

The findings are that smallholder rice farmers are technically inefficient because of inadequate credit, large family size and rice farmers engagement in non-farm work. Mean technical efficiencies for irrigators, non-irrigators, male farmers and female farmers are 48%, 45%, 58 % and 34 %, respectively, and the range fell between 10-98% for sample farms. Thus, inter-farm comparisons revealed that irrigated rice farmers are more technically efficient than non-irrigators whereas male farmers are more technically efficient than their female counterparts. Therefore, in terms of the use of available technology, this finding agrees with the argument often used against female farmers that they are less efficient (FAO 1985). Technical efficiency was higher among male-irrigated farmers than male-non-irrigator farmers. Similarly, female-irrigator farmers also achieved higher technical efficiency than female-non-irrigator farmers. The best rice farmer produced at about 98%, just 2% below frontier. The mean technical efficiency level for the whole sample farms was however, low (34%) compared to 89% and 75%, 96% and 83% efficiency values estimated by Huang & Bagi (1984) for India, Kumbhakar (1994) for India, Parikh & Shah (1994) for Pakistan, and Tadesse & Krishnamoorthy (1997) for India, respectively.

The availability of credit, family size and non-farm employment significantly determine technical inefficiency in the Upper East region, suggesting that technical inefficiency might be reduced by providing farmers with credit and non-farm job opportunities. Average plot size for women is relatively low (1 hectare) compared to their male counterparts (2 hectares). The findings show that women do not own and control land in the study area and they have problems in acquiring land from husbands. With similar labour productivity for male and female farmers, technical inefficiency might be reduced if credit and land constraints are removed. Similarly, plot size for non-irrigated farmers is higher than that of irrigators because many people demand farm plots on the limited irrigated land at Tono and Vea.

In the first place, the right kind, quantity and timely provision of credit must be emphasised. This is because mere increase of credit or other variable inputs to smallholders might not bring desirable results. Credit support to farmers could be achieved by way of improving rural banking and credit support systems. It is also important for the government to collaborate with non-governmental organizations operating in those areas with the aim of alleviating poverty. Participatory approaches involving all stakeholders should be adopted in the design and implementation of credit schemes to rice farmers.

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Appendixes

Table 1: Maximum Likelihood estimates of the stochastic frontier production function

Variables	Parameters	Coefficients	t-statistic
Constant	β_0	1.490	3.693***
Ln Labour	β_1	1.568	2.846**
Ln Land	β_2	0.811	9.050***
Ln Animal Power	β_3	1.988	10.546***
Ln Fertilizer	β_4	0.061	14.806***
Ln Capital	β_5	0.059	13.671***
Ln Labour X Ln Labour	δ_1	-0.651	-1.717
Ln Land X Ln Land	δ_2	-0.459	-3.639**
Ln Animal power X Ln Animal power	δ_3	-1.930	-10.284***
Ln Fertilizer X Ln Fertilizer	δ_4	0.018	5.435***
Ln Capital X Capital	δ_5	-0.960E-04	-0.534
Ln Labour X Ln Land	ϕ_1	-0.292E-03	-2.072*
Ln Labour X ln Animal power	ϕ_2	-1.021	-28.544***
Ln Labour X Ln fertilizer	ϕ_3	0.021	5.945***
Ln Labour X Ln Capital	ϕ_4	-0.057	-12.935***
Ln Land X Ln Animal power	ϕ_5	0.943	22.116***
Ln Land X Ln fertilizer	ϕ_6	-0.100	-23.197***
Ln Land X Ln Capital	ϕ_7	-0.546E-03	-1.174
Ln Animal power X Ln fertilizer	ϕ_8	0.216E-03	2.273*
Ln Animal power X Ln Capital	ϕ_9	0.021	5.755***
Ln Fertilizer X Ln Capital	ϕ_{10}	-0.699E-03	-9.004 ***
$\lambda = \sigma_u / \sigma_v$		1.7256***	0.361
$\gamma = \sigma_u^2 / \sigma^2$		0.749	
$\sigma = (\sigma_v^2 + \sigma_u^2)^{½}$		0.54738***	0.0359
Log likelihood		-210.4055	
N		440	

Note: $\sigma_u^2 = 0.22430$ and $\sigma_v^2 = 0.07532$; **, ** and * represent 1%, 5% and 10% level of significance respectively.

Table 2 Frequency distribution of farm-specific technical efficiency

Technical Efficiency (%)	Number of farmers	Percent
< 8	0	0.00
8-10	3	0.95
11-13	4	1.26
14-16	4	1.26
17-19	7	2.22
20-22	6	1.91
23-25	36	11.43
26-28	23	7.30
29-31	31	9.84
32-34	14	4.44
35-37	15	4.76
38-40	42	13.33
41-43	33	10.47
44-46	47	14.92
47-49	26	8.25
50-52	1	0.32
53-55	2	0.64
56-58	1	0.32
59-61	2	0.64
62-64	1	0.32
65-67	0	0.00
68-70	1	0.32
71-73	2	0.64
74-76	1	0.32
77-79	2	0.64
80-82	0	0.00
83-85	4	1.26
86-88	2	0.64
89-91	1	0.32
92-94	2	0.64
95-97	0	0.00
98-100	2	0.64
N	315	100.00
Mean	34	
Standard deviation	13	
Minimum	10	
Maximum	98	

Source: Field survey, 2003.

The mean technical efficiency is 47%, and the mode is within the 44% to 46% efficiency level. The lowest level of technical efficiency is about 10% and the best farm achieved a 98% level of technical efficiency.

Table 3: Mean technical efficiency by farm group

Farm Group	Technical Efficiency		
	Mean	**Maximum**	**Minimum**
Irrigators	47.47	97.58	10.17
Non-irrigators	44.69	89.18	10.17
t-value	2.199*	-	-
Male Irrigators	39.06	85.28	10.35
Female Irrigators	26.11	80.54	10.63
t-value	10.645***	-	-
Male non-irrigators	28.58	79.87	11.21
Female non-irrigators	25.14	78.54	10.11
t-value	0.165	-	-
Male farmers	58.03	98.44	10.23
Female farmers	34.34	89.84	10.40
t-value	16.921***	-	-
All Sample	34.21	91.60	13.51

Source: Computed from field survey data, 2003. *** and * represent 5% and 10% levels of significance.

The estimates in Table 2 show that male-irrigated rice farmers had a 39% mean level of technical efficiency compared with 29% for male-non-irrigators. Female-irrigated farmers and female-non-irrigators achieved 26% and 25% levels of technical efficiency, respectively. In terms of minimum and maximum levels of technical efficiency, it ranges between 10% and 85% for male-irrigators and 11% to 80% for non-irrigators (Table 2). On the other hand, technical efficiency ranges between 10% and 80% for both female-irrigator farmers and 10% and 80% for female-non-irrigator farmers.

Table 4: Relationship of technical inefficiency and farm characteristics (OLS)
Dependent variable: Technical Inefficiency Index

Explanatory Variable	Coefficient	t- statistic
Constant	1.384	12.517***
Credit	-0.108	-1.653*
Education	-0.004	-0.719
Distance	-0.005	-1.080
Extension contact	-0.008	-1.084
Landtitle	0.011	0.335
Family size	-0.004	-1.805*
Off-farm	-0.004	-3.081**
R^2	0.10	
F-statistic	3.261**	

Source: Field survey, 2003. ***, ** and * represent 1%, 5% and 10% levels of significance respectively.

The R^2 is 10% and all parameter estimates have the expected signs except the coefficient of the land title and distance variables.

[i] As an alternative to this, the Cobb-Douglas production frontier function was tried. However, it gave very high variances for λ and the total (common) variance, σ^2.
[ii] See Schmidt, P and Lovell, C. A. K (1979) and Olson, J. A, Schmidt, P and Waldman, D. M (1980) for details about the limitations of the COLS approach and the consequences of encountering a negative standard error for either the technical efficiency component, u, or the symmetric component, v.
[iii] One hundred and thirty two observations are excluded because of problems in computing the respective OLS residuals, which were used to calculate farm-specific technical efficiency.