Technical Efficiency of Rice Farmers in Northern Ghana

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Abstract

Examining the level of farm-specific technical efficiency of farmers growing irrigated and non-irrigated rice in Northern Ghana, this study fitted cross-sectional data into a transcendental logarithmic (translog) production frontier. The study concludes that rice farmers are technically inefficient. There is no significant difference in mean technical efficiencies for non-irrigators (53%) and irrigators (51%). The main determinants of technical efficiency in the study area are education, extension contact, age and family size. Providing farmers with both formal and informal education will be a useful investment and a good mechanism for improving efficiency in rice farming. There is also need for training more qualified extension agents and motivating them to deliver.

1. Introduction

Agriculture is the backbone of the Ghanaian economy. The agricultural sector contributes about 40% to the gross domestic product (GDP) and employs more than 60% of the labour force, mostly women (World Bank, 2002). The major staple crops produced in Ghana include cereals (mainly rice and maize) and starchy staples such as yams, cassava and plantain. Crop production in Ghana is for three main reasons: food production for consumption, raw materials for industry and production for export. Thus, among the various economic sectors of the Ghanaian economy agriculture is expected to lead economic growth in much of the country and especially in the northern regions.[1] The agricultural sector is targeted to grow at an annual rate of 5–6% in order to ensure food security and adequate nutrition for the people of the country, to supply raw materials to other sectors, and to provide producers with increasing incomes. Yet there has not been a study to estimate technical efficiency across different rice farming systems in Northern Ghana.

Trade liberalization is believed to have had a negative impact on the rice subsector despite the government's efforts to increase the output of major food crops such as rice. For example, imported white rice dominates rice consumption in Ghana. It is estimated that the country spends about US$100 million annually to import the rice needed to meet more than half of Ghana's rice requirements. Ghana's emergence as a significant rice importer in the mid 1980s coincided with the liberalization of its economy under the programmes for economic recovery and structural adjustment of those years. Prior to and following independence in 1957, Ghana had pursued a policy of food self-sufficiency, under which high tariff barriers and import restrictions protected indigenous rice production, but over the 1995–2005 period total rice production has not been stable. From 202,000 tonnes in 1995 the rice output reduced to 142,000 tonnes after nine years (Table 1). Rice output in Ghana is also low compared with countries like Vietnam, Thailand and China. Whereas Ghana's rice output stood at only 142,000 tonnes in 2005, Vietnam produced as much as 32 million tonnes of rice in the same year. As a result of advanced technology, Vietnam's rice cultivation has been rising at an average of 700,000 tonnes per year in the past five years (FAO, 2006). Despite the downward trend in rice output, the Ministry of Food and Agriculture (MOFA, 2005) indicated that the consumption of rice over the last decade almost doubled. More so, the economic reforms in the 1980s exposed Ghanaian rice producers to competitive improved quality milled white rice that originated in the United States and Thailand or, a later innovation, Vietnam and China. Consequently, Ghanaian producers rapidly began losing their share of the expanding national rice market (EURATA, 2001).

Table 1: Rice production in Ghana ('000 tonnes): 1995–2005

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Output	202	203	197	194	168	247	273	168	143	145	142

Source: Statistics, Research and Information Directory, MOFA, 2005.

Two systems of rice production can be distinguished: irrigated and non-irrigated. The former is practised by farmers who grow rice around large and small dams and the latter by farmers on up- and lowlands or who depend solely on rainfall for rice farming. Upland and lowland (non-irrigated) rice production in Ghana accounts for over 75% of total rice production, whereas irrigated paddies account for just 10% of total rice area (Seini, 2002). The introduction of irrigation facilities in the country has been used to augment rainfall, to extend the growing season, or to make farming possible in dry seasons or regions. Increased irrigation generates substantial production and income benefits (Rosegrant and Shetty, 1994). This is particularly important for Northern Ghana, which is endowed with irrigation facilities and where development economists are emphasizing the need to increase rice production in order to reduce food deficits and slow the rate of out-migration.[2] Thus, in terms of employment, it is envisaged that the availability or supply of irrigation facilities will create jobs for people in the country.

The two major irrigation dams in Northern Ghana are Tono in Tamale and Bontanga in and Navrongo. Other small dams are Vea, Libga and Golinga. Government support to irrigation projects in the country has almost stopped and the projects are more or less farmer owned or community managed. Apart from the removal of fertilizer subsidy in the early 1990s by the government, the Government of Ghana no longer provides farm machinery (tractors, ploughs, harrows, power tillers, seed, etc.) to irrigated farmers. Irrigation projects in the country have also witnessed retrenchment in project management staff as a result of recent government labour policy aimed at controlling government expenditure. The average farm sizes in both irrigation schemes are small, ranging between 0.2 and 0.6 ha. Nearly 80% of irrigated land is controlled by men. The demand for irrigated land in the study area far exceeds the supply and new entrants (rice farmers) can sometimes wait for one or two years before getting allocations. Like the non-irrigators, irrigating farmers rely mostly on accumulated experience rather than the usual extension services.

2. The research problem

Rice is an important food crop in Ghana and its consumption is growing, particularly among urban dwellers. Rice contributes 9% of the food requirements of the country. The importance of rice in the Ghanaian economy is also seen in its contribution to agricultural GDP and employment. Therefore as Ghana struggles to achieve accelerated growth in food production, increasing the output of rice has become an important goal.[3] The strategic nature of rice has long drawn the attention of policy makers who view promoting domestic rice production as a means of reducing dependency on imports, lowering the pressure on foreign currency reserves, ensuring stable and low-priced sources of food for people, and generating employment and income for rice growers (Randolph, 1995).

However, the ability of rice farmers in Ghana to adopt new agricultural technologies is affected by farmer and farm characteristics. Examples of such characteristics include age and household size of rice farmers, level of education and total number of years of schooling, total land area used for rice production, distance of farms from farmer's residence, and farmer's managerial ability or experience in rice farming. Others are off-farm work, extension visits and benefit of credit facility. Over 70% of the rice farmers in Northern Ghana are illiterate. High illiteracy rates affect farmers' ability to adopt new agricultural practices and to effectively mobilize and apply production inputs. Rice farmers also face high input costs (fertilizer, pesticides and machine power) and they lack incentives because of the removal of input subsidies in the 1990s. About 80% of rice farmers in the country are smallholders cultivating an average farm size of 2 hectares. The extension agent–farmer ratio is also high (about 1:3,000), denying farmers regular extension visits or contacts.

Studies have shown that technical efficiency measures for Ghana's agriculture are low. Abdulai and Huffman (2000) found that average efficiency for rice farmers in Northern Ghana is 63%, with profit efficiency ranging between 16% and 96%. The authors concluded that about 27% of potential maximum profit is lost because of inefficiency. Specifically, the researchers found profit inefficiency for farmers in Gushegu, Tamale and Savelugu districts to be 30%, 25% and 27%, respectively. Seidu (2004) provided evidence to show that smallholder rice farmers in the Upper East region of Ghana produce, on average, 34% below maximum output. The author estimated technical efficiency for smallholder irrigators and non-irrigators as 48% and 45%, respectively, while that of male farmers stood at 58% compared with 34% for female farmers. Seidu et al. (2004) concluded that smallholder rice farmers in the Upper East region are allocatively inefficient in the use of farm inputs like labour, bullock power and fertilizer.

Available evidence suggests that mean technical efficiency measurement for the agricultural sector is lower than that of other sectors. For example, Bhasin and Akpalu (2001) estimated mean technical efficiency for hairdressers, dressmakers and wood processors to be 76%, 83% and 89%, respectively.

The ability of rice farmers in Ghana to adopt new technology and achieve sustainable small-scale production depends on their level of technical efficiency. Efficiency measurement is very important because it is a factor for productivity growth. Efficiency studies help countries to determine the extent to which they can raise productivity by improving the neglected source, i.e., efficiency, with the existing resource base and the available technology. Such studies could also support decisions on whether to improve efficiency first or to develop a new technology in the short run. More importantly, enhanced technical efficiency will not only enable farmers to increase the use of productive resources, it will also give direction for the adjustments required in the long run to achieve food sustainability.

To do this there is need to assess the current levels of technical efficiency of rice farmers and to identify the factors that affect the levels. More importantly, there is need to determine whether irrigation improves efficiency, whether there are differences between irrigators and non-irrigators in their production efficiencies, and why. However, no study has been done to estimate technical efficiency across different rice farming systems in Northern Ghana. In fact, it is unlikely that the Ghana government's objectives of increasing food supply and income as stated in the Growth and Poverty Reduction Strategy (GPRS) can be fully achieved unless positive steps are taken to adequately improve farmers' technical efficiency. The critical questions to be answered are: What is the level of technical efficiency across irrigated and non-irrigated rice farmers in Northern Ghana? How do farmers' social, economic and demographic features relate to technical inefficiency?

Objectives of the study

The priority of the research therefore is to measure developed technical efficiency between irrigated and non-irrigated rice farmers in Northern Ghana with the aim of providing recommendations on how to increase rice production. The specific objectives are to:

- Examine the level of technical efficiency between irrigated and non-irrigated rice farmers in Northern Ghana.
- Derive farm-specific technical efficiency associated with input use and to relate the derived measure to farmers' social, economic and demographic characteristics; and
- Provide policy recommendations for improving rice production.

The study uses quantitative techniques to investigate the levels of technical efficiency between irrigated and non-irrigated rice farmers. The derived technical inefficiencies for the farm groups are then related to farmer social, economic and demographic features as well as farm characteristics in order to measure the determinants of technical efficiency in paddy farms in Northern Ghana.

Study hypotheses

Two hypotheses are tested in this study. The first hypothesis tested is the fitness and the correctness of the specified distributional assumption, that is, the existence of a stochastic frontier. The t-test is employed to test the null hypothesis of no stochastic distribution as against the alternative of the existence of stochasticity. That is,

H_O: l = 0
H_A: l ≠ 0

The second hypothesis involved testing for differences in technical efficiency between irrigated and non-irrigated farmers. The t-test is used to test the difference in means for the respective farms. That is,

H_O: Technical efficiency is the same for both irrigators and non-irrigators.
H_A: Technical efficiency is not the same for both irrigators and non-irrigators.

3. Literature review and study framework

Factors that explain technical and allocative inefficiency in a developing country's agriculture are many. An important characteristic is the prevalence of subsistence needs. Inefficiency can also result from socioeconomic, demographic or environmental factors, however. Farm-specific efficiency or inefficiency can be related to farmer characteristics. These variables may measure information status and managerial skills, such as education, technical knowledge and extension contacts, as well as system effects exogenous to the farm, such as credit, input markets or tenancy (Ali and Byerlee, 1991). Thus, individual farmer variability (technical inefficiency) and not random variability is the major cause for yield variability (Kalirajan, 1981a). Byiringiro and Reardon (1996) investigated the effects of farm size, soil erosion and soil conservation investments on land and labour productivity and allocative efficiency in Rwanda. The authors concluded that there is a strong inverse relationship between farm size and land productivity. Furthermore, for small farms, there was evidence of inefficiency in the use of land and labour, the cause being attributed to factor market access constraints.

Ecological issues also appear to have paramount implications for sustainable agricultural production. Tadesse and Krishnamoorthy (1997) found that 90% of the variation in output among paddy (IR-20) farms in Tamil Nadu, India, was due to differences in technical efficiency. The mean technical efficiency was calculated as 83%. Tadesse and Krishnamoorthy recommended that for small paddy farmers to follow the efficient resource use pattern, there is the need to provide them with more land and extension services.

Most studies dealing with agricultural production argue that schooling or the level of education of a farmer helps the farmer in the use of production information leading to increased yield. Pudasaini (1983) documented that education contributed to agricultural production in Nepal through both worker and allocative effects. The author also found that even though education enhances agricultural production mainly by improving farmers' decision making ability, the way in which it is done differs from environment to environment. Thus, in a technologically dynamic agricultural system, education improves farmers' allocative ability, enabling them to select improved inputs and optimally allocate existing and new inputs among competing uses. On the other hand, in traditional agriculture, it enhances their decision making ability mainly by increasing their ability to better allocate existing farm resources.

Kumbhakar et al. (1991) investigated the determinants of technical and allocative inefficiency in US dairy farms. The stochastic frontier approach was used involving a single-step maximum likelihood procedure. The findings were two. First, that levels of education of the farmer are important factors determining technical inefficiency. Second, that large farms are more efficient (technically) than small and medium-sized farms. The conclusion was that both technical and allocative inefficiencies decrease with an increase in the level of education of the farmer. This is similar to the conclusion reached by Ajibefun and Daramola (2003), that education is an important policy variable and could be used by policy makers to improve both technical and allocative efficiency.

However, Kalirajan and Shand (1985) argue that although 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. Using Tamil Nadu rice farmers as a case study, Kalirajan and Shand (1985) conducted a quantitative analysis of various types of education in relation to productivity in order to determine whether schooling of farmers had a greater influence on yield than non-formal education (defined as a farmer's understanding of the technology). The findings revealed that schooling (education) of farmers had an independent effect on yield, but it was not significant. On the other hand, a farmer's non-formal education was found to have a significant and greater influence on yield. Kalirajan and Shand concluded that farmers' schooling and productive capacity need not be significantly related under all circumstances.

Further, Adesina and Djato (1996) investigated the extent to which education affects inefficiency in agriculture using a sample of 410 rice farmers in northern Côte d'Ivoire. The objective was to examine the relative differences in technical, allocative and economic efficiency between educated and non-educated rice farmers. The analysis was based on a duality method, using the normalized restricted profit function approach with factor share equations. The authors found that there is no difference in either relative technical, allocative or economic efficiencies between educated (defined as those who had at least one year of formal schooling) and non-educated farmers. The analysis was repeated for an education threshold of six years of formal schooling, but this did not alter the results (considered as the minimum for literacy in Côte d'Ivoire). The conclusion was that educated farmers are not more efficient than non-educated farmers because the latter may have an empirical knowledge obtained from cumulative farming experience. Adesina and Djato recommended that rural development efforts should not be biased towards "educated" farmers as "non-educated" farmers are just as efficient. For Weirs (1999), at least four years of primary schooling are required to have a significant effect upon farm productivity.

The impact of agricultural extension on farm production has received considerable attention in the farm efficiency literature. Agricultural extension represents a mechanism by which information on new technologies, better farming practices and better management can be transmitted to farmers. Kalirajan (1981b) explained that extension workers' limited contact with the farmers and farmers' misunderstandings of the technology were responsible for the difference between the actual and maximum yields among the farmers. The researcher stressed the need for policy makers in a South Indian state to focus on extension work in order to increase rice production and reduce inefficiency.

Parikh and Shah (1995) also measured technical efficiency, in the North-West Frontier province of Pakistan. The study involved the use of a translog frontier production function on cross-sectional data from 397 farms during the 1988/89 cropping season. The average technical efficiency level was found to be 96.2%. The estimated farm level technical efficiency was found to depend on levels of credit and education, farmers' ages, and the extent of land fragmentation. That is, lack of education, restricted credit and fragmented holdings were found to be causes of inefficiency. Parikh and Shah (1995) concluded that policies to consolidate holdings, provide credit or educate farmers will tend to improve efficiency in agriculture.

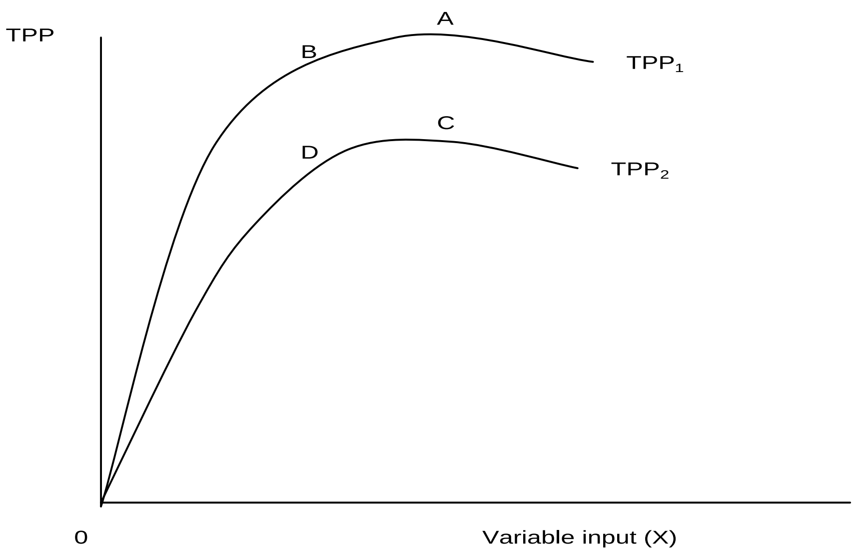
Owens et al. (2001) investigated the impact of farmer contact with agricultural extension services on farm productivity using panel data obtained during the period 1993–1997 in Zimbabwe. The data were drawn from a sample of households resettled in three regions in Zimbabwe. The results showed that access to agricultural extension services, defined as receiving one or two visits per agricultural year, raises the value of crop production by about 15%. The results also show that the impact of agricultural extension services differed across individual crop years, with the impact being markedly different in drought and non-drought years. The findings of a frontier analysis by Ogundele and Okoruwa (2004) show that farm size significantly determines levels of technical efficiency in Nigeria. Other determinants included labour, herbicides, seeds, education and farming experience. In overall terms, Ogundele and Okoruwa computed the average technical efficiency for each rice farm group at 90%.

Analytical framework

Relative technical efficiency between different production practices in developing countries is one of the most widely discussed and controversial issues in development literature. It has been four decades since Schultz (1964) advanced the celebrated hypothesis that farm families in developing countries were "efficient but poor". His hypothesis, which has had a lasting influence on researchers about smallholders' decision making, has been interpreted to mean that there are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture. Indeed, the analysis of economic efficiency has been broadened from the earlier emphasis by Schultz (1964) and others on allocative efficiency, to consider also technical efficiency, that is, the productivity of a given mix of inputs. Furthermore, efficiency is now viewed more in terms of system performance, including farmers and farm support systems, rather than focusing narrowly on farmer rationality (Ali and Byerlee, 1991).

An important assumption that guides production efficiency is that farms operate on, rather than within, the production possibility frontier (PPF) available to them. In other words, it is generally accepted that production takes place in the rational zone of production stages because that is the zone where maximum profit (output) can be obtained. Profit maximization is generally governed by three rules. First, that the marginal value product (MVP) of each factor must be equal to its price. Second, that factors must be combined in the least cost factor combination, and third, that products must be combined in the highest profit product combination. All these explain technical efficiency, which can also be defined as the ability of farmers to practise good skills or knowledge in the manner in which inputs can be combined. Figure 1 describes two possible relationships between a single variable input and a single output.

Figure 1: Technical and allocative efficiency



Source: Ellis (1993).

Total physical product one, TPP_1 in Figure 1, displays higher output for all levels of input use than TPP_2. TPP_1 is said to be technically superior to TPP_2. A farm operating at any point on TPP_1, say at point B, is more efficient technically than a farm operating at any point on TPP_2. The reason is that any point on TPP_1 represents a higher level of output for a given level of the variable input. This relationship defines technical efficiency. Thus, technical efficiency is the maximum attainable level of output for a given level of production input, given the best technologies available to the farmer. Allocative efficiency describes the adjustment of inputs and outputs to reflect relative prices, the technology of production already having been chosen. These adjustments are the marginal conditions for profit maximization, which states that MVP should equal marginal factor cost (MFC) for any single variable input, and that MVP per unit of an input should be equal across different outputs (the principle of equi-marginal returns). Economic efficiency is the situation of both technical and allocative efficiency.

Stochastic frontier production function

The available literature provides evidence to show that both the primal (production function) approach and dual approaches (the use of profit and cost functions) are used to analyse farm efficiency. 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 panel data approach. Interestingly, the application of either primal or dual approaches has produced varying results and conclusions, partly because of differences in study location, sample size, production practices and model specifications.

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. An economically efficient input-output combination would be on both the frontier function and the expansion path (Xu and Jeffrey, 1998).

Although several functional forms can be used to specify the stochastic frontier, desirable forms are those linear in parameters because they easily facilitate the calculation of technical efficiency (TE) or technical inefficiency (TI). Nevertheless, forms that are multiplicative in inputs and error terms are excellent candidates for the stochastic frontier (Kirkley et al., 1995). For example, let the stochastic frontier production model be specified as follows:

$$Y = f\left(X_{a,} b\right)e \qquad (1)$$

where Y is output (kg/ha), X_a denotes the actual input vector (i.e., input use/ha), b is the vector of production parameters, and e is the disturbance term. The frontier production function is represented by $f(X_a,b)$, and is a measure of maximum potential output for any particular input vector X_a.

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

$$Y = f\left(X\right)e^{u} \qquad (2)$$

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. It is unsatisfactory from an econometric point of view, however, 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 on the technology (Coelli, 1995).

Following the inadequacies of deterministic frontier estimation, three teams of researchers (Aigner et al., 1977; Meeusen and van den Broeck, 1977; Battese and 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:

$$Y = f\left(X_{a,} b\right)e^{v-u} \tag{3}$$

where *v* is a symmetric, normally distributed ($v \sim N(0, s_v^2)$) 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:

$$\begin{aligned}\ln Output &= b_0 + \sum_i b_i \ln X_i + \sum_j b_j Z_j + \tfrac{1}{2}\sum_i \sum_i b_{ii}\left(\ln X_i\right)^2 \\ &+ \tfrac{1}{2}\sum_j \sum_j b_{jj}\left(\ln Z_j\right)^2 + \sum_i \sum_j b_{ij} \ln X_i Z_j + b_k D_k + e\end{aligned} \tag{4}$$

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; b_i's are the parameters for the conventional inputs; b_j' s are the parameters for the conditioning factors; b_{ii}'s are the parameters for the interactive terms of the conventional inputs; b_{ij}'s are the parameters for the interactive terms between the conventional inputs and the conditioning factors; b_k's are the parameters for the dummies; and *e* is the error term defined as $e = v + u$.

Jondrow et al. (1982) 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

$$E(u/e) = s^{*2}\left\{f^*(el/s)/[1 - F^*(el/s)] - el/s\right\} \tag{5}$$

where *f** and *F** represent the standard normal density and distribution functions, respectively, and $s^2 = s_v^2 s_u^2 / s^2$, where s_u^2 and s_v^2 represent the variances of the parameters one-sided (*u*) and systematic (*v*), respectively. Therefore, total variance of output, s^2, can be expressed as $s^2 = s_v^2 + s_u^2$ or $s^2 = \left(s_v^2 + s_u^2\right)^{1/2}$. The ratio of the two standard errors as used by Jondrow et al. (1982) is expressed as

$$l = s_u / s_v \tag{6}$$

which measures total variation of output from the frontier that 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, $g = s_u^2 / s_v^2$, so as to determine, on the basis of the size of *g*, whether the differences between the best and actual practices were actual or accidental (Kalirajan and Shand, 1985). The smaller the ratio, the higher is the probability that the differences are accidental. The production function is chosen because the use of the profit function for agriculture in less developed countries is inappropriate on theoretical grounds since most of the economic applications do not support the model (Junankar, 1989).

After deriving farm-specific estimates of technical inefficiency the derived measures can be related to the characteristics of farmers and their environment specified as:

$$TI = \kappa(X) + w_i \qquad (7)$$

where X is a vector of farmer and farm attributes and w_i is the unexplained component of inefficiency. Kumbhakar et al. (1991) have criticized this approach on the grounds that technical inefficiency may be correlated with the inputs, causing inconsistent estimates of the parameters and technical inefficiency. Following Lovell (1993), we include variables under the control of farmers in the first stage (estimation of efficiency scores) and then variables not under the control of farmers in the second stage (explanation of the inefficiency scores).

4. Research methodology

Quantitative techniques are used to investigate the levels of technical efficiencies between irrigated and non-irrigated rice farmers in Northern Ghana. The derived technical inefficiencies for the farm groups are then related to the farmer's social, economic and demographic features as well as farm characteristics in order to measure the determinants of technical efficiency in paddy farms. Two separate groups of paddy farmers, irrigators and non-irrigators, are distinguished and the levels of technical efficiency for these farm groups and the extent to which farm and farmer characteristics affect technical inefficiency are compared and analysed.

Study area

Northern Ghana comprises three regions (Northern Region, Upper East Region and Upper West Region) with 34 districts (24 old and 10 new districts). The rainfall pattern is mono-modal. The rainy season permits a growing season of 150–160 days in the Upper East Region and 180–200 days in the two other regions. Mean total annual rainfall varies from 1,000 mm in the Upper East Region to 1,200 in the southeastern part of the Northern Region. The total area of Northern Ghana is 98,000 km^2, of which 16,000 km^2 are intensely farmed and about 8,000 km^2 are less intensely farmed. With 41% of the total land area, rice growers in Northern, Upper East and Upper West regions together supply more than half of national production (MOFA, 2005). Table 2 summarizes rice holdings for Ghana as a whole as of 2004; the dominance of Northern, Upper East and Upper West is clear in the table.

Table 2: Total number of holders in rice cultivation in 2004 by region

Region	No. of holders	Percentage
Western	6,379	2.2
Central	8,135	2.8
Eastern	3,271	1.1
Greater Accra	2,613	1.0
Volta	19,203	6.6
Ashanti	28,133	9.7
Brong Ahafo	10,306	3.6
Northern	64,854	22.7
Upper East	112,962	39.2
Upper West	32,093	11.1
National	**287,949**	**100**

Percentages are author's own calculation.
Source: SRID, MOFA (2005).

Since 1960 the government has placed great empasis on rice production in the North of the country. The European Union Rural and Agricultural Temporary Association (EURATA, 2001) reported that 28% of the total land area is suitable for agriculture, with 5–10% having potential for lowland rice development. Land availability for agriculture differs across regions. The Ministry of Food and Agriculture (MOFA) indicates that there is still sufficient area available for agricultural development of Northern Region in both uplands and lowlands, whereas in Upper West Region, most suitable and marginal uplands are already cultivated but sufficient area is available in lowlands. In Upper East Region, most suitable and marginal soils in both upland and lowland areas are already cultivated intensively.

Irrigation management in Northern Ghana

Tono and Bontanga are the two major irrigation projects in Northern Ghana. Both operate gravity systems. The Bontanga irrigation scheme was established in 1984 and the Tono project in 1985. Since then the two major projects have not witnessed any significant maintenance. Government support to irrigation projects in the country has almost stopped and the projects are more or less farmer owned. For example, the Bontanga irrigation project is managed by a team of three project staff and the executive committee members of the Bontanga Irrigation Farmers Association (BIFA). The project management team at Tono comprises a few staff appointed by the government, farmer organizations (FOs) and village committees. The FOs serve as a link between the management team and the farmers. The Irrigated Company of Upper Region (ICOUR) explains that apart from the high cost involved in providing irrigation infrastructure, the schemes are expensive to run. Farmers participating in and benefiting from the projects are therefore made to pay an irrigation levy each dry season representing the cost of services and the maintenance of the structures. The rate ranges between 0.2 million cedis in the northern part of Ghana and 2 million cedis in southern Ghana.

To serve a farmer population of about 600, the Bontanga irrigation project has one extension agent and one water bailiff. The dam has two main canals, each with 14 laterals that supply water to inlets or the farms. The left and right canals are 6 km and 5 km long, respectively. Tono irrigation scheme has a farmer population of 3,000 served by three extension agents. The length of the main canals in Tono is 42 km. The long distances make the work of the extension officers particularly difficult. Thus, an important feature of the irrigation projects is that they are mostly community managed. The limited number of extension agents negatively affects farmers' technical efficiency. To enhance the extension work some of the farmers have been trained as lateral leaders and their role is to ensure even distribution of water. The distribution of water at Bontanga is based on zones because the available water cannot serve every farmer at the same time. The average farm sizes in both irrigation schemes are small, ranging between 0.2 and 0.6 ha.

Traditionally, access to land for farming purposes in Northern Ghana is done regardless of ethnicity. For irrigated farming, land allocation is not based on minority or majority tribe, but gender is an issue because nearly 80% of irrigated land is controlled by men. The experience of Tono shows that farmers' groups obtain land through the village committee executives. Each village committee is elected and is made up of two representatives from each of nine villages in a land tenure committee. The land tenure committee is headed by the District Chief Executive who is the political head for the district. Allocation of land to villages is determined by the farmer population in each village. Although the findings provide evidence to show that land allocation is devoid of ethnicity, the allocation procedure can be undermined by the District Chief Executive, traditional authorities or the leaders of FOs. Friends, political party supporters and mostly relatives are often favoured in the allocation of farm plots to rice farmers. When this happens, it affects farmers' technical efficiency because land may not be allocated on the basis of farmers' capability. The demand for irrigated land far exceeds the supply and new entrants (rice farmers) can sometimes wait for one or two years before getting allocations.

The projects face lots of challenges that reduce farm yield and productivity. For example, apart from the removal of fertilizer subsidy in the early 1990s, the Government of Ghana no longer provides farm machinery (tractors, ploughs, harrows, power tillers, seed, etc.) to irrigated farmers. Irrigation projects in the country have also witnessed retrenchment in project management staff as a result of recent government labour policy aimed at controlling government expenditure. Particularly, most of the irrigation schemes were run on high costs because of large numbers of employees and general operation costs. The recent government irrigation policy change is attributed to the need to reduce such operation costs.[4] The consequences of the policy shift are many. For example, irrigated farmers are compelled to rely on outsiders (non-irrigators, a majority of whom own tractors) for tractor services. These tractors are said to be in poor condition at the time of demand because of intensive and extensive use by the non-irrigators. Experience shows that non-irrigated farmers maintain their tractors in April every year, which is usually after the dry season farming.

Like the non-irrigators, irrigated farmers rely mostly on accumulated experience rather than the usual extension services. The lack of farm machinery (for example tractors) makes it difficult for farm planning. Farmers are therefore unable to crop early. When the tractors are hired from outside, the farmers often face the problem of bad ploughing, which is not conducive for growing rice. Bad ploughing is attributed to the unprofessional nature of the tractor operators. The argument is that land preparation in a bonded area like the irrigation project is difficult and therefore needs well-trained tractor operators. Thus, one of the determinants of rice yield from an irrigated farm is land preparation. A level field is highly recommended and this is hardly attained through the use of untrained tractor operators. Farmers also complained of lack of levellers and irregular supply of irrigation water. Farmers have to water their crops according to a water distribution timetable (for example two times a week at Bontanga). Also, in instances where there is too much water there are no mechanisms to check excess supply.

The inadequacy of irrigation facilities is also partly due to farmers' inability to pay their irrigation levies. This, coupled with government reluctance to support the project, makes irrigated farming almost unattractive to most farmers. Finally, because of continuous cropping the schemes are suffering from a build up of pests and diseases.

This study is particularly relevant for a country such as Ghana because although Northern Ghana is characterized by low literacy standard, large dependent families and subsistence farming (EURATA, 2001), it possesses great potential in rice production because of its rich soils and abundant labour. Also, rice farming in the region has the potential of increasing productivity of food crop farming, providing employment to the youth and therefore contributing to poverty reduction.

Sampling procedure

Farm-level data were collected through a survey of rice farmers in Northern, Upper East and Upper West regions of Ghana for the 2005/06 cropping season.[5] The dispersed nature of rice farmers in Northern Ghana and the lack of any comprehensive sampling frame or systematic numbering of rice farmers precludes the use of a strictly stratified or cluster sampling technique. Farmers were selected on the basis of probability and non-probability sampling procedures. The initial sampling frame consisted of 732 rice farmers from 11 districts across the three regions.[6] Random sampling was then used to select 252 irrigators and 480 non-irrigators from farm communities within each district.

Sampling at the district level was purposive based on major rice producing districts. Irrigated farmers were sampled from Northern and Upper East regions because the three main irrigated dams (Bontanga, Tono and Vea) are located in these regions. Out of the 252 irrigators, 92 (40%) were interviewed in Northern Region whereas 160 (60%) were interviewed in Upper East Region (Table 3). The allocation of the sample size between the two regions was determined by the contributions of the regions to zonal rice output during the 2004/05 cropping season. Twelve communities, four in each irrigated district (Tolon-Kumbungu, Kassena-Nankana and Bolgatanga) were visited. Thus, at least, 21 irrigated farmers were interviewed in each community. For non-irrigated farmers, 480 were also drawn randomly from 24 communities in 11 districts across the three regions. Sample sizes for each district are presented in Table 3, with represented communities shown in Table 4. The selection of non-irrigators was determined by the number of holders in each district (Table 2).

Table 3: Sampling size by region and district

Region	No. of districts	Districts	No. of irrigated farmers	No. of non-irrigated farmers	Total
Northern	5	Tamale Metropolitan	-	65	65
		Tolon-Kumbungu	92	25	117
		Savelugu-Nanton	-	34	34
		Gushegu	-	29	29
		East Gonja	-	16	16
		Total	**92**	**149**	**241**
Upper East	4	Bolgatanga	93	46	139
		Kassena-Nankana	67	62	129
		Builsa	-	85	85
		Bawku West	-	65	65
		Total	**160**	**258**	**418**
Upper West	2	Wa municipal	-	36	36
		Nadowli	-	17	17
		Total	**0**	**53**	**53**
Total	**11**		**252**	**480**	**732**

Table 4: Number of communities by district

District	No. of irrigated communities	No. of non-irrigated communities
Tamale Metropolitan	-	3
Tolon-Kumbungu	4	1
Savelugu-Nanton	-	2
Gushegu	-	2
East Gonja	-	1
Bolgatanga	4	2
Kassena-Nankana	4	3
Builsa	-	4
Bawku West	-	3
Wa municipal	-	2
Nadowli	-	1
Total	**12**	**24**

Analytical models

The variable inputs used for irrigated and non-irrigated agriculture in Northern Ghana include labour, seed, chemical fertilizer, pesticides, animal power (bullock),[7] machine power (tractor), manure and irrigation expenses. However, variable inputs like seed, pesticides, bullock plough and manure are excluded from the analysis for various reasons. Seed is not included in the model 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 are also excluded because a large number of farmers do not use them. The experience of Northern Ghana indicates that where farmers use pesticides and manure it is difficult to quantify them. And because bullock ploughs are not used in all parts of Northern Ghana, it might not be reasonable to include them in the specification either.

Heckman (1976, 1979) discussed sample selection bias as a specification error and has proposed a simple practical solution for such situations that treats the selection problem as an omitted variable. The emphasis was on the bias that results from using non randomly selected samples to estimate behavioural relationships as an ordinary specification bias that arises because of a missing data problem. The author wrote that sample selection bias may arise in practice for two reasons. First, there may be self-selection by the individuals or data units being investigated and, second, sample selection decisions by analysts or data processors operate in much the same fashion as self-selection. He developed a simple estimator (two-step estimator) that can be used in a variety of statistical models for truncation, sample selection and limited dependent variables, as well as in simultaneous equation models with dummy endogenous variables. This approach, known as the two-step or limited information maximum likelihood method, is widely applied in economics and other social sciences (Hill et al., 2003) and has become the standard estimation procedure for empirical wage equations (Puhani, 2000). Nevertheless, the two-step estimator has been criticized recently. For example, the conclusions of several Monte Carlo studies on the usefulness of Heckman's two-step estimator, as well as theoretical considerations on this process, cast doubt on the omnipotence implicitly ascribed by many applied researchers to Heckman's (1976, 1979) two-step estimator.

It is against this background that Puhani (2000) advises that before deciding on which estimator to apply the first step should be to investigate whether there are collinearity problems in the data. If collinearity problems are present, the two-step model may be the most robust and simple to calculate. In the absence of collinearity problems, the full information maximum likelihood estimator is preferable to the limited information maximum likelihood two-step method of Heckman (Puhani, 2000: 65). The inverse Mills ratio is a concept in statistics. It is the ratio of the probability density function (PDF) over the cumulative density function (CDF) of a distribution. Following Puhani's advice, we investigated the collinearity problem by calculating R^2 of the regression of the inverse Mills ratio on the regressors of the outcome equation.[8] Specifically, this involved first using a scale of 1 for irrigated rice farmers and 0 for non-irrigators in the selectivity model to determine whether a farmer cultivates rice on irrigated plots. The next step dealt with the estimation of our equation of interest, which involved explanatory variables in the probit model together with the inverse Mills ratio. The low R^2 of the regression of the inverse Mills ratio obtained was low (0.17). The results are interpreted to mean that there is no sample selection bias in the sample selection model. This may be attributed to the fact that selectivity bias occurs more frequently in empirical work involving the estimation of wage equations or consumer expenditures (Puhani, 2000), and is less likely in an analysis of independently measurable variable. More so, the purpose of Heckman's estimator was only to "provide good starting values for maximum likelihood estimation routines in the sense that it provides estimates quite close to the maximum likelihood estimates" (Heckman, 1979: 160). In the absence of collinearity (measured by low R^2 of the regression of the inverse Mills ratio) this present study estimates the parameters of the sample selection model by using the maximum likelihood estimator. The rice output function to be estimated is specified as follows:

$$\begin{aligned} \ln Y &= b_0 + b_1 \ln LD + b_2 \ln LB + b_3 \ln C + b_4 \ln F + d_1(0.5 \ln LD)^2 + d_2(0.5 \ln LB)^2 \\ &+ d_3(0.5 \ln C)^2 + d_4(0.5 \ln F)^2 + f_1 \ln LD * \ln LB + f_2 \ln LD * \ln C \\ &+ f_3 \ln LD * \ln F + f_4 \ln LB * \ln C + f_5 \ln LB * \ln F + f_6 \ln C * \ln F + e \end{aligned} \quad (8)$$

where, *ln* = natural logarithm; *Y* = rice output per hectare (kg/ha); *LD* = land (farm size) in hectares; *LB* = amount of labour (person-days/ha); *C* = capital input expressed in machine (tractor, rice puddlers/rotavators) hours per hectare; and *F* = fertilizer input (kg/ha). β*'s* are parameters of the linear terms, ***d's*** are parameters of the quadratic terms, ***f'****s* are parameters of the cross-product or interactive terms, and *e* is a disturbance term, defined as

$$e = v - u$$

The a priori signs of the parameters are as follows: $\beta_i > 0$; $d_j > 0$; *and* $f_m > 0$, where $i = 1, 2, \ldots, 4$; $j = 1, 2, \ldots, 4$; and $m = 1, 2, \ldots, 6$.

V is a symmetric, normally distributed ($v \sim N(0, s_v^2)$) 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 parameters of the translog production frontier as specified above were estimated separately for each farm group using maximum likelihood method in the LIMDEP econometric software. The maximum likelihood estimation (MLE) produces better results than ordinary least squares (OLS) and corrected ordinary least squares (COLS) in larger samples (Olson et al., 1980). Given the distributional assumptions for v and u, that is $v_i \sim N(0, s_v^2)$ and $u_i \sim |N(0, s_u^2)|$, the maximum likelihood estimation also provides sufficient information to calculate a conditional mean for u (Jondrow et al., 1982). Further, since output is stochastic because of erratic events such as weather in the case of Ghana, firms are expected to select inputs to maximize expected profits. Input choices based on maximization of expected profits are subject to human errors, which are not necessarily correlated with the error term in a production function. When not correlated, estimation of the production function by maximum likelihood yields unbiased, consistent and asymptotically efficient parameters (Kirkley et al., 1995). Moreover, the translog production function is general and flexible and allows analysis of interactions among variables, as well as the measurement of farm-specific technical efficiency (Antle, 1984). Finally, the implementation and interpretation of the technical inefficiency measures derived from the stochastic approach are straightforward.

Determinants of technical efficiency

Once the frontier has been estimated and reasonable estimates of technical efficiency or inefficiency have been obtained, it is possible to examine the determinants of efficiency in production. Lovell (1993), however, advises that the first stage (estimation of efficiency scores) should include variables under the control of the farmer, while the second stage (explanation of the efficiency scores) should include variables not under the control of the farmer, such as site variables, demographic variables, socioeconomic variables, environmental variables and quasi-fixed factors. In fitting the relationship between technical efficiency (TE) and farmer and farm attributes, the following specification will be used:

$$ln\ TE = \alpha_0 + \alpha_1 EDUC + \alpha_2 EXTCON + \alpha_3 FAMILY + \alpha_4 SOILQ + \alpha_5 CREDIT + \alpha_6 GENDER + \alpha_7 \mathrm{EXPENDU} + \varepsilon \quad (9)$$

where, $EDUC$ = farmer's years of education; $EXTCON$ = contact with extension personnel (number of extension contacts); $FAMILY$ = household size (number of dependents); $SOILQ$ = number of years land has been used for rice farming; $CREDIT$ = amount of farm credit received during the cropping season (cedis); $GENDER$ (1 = male, 0 = otherwise); $EXPENDU$ is an interactive term between age and education; a_i = parameters; and e = error term.

Data and data sources

Farm-level data were obtained from 732 rice farms (252 irrigators and 480 non-irrigators) across the three regions of Northern 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, soil quality, off-farm work, extension service contract, access to credit and distance of farm from farmer's residence. Data on farm features including farm size, location, input and output totals, farming method, farming system, yield and use of agro-chemicals were collected.

Other important areas covered include irrigation development related microeconomic policies of Ghana, national rice specific policies and projects, production costs of farmers (nature, magnitude and type), input and output prices, and availability and accessibility of farm resources. The rest are rainfall and irrigation management and water distribution. Finally, data were obtained by interviewing farmers on employment (family and hired labour), gender of labour, labour use and wage rate.

Secondary data were gathered from the annual reports of the Irrigation Development Authority (IDA) national office and regional offices, and the Ministry of Food and Agriculture. Other sources included the Institute of Statistical, Social and Economic Research (ISSER) annual publications on the State of the Ghanaian Economy and reports by the Ghana Statistical Service.

5. Results and discussions

Table 5 presents summaries of the data means of variables used in the analysis. The mean age of sampled farmers is 42. There is a four-year difference between the mean ages of irrigators (39) and non-irrigators (43). The mean ages of rice farmers suggest that rice farming is dominated by the youth. Average years of education (eight) are the same for both farm groups but are low compared with national average of ten. These results suggest high illiteracy rates among rice farmers, confirming EURATA (2001) conclusions that literacy standards are low in Northern Ghana. The mean years of education shows that on average the highest level of education attained by a farmer is primary school. Average household size is high for the sampled farms. The results revealed that the main reason for maintaining large household sizes is to ensure adequate supply of family labour for rice production activities. Larger families also enable household members to earn additional income from non-farm activities.

Table 5: Means of variables used in the study by farming system

Variable	Non-irrigators = 482			Irrigators = 250			Sample = 732		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Age of farmer (Years)	16	70	**43**	20	82	**39**	16	82	**42**
Household size (Number of dependents)	0	50	**10**	0	69	**9**	9	69	**9**
Education (Years)	2	20	**8**	2	20	**8**	2	20	**8**
Farm size (Land) (ha)	0.2	7.4	**2**	0.1	80	**1.3**	0.1	80	**1.8**
Experience (Years)	1	18	**14**	1	35	**10**	1	35	**14**
Extension contact (Number)	0	22	**4**	1	18	**3**	0	22	**4**
Credit (Cedis)	0.1	50	**1.5**	0.6	10	**1.7**	0.1	1.7	**1.6**
Rice output (Kg/ha)	40	3,080	**2,115**	37	1,234	**1,742**	37	1,234	**1,986**
Fertilizer (Kg/ha)	9	750	**321**	1	350	**227**	1	750	**271**
Soil quality (Years)	3	7	**5**	2	10	**6**	2	10	**5**
Capital (Machine hrs/ha)	0.4	954	**31**	0.5	126	**11**	0.4	954	**24**

Note: Credit is calculated in millions.
Source: Field survey, 2006.

Average farm size also differs between irrigators (1.3 ha) and non-irrigators (2 ha). Thus, non-irrigators own bigger plots. They also received greater number of extension contacts (four times) as compared with irrigators (three times). The results show that there is limited supply of irrigated land in the study area as against demand. This might be the reason why organizations managing the facilities are compelled to allocate small plots to farmers in order to encourage irrigated rice farming. Thus, land fragmentation characterizes the irrigation system of farming in the study area. In terms of experience in rice cultivation, the findings show that non-irrigators have an average of 14 years of accumulated rice farming as compared to ten years for irrigators. Results of field discussions show that non-irrigated rice farmers use their accumulated farming experience to guide them in planting and in the application of fertilizers and weeding.

Table 5 also indicates that average credit availability to rice farmers appeared to be inadequate compared with the input requirements of rice farming. The mean yield for sampled farmers was 1,984 kg/ha. It is high for non-irrigators (2,115 kg/ha). Thus, the yield difference between irrigators and non-irrigators is surprising. However, this finding suggests a difference in the quantities of inputs used. For example, average use of fertilizer is 321 kg/ha and 227 kg/ha, respectively, for non-irrigators and irrigators. The difference could also be attributed to the longer rice farming experience of the non-irrigators as well as the possession of large family sizes that offers them various forms of labour (children and adults, both men and women) for rice activities.

Technical efficiency

Estimates of the stochastic frontier for the pooled sample of irrigators and non-irrigators,[9] which show the best practice performance (that is, efficient use of the available technology), are presented in tables 6, 7 and 8.

Table 6: MLE for pooled sample using translog production function

Variables	Parameters	Coefficients	t-statistic
Constant	β_0	2.324	1.699*
Log of land (LD)	β_1	0.742	1.130
Log of labour (LB)	β_2	2.072	2.465**
Log of capital (C)	β_3	0.119E-03	0.001
Log of fertilizer (F)	β_4	0.1710E-02	2.687***
Log LD * Log LD	δ_1	-0.309	-0.641
Log LB * Log LB	δ_2	-1.100	-1.829*
Log C * Log C	δ_3	0.114	0.579
Log F * Log F	δ_4	0.399	4.784***
Log LD * Log LB	ϕ_1	0.104	0.542
Log LD * Log C	ϕ_2	-0.110	-0.535
Log LD * Log F	ϕ_3	-0.175	-2.140**
Log LB *Log C	ϕ_4	-0.105	-1.107
Log LB *Log F	ϕ_5	-0.651E-01	-1.069
Log C * Log F	ϕ_6	0.707E-01	1.248
$\lambda = \sigma_\upsilon / \sigma_\varpi$		2.746**	2.448
$\gamma = \sigma_u^2 / \sigma^2$		0.860	
$\sigma = (\sigma_v^2 + \sigma_u^2)^{ý}$		0.975***	9.393
Log likelihood		-122.4166	
R^2		55	
N		732	

Note: $\sigma_u^2 = 0.83939$ and $\sigma_v^2 = 0.11130$; ***, ** and * represent 1%, 5% and 10% level of significance, respectively.
Source: Field survey, 2006.

The ratios of the standard error of *u* to that of *v*, *l*, for pooled sample (2.746), irrigators (2.363) and non-irrigators (2.847) exceeded one in value and are statistically different from zero at the 5% level of significance. The values of *l* and the fact that they are significantly different from zero, imply good fit and the correctness of the specified distributional assumption. The null hypothesis, H_0: $\lambda = 0$, is rejected in favour of the alternative.

Table 7: MLE for irrigated rice farmers using translog production function

Variables	Parameters	Coefficients	t-statistic
Constant	β_0	4.382	4.779***
Log of land (LD)	β_1	0.349	1.056
Log of labour (LB)	β_2	1.327	3.866**
Log of capital (C)	β_3	0.456E-01	0.354
Log of fertilizer (F)	β_4	0.657E-03	1.445
Log LD * Log LD	δ_1	-0.341	-1.161
Log LB * Log LB	δ_2	-1.396	-1.000**
Log C * Log C	δ_3	0.135	0.970
Log F * Log F	δ_4	0.265	2.594***
Log LD * Log LB	ϕ_1	-0.103E-01	-0.114
Log LD * Log C	ϕ_2	-0.252	-2.551**
Log LD * Log F	ϕ_3	0.425E-01	0.857
Log LB * Log C	ϕ_4	-9.959E-01	-1.255
Log LB * Log F	ϕ_5	-8.826E-01	-1.382
Log C * Log F	ϕ_6	0.165	0.312
$\lambda = \sigma_u / \sigma_v$		2.363**	7.778
$\gamma = \sigma_u^2 / \sigma^2$		0.848	
$\sigma = (\sigma_v^2 + \sigma_u^2)^{ý}$		0.847***	26.88
Log likelihood		-306.2379	
R^2		0.97	
N		250	

Note: $\sigma_u^2 = 0.60913$ and $\sigma_v^2 = 0.10913$; ***, ** and * represent 1%, 5% and 10% level of significance, respectively.
Source: Field survey, 2006.

Moreover, the estimate of *g*, which is the ratio of the variance of farm-specific technical efficiency, *u*, to the total variance of output, s^2, is 0.860 for the pooled sample, 0.848 for irrigators and 0.448 for non-irrigators. This can be interpreted to mean that the differences between actual (observed) and frontier output are dominated by technical inefficiency. The results suggest that about 86% of the variation in output among the farms (both irrigators and non-irrigators) is due to the differences in technical efficiency and that 14% of the variation in rice output among rice farms (irrigated and non-irrigated) is due to random shocks outside the farmers' control (Dawson and Lingard, 1989; Dawson et al., 1991; Apezteguia and Garate, 1997). Inefficiency in rice farming results from factors beyond the control of farmers. Examples of such random shocks include weather (poor rainfall), floods, bushfires and diseases. The mean, maximum and minimum technical efficiencies for irrigators and non-irrigators are presented in Table 9.

Table 8: MLE for non-irrigated rice farmers using translog production function

Variables	Parameters	Coefficients	t-statistic
Constant	β_0	4.370	5.439***
Log of land (LD)	β_1	0.426	1.527
Log of labour (LB)	β_2	1.304	2.729***
Log of capital (C)	β_3	0.179	1.614
Log of fertilizer (F)	β_4	0.692E-03	1.923*
Log LD * Log LD	δ_1	-0.288	-1.144
Log LB * Log LB	δ_2	-0.360	-1.150
Log C * Log C	δ_3	-0.287	-0.233
Log F * Log F	δ_4	0.201	2.452**
Log LD * Log LB	ϕ_1	-0.343E-01	-0.423
Log LD * Log C	ϕ_2	-0.301	-3.491***
Log LD * Log F	ϕ_3	0.557E-01	1.336
Log LB * Log C	ϕ_4	-0.111E-01	-1.784*
Log LB * Log F	ϕ_5	-0.544E-01	-1.139
Log C * Log F	ϕ_6	0.156E-01	0.357
$\lambda = \sigma_u / \sigma_v$		2.847***	8.482
$\gamma = \sigma_u^2 / \sigma^2$		0.448	
$\sigma = (\sigma_v^2 + \sigma_u^2)^{ý}$		0.749***	33.720
Log likelihood		-243.3225	
R^2		0.86	
N		482	

Note: $\sigma_u^2 = 0.49889$ and $\sigma_v^2 = 0.06154$; ***, ** and * represent 1%, 5% and 10% level of significance, respectively.
Source: Field survey, 2006.

Table 9: Mean technical efficiency by farm group

Farm group	Technical efficiency		
	Mean	Maximum	Minimum
Irrigators	51.2	75.8	15.0
Non-irrigators	53.4	88.0	12.1
t-ratio	*(0.036)*		
All sample	**52.8**	**88.3**	**12.4**

Note: Technical efficiency index is obtained from the OLS residuals.
Source: Computed from field survey data, 2006.

The lowest level of technical efficiency is about 12% and the best farm achieved an 88% level of technical efficiency. The mean technical efficiency for pooled sampled farmers is 53%, indicating that rice farmers (both irrigators and non-irrigators) in Northern Ghana produce below the frontier. The mode is within the 44% to 46% efficiency level. The mean for pooled sampled farms is low compared with 83%, 96%, 75% and 89%, which were found by Huang and Bagi (1984), Parikh and Shah (1995), Kumbhakar (1994), and Tadesse and Krishnamoorthy (1997), respectively.

The low levels of technical efficiency among rice farmers suggest the presence of random shocks (production risks) and managerial inefficiency. Figures in Table 9 show that non-irrigated rice farmers had a 53% mean level of technical efficiency compared with 51% for irrigators. Technical efficiency ranges between 15% and 75% for irrigators and 12% to 88% for non-irrigators. The low technical efficiency measures, however, contradicts Abdulai and Huffman (2000) who found the mean level of profit efficiency to be relatively high for farmers drawn from four districts in Northern Region of Ghana. The contradiction can be attributed to differences in methodologies. Whereas Abdulai and Huffman (2000) utilized the profit function approach to analyse rice farmers drawn from only Northern Region, the present study examined technical efficiency of farmers drawn from the three northern regions based on a production function analysis.

Difference-of-mean tests show that at the 5% level of significance, there is no difference in technical efficiency between irrigators and non-irrigators. Thus, on the basis of difference-of-mean test results the null hypothesis, which states that technical efficiency is the same for irrigators and non-irrigators, is not rejected. This finding confirms the findings of Seidu (2004) on Upper East Region of Ghana that both small-scale irrigators and non-irrigators are technically inefficient. Our results therefore suggest that when sample selection is not based on farm size (small, medium and large), technical efficiency appears to be the same for irrigators and non-irrigators. This finding is not surprising because the irrigated schemes in the study area are old and are characterized by poor irrigation water control, lack of irrigation facilities, few extension agents and lack of maintenance. The extension officers at the irrigated dams are not only few; they also offer no new ideas for improving farmer efficiency. More so, the analysis shows that irrigated farmers have relatively lower rice farming experience (see Table 5). The lack of maintenance is attributed to the inadequacy of basic farm machinery like tractors and power tillers.

Further, the irrigated dams suffer from poor farmer or community management because of farmers' inability to mobilize themselves effectively for regular payment of irrigation levies. Another reason is that over 70% of non-irrigated farmers cultivate rice on valley bottoms and these areas are well known for their high rice potential. Finally, the amount of rainfall recorded in the Upper East (845 mm) and Northern regions (821 mm) during the study period (2005/06) were above national average, suggesting that the rainfall was adequate for rice cropping.[10] MOFA (2006) confirms this finding by reporting that the rainfall pattern during the 2005/06 cropping season was favourable.

Determinants of technical inefficiency

Results on the effects of farm and farmer socioeconomic and demographic factors have an important impact on technical efficiency. We looked at age, credit availability, education, extension contact, household size and farmer experience, among others. The results are summarized in Table 10.

The relationship between technical inefficiency and farm and farmer characteristics is derived using the ordinary least squares (OLS) estimator (Table 10). The R^2 is 67% for sampled farms and 59% and 48%, respectively, for irrigators and non-irrigators. The education variable has the right sign and is significant for both farm categories. The role of education in improving farmers' efficiency is widely known because it enables farmers to understand the socioeconomic conditions governing their farming activities and to 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 non-government organizations (NGOs) engaged in micro credit delivery. Education also enhances farmers' understanding of extension recommendations. The results agree with findings by Kalirajan and Shand (1985), Abdulai and Huffman (2000), Weirs (1999), and Owens et al. (2001) that education is relevant for improving efficiency.

Table 10: Technical efficiency and farm characteristics (OLS)
Dependent variable: Technical efficiency index

Explanatory variable	**Coefficient and t-ratios**		
	Irrigators & non-irrigators	**Irrigators**	**Non-irrigators**
Constant	0.187 (2.096)	9.041 (-4.104)*	0.560 (9.412)***
Education	1.118 (1.220)**	0.180 (1.958)*	0.011 (2.293)**
Expendu	0.212 (0.500)	-	0.927 (9.350)*
Extension contact	0.435 (2.113)**	0.443 (2.322)*	0.023 (2.263)**
Soil quality	0.3132 (0.776)	0.002 (0.247)	0.031 (1.392)
Household size	0.046 (0.513)	0.135 (0.774)	0.011 (3.807)***
Credit	-0.008 (-0.102)	-0.022 (-0.269)	-
Gender	-0.106 (-0.854)	-0.110 (-0.944)	-
Age (squared)	0.008 (5.290)*	0.065 (1.170)	0.790 (2.240)**
R^2	0.67	0.59	0.48
N	**732**	**250**	**482**

Note: *** and ** represent 1% and 5% levels of significance, respectively.
Source: Field survey, 2006.

The coefficient of the interactive term between the education and experience variables is significant for non-irrigators, implying that apart from the average eight years of education for sample farmers, non-irrigated farmers utilize their accumulated experience in rice farming. When farmers accumulate knowledge, they are able to plan, keep simple farm records and manage their farms more accurately. They are also able to do early planting and timely weeding as well as using quality rice seed. Accumulated experience assists farmers in the mobilization and use of family labour instead of relying on farm agents as has been practised by irrigators. Thus, the non-irrigated farmers' rich experience gives them relatively greater managerial efficiency, which suggests greater technical efficiency.

The coefficient of extension contact is positive and significant, suggesting that such contact increases farm efficiency because farmers are able to use modern techniques of rice farming involving land preparation, planting, application of agro-chemicals (for example, fertilizer) and harvesting. This finding confirms the results of Xu and Jeffrey (1998) that extension visits to farmers are important for reducing farm inefficiency. The explanation is that farmers who have adequate extension contact avail themselves of modern agricultural technology for input mobilization, input use and disease control, which enables them to reduce technical inefficiency.

The coefficient of the household size variable is positively related to technical efficiency, suggesting that a large family size enhances technical efficiency on non-irrigated lands. The significance of the household size variable for non-irrigators seems plausible. First, larger farm families provide farmers with a variety of labour (children, youth, men and women), which leads to division of labour and specialization. Second, irrigated farmers suffer from scarcity of hired labour for laborious rice activities because of the recent increase in out-migration of the youth from Northern Ghana to Southern Ghana in search of jobs. Perhaps, non-irrigators operate with the assumption that if there is a big farm that needs labour, it can be productive for the household to employ its own children in order to avoid the hassle of hiring workers each season, spending extra money and supervising them. Third, non-irrigated farmers own farms that are more than twice the size of those of irrigators because irrigated land is scarce and fragmented. This implies that non-irrigators can improve technical efficiency by expanding farm size or practicing fallowing especially in the Northern and Upper East regions. These findings confirm the conclusions reached by Ogundele and Okoruwa (2004) that farm size significantly determines levels of technical efficiency and the results of Parikh and Shah (1995) that land fragmentation leads to technical inefficiency. Apart from land fragmentation, irrigated land in the study area is managed by farmer organizations. When land is managed by these organizations it is often difficult to ensure adherence to irrigation rules and regulations.

6. Conclusions

This study estimated technical and allocative efficiency of smallholder rice farmers in Northern Ghana over the 2005/06 cropping year to determine ways in which rice production might be increased through more efficient use of farming resources. The data were obtained from a random sample of 732 rice farmers, including 252 irrigators and 480 non-irrigators. The findings are that rice farmers, irrigators and non-irrigators, are technically inefficient. Mean technical efficiencies for irrigators, non-irrigators and sampled farms are 51%, 53% and 53%, respectively. Technical efficiency ranged between 12% and 88% for sampled farms. Inter-farm comparisons revealed that there is no significant difference in technical efficiency between irrigated and non-irrigated rice farmers in the study area. At 53%, the mean technical efficiency level for the pooled sampled farms is low compared with 89% and 96% efficiency values estimated for India and Pakistan, respectively. The low levels of technical efficiency among rice farmers suggest the presence of random shocks (production risks) and managerial inefficiency. The evidence shows that when sample selection is not based on farm size (small, medium and large), technical efficiency appears to be the same for irrigators and non-irrigators. The finding is not surprising because the irrigated schemes in the study area are old and are characterized by poor irrigation water control, lack of irrigation facilities, few extension agents and lack of maintenance.

Rice production in the region is threatened by various kinds of production risks. About 14% of the variation in rice output is due to factors beyond the control of the farmers. Examples of such risks include erratic rainfall, crop diseases, worms, bushfires, birds and grasshoppers. The study provides evidence to show that technical efficiency of farmers growing rice in Northern Ghana is significantly determined by the level of education of rice farmers, extension contact, farmers' age (farmers' accumulated experience) and family size. Specifically, while the level of farmer's education and extension contact significantly determine technical efficiency in irrigated rice farming, non-irrigated rice farming is significantly influenced by farmers' age, family size in addition to the level of farmer's education and extension contact.

7. Recommendations

In the first place, technical efficiency for both irrigators and non-irrigators in Northern Ghana is low, suggesting the presence of technical inefficiency. There is the need for policy makers to develop formal and informal education programmes that will improve farmers' abilities to retrieve and process information about modern agricultural technology. Providing them with education will be a useful investment and a good mechanism for improving efficiency in rice farming. The emphasis should be on providing education that will help farmers to understand the socioeconomic and policy conditions governing their farming activities. The education package must also include the provision of farmer field schools to expose them to farm record keeping, group dynamics, resource mobilization and irrigation management. Another way is to strengthen the capacity of rice farmers through farmer centred training workshops geared towards managerial efficiency as well as resource use efficiency. This should be done in a collaborative manner involving the government, district assemblies and NGOs.

The Ministry of Food and Agriculture should intensify its extension services programme by training and deploying qualified extension agents. The agents, in turn, should intensify farmer education about input use. The extension agent–farmer ratios, as well as extension contact with farmers in the study area, are low. There is therefore need to motivate and train the existing extension agents to work more effectively and to train more agents.

Notes

1. Northern Ghana is defined to include three regions, Northern, Upper East and Upper West.

2. Out-migration is common in Northern Ghana. It involves the movement of young girls and boys to urban cities like Kumasi, Accra and Tema in Southern Ghana to look for jobs.

3. The policy of the Ghana government is to reduce rice imports by 30%.

4. As part of policy change, the Government of Ghana is in the process of privatizing extension service delivery.

5. This number was chosen to represent the over 10,000 rice farmers in the three regions.

6. There are 110 and 24 districts in Ghana and in Northern Ghana, respectively. New districts were created in 2004, raising the total number of districts in the country and Northern Ghana to 138 and 32, respectively. However, the new districts are excluded from the analysis because they were not active or functioning at the time this study was conducted.

7. Bullock ploughs are predominantly used in the Upper East Region and some parts of Northern Region.

8. The alternative method is to calculate the corresponding condition number using LIMDEP 7.0 (see Puhani, 2000: 68). The approach we used here involved the estimation of two equations, the sample selection equation and the equation of primary interest. The equation that determines the sample selection was stated as $z_i = b'w_i + u_i$, where i is the index for each survey respondent; z is dependent variable; b is the vector of variable coefficients to be estimated; w is the vector of demographic characteristics; and u is the error term. The equation of interest was stated as $y_i = a'x_i + e_i$, where y is the dependent variable; a is the coefficients to be estimated; x is the explanatory variable in the probit model plus the inverse Mills ratio; and e is the error term.

9. 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, δ^2.

10. Seini (2002: 96) describes the average annual rainfall in Ghana, which ranges between 800 and 2,000 mm, as most adequate to sustain agricultural production.

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