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Structural Adjustment and Economic Efficiency of Rice Farmers in Northern Ghana*

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Increasing agricultural productivity and employment in sub-Saharan African countries has received widespread attention in the literature on economic development and poverty alleviation. Agricultural growth, however, is linked to farm profits. Over the past few years, considerable research has examined agricultural efficiency in the region.1 This issue has gained attention in the light of structural adjustment programs— involving market liberalization, fiscal austerity, and currency devaluation—that are currently being implemented in many sub-Saharan African countries and global trade liberalization being pursued under the World Trade Organization.2

The experience of structural adjustment programs since the beginning of the 1980s shows how particularly important farm household efficiency is to the African rural economy. The fundamental role of structural adjustments was to enable private markets to perform better by eliminating the dominant public sector, encouraging the development of the private sector, and letting prices perform their signaling role for the allocation of factors of production, goods, and services. One of the main explanations for previous failures to intensify food crop production in the region has been poor public policies, including subsidizing cereal imports, which penalized domestic cereal production.

Under structural adjustments, changes in the fiscal environment that reduce subsidies on food items are supposed to make agriculture more profitable. However, the reduction or removal of subsidies on agricultural inputs such as fertilizer, fuel, or machinery tends to increase the prices of these inputs to farmers. Available evidence shows that the agricultural sector’s response to these policy reforms has been encouraging...
as output and productivity have increased in countries that pursued the reforms relative to countries that made only minor changes in policies. 3

Although considerable efforts have been directed at examining efficiency of farmers in the region, particularly during this unfolding process of agricultural and economic reform, little attention has been given to the relationships among market indicators, household characteristics, and production efficiency. 4 This contrasts greatly with the increasing number of such studies in other developing regions and developed countries. 5 If we can establish a better understanding of how market indicators and household characteristics affect production efficiency, policy makers can better implement measures that contribute to enhancing agricultural efficiency. The significance of such policies in the phase of increasing competition between domestic and imported agricultural products cannot be overemphasized.

If agricultural households are integrated into output and input markets, then profit maximization becomes an appealing economic goal. This article uses a unique data set for rice-producing agricultural households in northern Ghana to examine household’s profit efficiency and the relationship between farm and household attributes and profit inefficiency. The main hypotheses are that (i) households’ rice production decisions are consistent with profit maximization and, (ii) to the extent that profit inefficiency differs across households, it is related to farmers’ schooling, specialization in rice production, and access to credit. The presentation is divided into four sections, including a final section with conclusions and policy implications.

**Price Production in Ghana**

Rice production has increased substantially over the past 3 decades. Annual production averaged 80,000 tons in the past 10 years, compared to an average of about 32,000 tons in the 1960s. Increases in total output are mainly due to land area expansion, with yield gains playing a minor role. Area expansion took place mainly in the Northern region, although irrigation products are gradually transforming the Accra-Keta coastal plain into a rice-growing area. Imported rice still accounts for a large proportion of domestic consumption because local production falls short of domestic demand. 6 The Ghana Seed Company, which maintains contact with national and international research institutes, has improved varieties of *Oryza sativa*, originally introduced into the country from Asia. The improved varieties that are presently cultivated in Northern Ghana (GR 18 and GR 19) have virtually the same yield potentials. 7 Although considerable efforts have been put into increasing yields in the country, adverse weather conditions and low input use still keep average yields low.

As in most developing countries, the government consistently regulated agricultural supply and prices by intervening in both input and out-
put markets until 1984. The rice sector, which experienced a relatively free trade regime during the 1950s and 1960s, had restrictions imposed on imports in the 1970s to encourage domestic production. The Food Distribution Corporation controlled the price of imported rice at distribution centers, and official prices were set for domestic rice between 1974 and 1983. The overvaluation of the Ghanaian currency contributed to an increase in protection of the rice sector between 1974 and 1983. Protection of the sector decreased substantially in 1984 and again in 1985 as the exchange rate was successfully devalued. The liberalization of food trade and imports of agricultural inputs such as fertilizers and pesticides exposed the sector to competition with imported rice. The devaluation of the currency, however, made imported rice relatively more expensive than domestic rice, giving domestic producers a competitive edge. Imported rice was about 10% cheaper than domestic rice before the adjustment programs in 1983 and over 25% more expensive at the wholesale level after 1984.8

Modeling Production and Efficiency of an Agricultural Household
In this study, we assume that households make farm production decisions independent of their consumption and time-allocation decisions. This assumption stems from three main reasons. First, rice is mainly a commercial crop in the study area. All farmers in the sample produced rice for sale, although some rice was used for home consumption. Farmers in the sample include only those for whom rice was the sole commercial crop. Second, rice produced was both for home consumption and for sale. Third, farm households in the sample participated actively in the local labor markets. Sixty-nine percent of the family heads worked off farm, 79% of the households had family members working off farm, and 40% of the farms hired labor. Overall, 94% of the sample farms had one or more of these three main outcomes. Therefore, farm households can reasonably be assumed to make rice production decisions as if they are maximizing profit on rice production net of the cost of family labor valued at the off-farm wage rate per year.9

Defining Efficiency
The question of how to measure efficiency has received considerable attention in the economic literature. “Efficiency” can be defined as the ability to produce a given level of output at lowest cost.10 The traditional concept of efficiency, as defined by M. J. Farrell, has three components: technical, allocative, and economic.11 “Technical efficiency” is defined as the ability to achieve a higher level of output, given similar levels of inputs. “Allocative efficiency” deals with the extent to which farmers make efficient decisions by using inputs up to the level at which their marginal contribution to production value is equal to the factor cost. Technical and allocative efficiencies are components of economic effi-
ciency. It is possible for a firm to exhibit either technical or allocative efficiency without having economic efficiency. Therefore, both technical and allocative efficiencies are necessary conditions for economic efficiency.

Production functions have traditionally been used to examine efficiency of farmers in Africa. A production function approach, however, fails to capture inefficiencies associated with different factor endowments and different input and output prices across farms. Under such conditions, farms may exhibit different “best-practice” production functions and operate at different optimal points. L. Lau and P. Yotopoulos, therefore, popularized the use of the profit function approach, in which farm-specific prices and levels of fixed factors are incorporated in the analysis of economic efficiency. The advantage of using this approach is that when input and output prices are exogenous to farm household decision making, they can be used to explain input use and output supplied. The resulting parameter estimates, in general, will be statistically consistent. In the profit function approach, economic efficiency can be defined as the ability of a firm to achieve potential maximum profit, given the level of fixed factors and prices faced by the firm.

D. J. Aigner, C. A. Knox Lovel, and P. Schmidt, however, showed that profit function models do not provide a numerical measure of firm-specific efficiency and popularized the use of the frontier approach. The stochastic frontier approach has gained popularity in firm-specific efficiency studies. Examples of recent applications include M. Ali and J. C. Flinn, and S. C. Kumbhakar and A. Bhattacharya. Profit or economic inefficiency in this framework is defined as profit loss from not operating on the profit frontier, taking into consideration farm-specific prices and fixed factors. Within the frontier framework, Kumbhaker has recently used a translog cost function to establish an exact relationship between allocative inefficiency in the cost share equations and in the cost function.

The Stochastic Profit Frontier
Consider a farm that maximizes profits subject to competitive input and output markets and a single-output technology that is quasi-concave in the \((n \times 1)\) vector of variable inputs, \(X\), and the \((m \times 1)\) vector of fixed factors, \(Z\). The actual normalized profit function that is assumed to be “well-behaved” can be expressed as

\[
\pi(p, Z) = Y(X^*, Z) - \sum_i p_i X_i^*, \quad X^* = g(p, Z),
\]

where \(Y(\cdot)\) is the production function; the asterisk denotes optimized values; \(p_i = W/P\); \(p_i\) is the normalized price of input \(i\); and \(P\) and \(W\) are

the output and input prices, respectively. The stochastic profit function can then be expressed as

$$
\pi_j = f(p_{ij}, z_{kj}) \cdot \exp e_j,
$$

(2)

where $\pi_j$ is normalized profit of the $j$th farm, computed as gross revenue less variable cost, divided by farm-specific output price $P$; $p_{ij}$ is the normalized price of input $i$ for the $j$th farm, calculated as input price divided by farm-specific output price $P$; $z_{kj}$ is the level of the $k$th fixed factor for the $j$th farm; and $e_j$ is an error term. The error term, $e_j$, is assumed to behave in a manner consistent with the frontier concept

$$
e_j = V_j - U_j,
$$

(3)

where $V_j$ is the symmetric error term and $U_j$ is a one-sided error term. The $V_s$ are assumed to be independently and identically distributed as $N(0, \sigma^2_v)$. We assume that $U_j$ has a half-normal nonnegative distribution, $N(0, \sigma^2_u)$. The error terms $U_j$ and $V_j$ are also assumed to be independent of each other. The error term $U_j$ is used to represent inefficiency. That is, it represents profit shortfall from its maximum possible value given by the stochastic frontier. Thus, if $U_j = 0$, the firm lies on the profit frontier, obtaining potential maximum profit given the prices it faces and the levels of fixed factors. If $U_j > 0$, the firm is economically inefficient, and profit is less than the maximum.

An average frontier model results if the frontier model is estimated without the one-sided disturbance term, $U_j$. Farrell has criticized this approach. By contrast, a full deterministic or full frontier model, often estimated by linear programming techniques, results if the random error term $V_j$ is omitted. It is essential to estimate the frontier function to provide an estimate of industry best-practice profit for any given level of prices and fixed factors. An estimated value of profit efficiency for each observation can be calculated as $\exp(-U_j)$.

Following J. Jondrow, C. A. Lovell, I. S. Materov, and P. Schmidt, the unobservable value of $U_j$ may be obtained from its conditional expectation given the observable value of $V_j - U_j$. The farm-specific profit inefficiency index (PIE) is given as

$$
\text{PIE} = (1 - \exp(-U_j)).
$$

(4)

Profit loss due to inefficiency is represented as potential maximum profit given farm-specific prices and fixed factors, multiplied by farm-specific profit inefficiency index. The second objective of the study is achieved by relating the profit inefficiency index to farm and household attributes. This can be specified as $\text{PIE} = g(X) + w$, where $\text{PIE}$ is the profit inefficiency index, $X$ is a vector of farm household attributes, and
$w_i$ is the unexplained component of inefficiency, for example, weather and prices peculiar to a particular farm. The profit inefficiency index is therefore hypothesized to be related to attributes of the farm household.

**Empirical Model**

Flexible functional forms for the profit function include the normalized quadratic, normalized translog, and generalized Leontif. In this study, we have chosen to use the normalized translog stochastic profit function, which is assumed to be "well-behaved":

$$
\ln \pi = \alpha_0 + \sum_i \alpha_i \ln P_i + \frac{1}{2} \sum_i \gamma_i \ln P_i \ln P_i \\
+ \sum_i \sum_l \delta_{il} \ln P_i \ln Z_l + \sum_k \beta_k \ln Z_k \\
+ \frac{1}{2} \sum_k \sum_h \phi_{lh} \ln Z_k \ln Z_h + V - U,
$$

where $i, l = k, h = 1, 2$; $\pi$ is normalized profit computed as gross revenue less variable costs, divided by farm-specific rice price; $P_i$ is the money wage rate of labor per hour normalized by the price of rice; $P_2$ is the money price per kilogram of fertilizer nutrients normalized by the price of rice; $Z_i$ is the land input, measured as hectares of rice grown per farm; $Z_2$ is the capital input computed as the sum of costs of animal and mechanical power; and $V$ and $U$ are the error terms defined in equation (3). The estimate of $U_i$ is obtained by replacing $e_i$ by its sample residual and the unknown parameters given in equation (5).

The empirical measure of the profit inefficiency index, $\text{PIE}^*_i$, is obtained by inserting the sample residual for $U_i$ in equation (4). In fitting the relationship between profit inefficiency and household attributes, the inefficiency index was redefined as $\ln[\text{PIE}/(1 - \text{PIE})]$ so that it can potentially take on values from plus-to-minus infinity. This form ensures a normal distribution for the index.\(^{23}\)

The specification used is

$$
\ln[\text{PIE}/(1 - \text{PIE})]_i = \alpha_0 + \alpha_c \text{CRED}_i + \alpha_e \text{EDUC}_i \\
+ \alpha_g \ln \text{NFARM}_i + \alpha_s \text{SPEC}_i \\
+ \alpha_a \text{AGE}_i + \alpha_e \ln \text{AGESQ}_i \\
+ \alpha_t \text{CRED}_i \times \text{EDUC}_i + \alpha_d \text{DIST}_i \\
+ \alpha_{ij} \text{DUM}1_j + \alpha_{ij} \text{DUM}2_j \\
+ \alpha_{ij} \text{DUM}3_j + \epsilon_i.
$$
where CRED, EDUC, NFARM, SPEC, and AGE denote access to credit, level of head’s education, head’s nonfarm employment, level of specialization in rice, and age of the household head, respectively. CRED * EDUC is a multiplicative interaction term included to examine the impact of education on inefficiency, given that the credit constraint is removed. DIST is the distance to the regional capital in kilometers. DUM1, DUM2, and DUM3 represent political district dummies, and ε is an error term.24

Data and Empirical Definition of Variables
The data used for this empirical application are a subsample of a random sample survey conducted in 1992–93 of 256 farmers in four districts of Northern Ghana. The farms in the sample are located in the Tamale, Savelugu, Tolon, and Gushiegu-Karaga districts.25 Information from these farm households was gathered through repeated visits using a questionnaire. Additional survey data were obtained from the Northern Region Ministry of Agriculture in Tamale. The data cover information on farm and nonfarm activities, as well as demographic and locational characteristics. Information on farm activities includes fertilizer applications and prices, wages, capital assets, and livestock production. With respect to cash-oriented nonfarm activities, the information includes weekly or monthly earnings and detailed individual time allocation.

The Northern Region presently accounts for more than half of the total rice production in the country. Until irrigation projects gradually transformed the Accra coastal plain into a major area of rice production, the Northern region alone accounted for an average of 63% of rice production between 1977 and 1987. From the original 256 households in the survey, 120 farmers who cultivated rice—the most important cash crop grown in the area—were chosen from the four districts based on complete availability of needed information on the household. Table 1 describes selected characteristics of the sample farms. Output is measured in tons of paddy rice per hectare. The mean rice yield over the sampled farms was 1.5 tons per hectare of paddy rice, with a range of about 0.5 tons per hectare to 2.1 tons per hectare. The yield gap between the average and the lowest farm yield was 1.0 ton per hectare, and that between the average and the highest was 0.6 tons per hectare, suggesting that there is considerable room for improving average rice yields in the area.

The input of land is measured as hectares of rice grown per farm in the year of the survey; total land cropped is measured as the total hectares that were under crop cultivation in that year. As in S. S. Sidhu and C. A. Baanante, the total labor expenditure per farm includes the imputed costs of family labor used in production at the wage rate paid to permanent hired labor.26 The money wage rate used in the analysis is obtained by dividing the total labor expenditure for rice production per farm by the quantity of labor including both family and hired labor. Female and
TABLE 1

SELECTED CHARACTERISTICS OF SAMPLE FARMS IN THE NORTHERN REGION
OF GHANA, 1992–93

<table>
<thead>
<tr>
<th>Farm and Household Characteristics</th>
<th>Definition</th>
<th>Minimum</th>
<th>Mean</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total farm area</td>
<td>Total land cultivated in hectares</td>
<td>.8</td>
<td>4.1</td>
<td>27.8</td>
</tr>
<tr>
<td>Household size</td>
<td>No. of persons in household</td>
<td>3</td>
<td>8.4</td>
<td>14</td>
</tr>
<tr>
<td>Head’s age</td>
<td>Age of household head years old</td>
<td>19</td>
<td>39.2</td>
<td>54</td>
</tr>
<tr>
<td>Education level</td>
<td>Years of schooling of household head</td>
<td>0</td>
<td>3.66</td>
<td>12</td>
</tr>
<tr>
<td>Nonfarm employment</td>
<td>Hours spent on nonfarm work per year</td>
<td>0</td>
<td>541.9</td>
<td>1,760</td>
</tr>
<tr>
<td>Distance</td>
<td>Distance to the regional capital in km</td>
<td>0</td>
<td>29.6</td>
<td>62.5</td>
</tr>
<tr>
<td>Credit constraint</td>
<td>Dummy: 1 if head is credit constrained</td>
<td>⋮</td>
<td>.38</td>
<td>⋮</td>
</tr>
<tr>
<td>Tamale</td>
<td>Dummy: 1 if resides in Tamale district</td>
<td>⋮</td>
<td>.24</td>
<td>⋮</td>
</tr>
<tr>
<td>Savelugu</td>
<td>Dummy: 1 if resides in Savelugu district</td>
<td>⋮</td>
<td>.24</td>
<td>⋮</td>
</tr>
<tr>
<td>Tolon</td>
<td>Dummy: 1 if resides in Tolon district</td>
<td>⋮</td>
<td>.25</td>
<td>⋮</td>
</tr>
<tr>
<td>Gushiegu-Karaga</td>
<td>Dummy: 1 if resides in Gushiegu-Karaga district</td>
<td>⋮</td>
<td>.27</td>
<td>⋮</td>
</tr>
<tr>
<td>Rice production:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm size</td>
<td>Area in hectares</td>
<td>.7</td>
<td>3.2</td>
<td>19.6</td>
</tr>
<tr>
<td>Fertilizer use</td>
<td>Nutrient kg per hectare</td>
<td>90</td>
<td>180</td>
<td>240</td>
</tr>
<tr>
<td>Yield</td>
<td>Tons per hectare</td>
<td>.5</td>
<td>1.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Paddy price*</td>
<td>Cedis per 100 kg</td>
<td>13,800</td>
<td>14,500</td>
<td>15,100</td>
</tr>
<tr>
<td>Labor</td>
<td>Days per hectare</td>
<td>116</td>
<td>198</td>
<td>214</td>
</tr>
<tr>
<td>Wage rate*</td>
<td>Cedis per hour</td>
<td>43</td>
<td>57</td>
<td>72</td>
</tr>
</tbody>
</table>

* The reigning exchange rate was about 400 cedis to 1 U.S. dollar.

child labor used is converted into man equivalents by treating two women (or children) as equal to one man. Capital input is computed as the sum of costs of animal and mechanical power used in rice production. Price of fertilizer is measured as total expenditure on fertilizer per kilogram of fertilizer nutrients (including transportation and spreading cost). During the period under study, there were neither price support nor input subsidy schemes for rice farmers. Moreover, the import of rice had been completely liberalized, leaving production and distribution to the forces of supply and demand. The farm level observed prices show some variation that seem to be due to location and other factors. Variation in the price of fertilizer appears to be due largely to location.

Variables representing farm and household characteristics used in the analysis of the determinants of profit inefficiency include the level of specialization in rice production, hours of nonfarm employment, and ac-
cess to credit. Level of specialization in rice production is measured as the proportion of a farm’s land area used in rice cultivation relative to the total area that was under cultivation during the survey period. It is hypothesized that farmers who specialize in rice production would tend to devote more attention and resources to crop production in the rice sector than would other producers, thus gaining information that would aid them in adopting technologies that increase efficiency.

The net effect of nonfarm work on efficiency is ambiguous, since participation in the nonfarm labor market may restrict production and decision-making activities, thereby increasing inefficiency. However, increased nonfarm work reduces financial constraints, particularly for resource-poor farmers, and thus enables them to purchase productivity-enhancing inputs. Access to formal credit permits a farmer to enhance conventional allocative efficiency by overcoming financial constraints for the purchase of fertilizer, for example, or a new technological package such as high-yielding seeds. Credit, therefore, increases the net revenue obtained from fixed inputs, market conditions, and individual characteristics, while credit constraint decreases the efficiency of farmers by limiting the adoption of high-yielding varieties and the acquisition of information needed for increased productivity. Credit would have no effect on production if it simply displaced another source of financing such as savings. However, credit can have a negative impact on profits if lenders treat it as a welfare program because farmers tend to perceive default costs as minor. S. R. Weissman, however, reports that credit shortages in his study area adversely affected small farmers’ access to inputs and cooperative storage facilities.

Two variables representing characteristics of the household head, age and education (number of years of schooling), are included in the analysis of the determinants of profit inefficiency. The simplifying assumption is that the household head, whether male or female, is also the primary decision maker on the family farm. Education, which represents human capital of the household head, is hypothesized to have a positive impact on efficiency. This view of the role of human capital in production, commonly referred to as “allocative ability,” stems from the fact that reallocation of resources in response to changes in economic conditions requires (i) perceiving that change has occurred, (ii) collecting, retrieving, and analyzing useful information, (iii) drawing valid conclusions from the available information, and (iv) acting quickly and decisively. Allocative skill is human capital in the sense that it is acquired at a cost and tends to yield a valuable stream of services over future periods. It is acquired in schooling, by seeking information, and in experience from reallocating resources. Household head’s age and age-squared are included to proxy general experience and nonlinear life cycle effects.

District level dummies are included to capture the impacts of loca-
tional characteristics on inefficiency. Factors that contribute to relatively higher efficiency in certain districts are, among others, (i) easier access to information because of the favorable location of extension services, improved seed multiplication units, agricultural financial institutions, and fertilizer depots in the more accessible districts; (ii) better health and water facilities; and (iii) greater market access for farmers’ products. Therefore, farmers located in such districts are exposed to a modernizing environment where new crop varieties, innovative planting methods, and capital inputs such as insecticides and tractors or machines are readily available. In particular, T. W. Schultz argued that education is likely to be more effective under modernizing conditions.34 The distance to the regional capital, which is the main regional market for rice farmers, is also included to capture the effects of transaction costs for purchasing farm inputs, selling farm outputs, and purchasing consumer goods. If a rice farm is located relatively far away from the regional market, the farmer uses more time to obtain inputs and the purchase price gross of transport costs is higher. All of which affects the efficiency of farm production. Farmers with very poor access to markets for consumer goods also tend to be less interested in profit-maximizing activities compared to those living in areas with a sufficient supply of consumer goods.

**Translog Profit Frontier Results**

Maximum-likelihood estimates for the parameters of the normalized translog profit function subject to restrictions of homogeneity and symmetry are given in table 2. The equation was estimated by LIMDEP, version 7.0, developed by W. Greene.35 The coefficients of the prices for fertilizer and labor have the expected negative signs, while those for land and capital are positive as expected. The ratio of the standard errors of \( U \) and \( V \), \( \lambda \), is 2.19, implying that the one-sided error term \( U \) dominates the symmetric error \( V \). This result indicates that variation in actual profit from maximum profit (frontier profit) between farms mainly arose from differences in farmer practices rather than random variability. The average measure of inefficiency is 27.4%, which suggests that, on average, about 27% of potential maximum profit is lost owing to inefficiency. This corresponds to a mean profit loss of 38,555 cedis per hectare. This discrepancy between observed profit and the frontier profit is due to both technical and allocative inefficiency.

The frequency distribution of the farm specific profit inefficiency is reported in table 3. The table shows that sample farm profit inefficiency varies widely. Although the minimum observed profit inefficiency is 0.16%, and the maximum is 95.5%, 70% of the sample farms exhibit a profit inefficiency of 35% or less. We also estimated a stochastic frontier production function to ascertain technical efficiency of the sample farms.36 The frequency distribution reveals that the mean technical inefficiency is 0.19, with a minimum of zero and maximum of 70.8, which
TABLE 2
MAXIMUM LIKELIHOOD ESTIMATES OF TRANSLOG PROFIT FRONTIER

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter</th>
<th>Coefficient</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$\alpha_0$</td>
<td>4.7642</td>
<td>1.6303</td>
</tr>
<tr>
<td>$\ln p_1$ (fertilizer)</td>
<td>$\alpha_1$</td>
<td>-.6918</td>
<td>.2281</td>
</tr>
<tr>
<td>$\ln p_2$ (labor)</td>
<td>$\alpha_2$</td>
<td>-.1952</td>
<td>.1393</td>
</tr>
<tr>
<td>$\ln p_1 \times \ln p_1$</td>
<td>$\alpha_{11}$</td>
<td>.1021</td>
<td>.2424</td>
</tr>
<tr>
<td>$\ln p_1 \times \ln p_2$</td>
<td>$\alpha_{12}$</td>
<td>-.2367</td>
<td>.8835</td>
</tr>
<tr>
<td>$\ln z_1$ (land)</td>
<td>$\beta_1$</td>
<td>.6131</td>
<td>.2417</td>
</tr>
<tr>
<td>$\ln z_2$ (capital)</td>
<td>$\beta_2$</td>
<td>.2327</td>
<td>.1149</td>
</tr>
<tr>
<td>$\ln z_1 \times \ln z_1$</td>
<td>$\gamma_{11}$</td>
<td>.2057</td>
<td>.5571</td>
</tr>
<tr>
<td>$\ln z_1 \times \ln z_2$</td>
<td>$\gamma_{12}$</td>
<td>.2040</td>
<td>.0742</td>
</tr>
<tr>
<td>$\ln p_1 \times \ln z_1$</td>
<td>$\gamma_1$</td>
<td>.4095</td>
<td>.1033</td>
</tr>
<tr>
<td>$\ln p_1 \times \ln z_2$</td>
<td>$\gamma_2$</td>
<td>-.5692</td>
<td>.1438</td>
</tr>
<tr>
<td>$\ln p_2 \times \ln z_1$</td>
<td>$\gamma_{12}$</td>
<td>.0979</td>
<td>.3549</td>
</tr>
<tr>
<td>$\ln p_2 \times \ln z_2$</td>
<td>$\gamma_2$</td>
<td>.9391</td>
<td>.8967</td>
</tr>
<tr>
<td>Lambda ($\sigma_u/\sigma_v$)</td>
<td>$\lambda$</td>
<td>2.1970</td>
<td>.4400</td>
</tr>
<tr>
<td>Sigma</td>
<td>$\sigma$</td>
<td>.4656</td>
<td>.0748</td>
</tr>
<tr>
<td>$\sigma_u^2$</td>
<td>.1796</td>
<td>.0372</td>
<td></td>
</tr>
<tr>
<td>$\sigma_v^2$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-likelihood</td>
<td></td>
<td>-320.117</td>
<td></td>
</tr>
</tbody>
</table>

indicates that, on average, about 19% of potential maximum output is lost owing to technical inefficiency. While 70% of the sample farms exhibit profit inefficiency of 35% or less, about 46% of the sample farms are found to exhibit technical inefficiency of 35% or less, indicating that among the sample farms technical inefficiency is much lower than profit inefficiency.

TABLE 3
FREQUENCY DISTRIBUTION OF FARM-SPECIFIC PROFIT INEFFECTIVITIES IN STOCHASTIC TRANSLOG PROFIT FRONTIERS

<table>
<thead>
<tr>
<th>Inefficiency Index (%)</th>
<th>Number of Farmers</th>
<th>Percentage</th>
<th>Inefficiency Index (%)</th>
<th>Number of Farmers</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–1</td>
<td>3</td>
<td>2.5</td>
<td>35–40</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>1–3</td>
<td>6</td>
<td>5</td>
<td>41–45</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>3–5</td>
<td>11</td>
<td>9</td>
<td>45–50</td>
<td>8</td>
<td>7.5</td>
</tr>
<tr>
<td>5–7</td>
<td>8</td>
<td>7.5</td>
<td>50–55</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>7–9</td>
<td>5</td>
<td>4</td>
<td>55–60</td>
<td>2</td>
<td>1.7</td>
</tr>
<tr>
<td>9–14</td>
<td>7</td>
<td>5.8</td>
<td>60–70</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>14–20</td>
<td>13</td>
<td>10.8</td>
<td>70–75</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>20–25</td>
<td>13</td>
<td>10.8</td>
<td>75–79</td>
<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td>25–30</td>
<td>8</td>
<td>7.5</td>
<td>80–95</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>31–35</td>
<td>10</td>
<td>8.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note.—Mean = 27.4; standard duration = 26.6; minimum = .16; maximum = 95.5.
Since estimated efficiency indices of sample farms from different studies for other countries vary widely in terms of databases, reference periods, and farm structures, comparison of estimates from other studies must be interpreted cautiously. However, it is still important, for policy purposes, to compare the signs and magnitudes of estimated efficiency measures. Ali, Parikh, and Shah applied a translog profit frontier on farm-level aggregate crop data for a cross section of farmers in Pakistan and obtained a profit inefficiency of 0.24.\(^{37}\) In another study, Ali and Flinn, also working with data on Pakistan rice farmers, obtained a mean profit inefficiency index of 0.28.\(^{38}\) It is interesting to note that our estimates do not differ remarkably from these results, given that the average inefficiency index in our study is 0.27. In a recent study of over 1,800 Chinese household farms, using a translog stochastic profit frontier, J. Wang, E. J. Wailes, and G. L. Cramer obtained a mean profit efficiency measure of 0.61, implying that inefficiency accounts for an average of 38.9% loss of profits.\(^{39}\) This is much higher than the inefficiency we observed for the sample farms in this study.

There are several factors that affect the estimates of profit inefficiency in our study. First, some effects are due to the particular farms in our sample, such as soil, weather, or prices. Hence, some of the farms identified as inefficient by the present method might not really be so if such individual effects were controlled. Second, although nonphysical inputs like information and supervision influence the ability of the farmer to use efficiently the available technology, we do not have access to these data. As a substitute, we use farm and household characteristics such as credit availability, education level of household head, number of hours spent on nonfarm work, distance to market, age, and location to explain inefficiency among the sample farms.

**Determinants of Profit Inefficiency**

The parameter estimates of the relationship between profit inefficiency obtained from the stochastic frontier model and farm and household characteristics using an ordinary least squares estimator are shown in table 4. We used the Breusch-Pagan test to test for potential heteroskedasticity, given the large variation in the level of specialization in rice production. The computed \(\chi^2\) value (20.76) was above the critical value (18.3) at the 5% level with 11 degrees of freedom, suggesting the presence of heteroskedasticity. In order to account for the heteroskedasticity, we calculated the standard errors from H. White’s formula, which accounts for nonparametric forms of heteroskedasticity.\(^{40}\) For purposes of comparison, the ordinary standard errors are also presented in table 4. The joint hypothesis that all nonintercept coefficients in the model are zero is rejected. The sample value of the Wald statistic is 26.82, with a critical value of \(\chi^2_{11}\) at the 5% significance level of 18.3.

The results show that the level of education (human capital) of the
household head tends to have a highly significant impact on profit inefficiency. The negative sign indicates that higher levels of education reduce inefficiency, a finding that is consistent with the review of M. E. Lockheed, D. T. Jamison, and Lawrence Lau. It is also in line with the findings of other studies such as Ali and Flinn for Pakistan and Kumbhakar and Bhattarcharya for India. The coefficient of the interaction term is also negative, albeit significant at the 10% level, suggesting that more educated farmers without credit constraints are more efficient than their counterparts who face credit constraints. The positive and significant coefficient of the nonfarm employment variable indicates that farmers engaged in nonfarm activities tend to exhibit higher levels of inefficiency. The positive relationship suggests that increases in nonfarm work are accompanied by a reallocation of time away from farm-related activities, such as adoption of new technologies and gathering of technical information that is essential for enhancing production efficiency.

A negative and statistically significant relationship is also found between access to credit and profit inefficiency, suggesting that farmers who face a credit constraint on purchased inputs experience higher profit inefficiency. The effect of the household head’s age on inefficiency is nonlinear. As a young household head ages, the efficiency of the household decreases until maximum inefficiency is reached when the household head is 33 years old. After that, the household becomes more efficient as the household head’s age increases.
The positive effect of distance to regional capital on profit inefficiency is as expected related to higher transactions and transport costs. The coefficients for the district dummies suggest that farmers located in the Tamale and Savelugu districts exhibit higher efficiencies relative to farmers in the Gushiegu area. However, no significant difference in inefficiency exists between farmers in the Tolon and Gushiegu districts. The mean levels of profit inefficiency were 26.4% and 26.9% for farmers in the Tamale and Savelugu districts, respectively. These compare favorably with the 30% mean level of profit inefficiency for farmers in the Gushiegu area, and they imply mean per-hectare losses of 34,699 cedis, 37,852 cedis, and 42,213 cedis, for the Tamale, Savelugu, and Gushiegu districts, respectively. The joint hypothesis that the three coefficients of the district dummies are zero is rejected. The sample value of the Wald statistic is 9.32, while the critical value ($\chi^2(3)$) is 7.81. This is not surprising because the regional public extension service and fertilizer depots are located in the Tamale district and, to a lesser extent, in the Savelugu district. Thus farmers in Tamale and Savelugu districts have better access to extension services and agricultural information than farmers located in other districts. Our finding lends support to Schultz’s hypothesis that the effectiveness of education on efficiency is enhanced in a modernizing environment.

**Conclusions and Policy Implications**

In this article we employ a stochastic translog profit frontier model to examine rice production efficiency. The estimated rice translog frontier function is consistent with profit maximization and with prices playing a major role in farmers’ production decisions. The results show that mean level of profit efficiency is relatively high, but significant variation in efficiency and inefficiency exists. The average inefficiency is 27.4%.

The findings from the inefficiency analysis suggest that higher household head’s education, access to credit and greater specialization, and being located in districts where extension services and better infrastructure are available are significant variables for increasing profit efficiency. Increasing participation in nonfarm activities by farmers, however, tends to lower profit efficiency. These findings have important policy implications in promoting efficiency among farmers in Ghana and in Africa in general. In particular, the significance of the education variable implies that perceiving and responding efficiently to changes in market prices require allocative ability that is acquired by investing in education and useful information. Furthermore, the marginal value of an additional year of the household head’s education (about a 25% increase) from greater economic efficiency in rice production is 18,142 cedis per farm per year, evaluated at the sample mean of the data. At 3–4 years of schooling, the opportunity cost of a student’s time to acquire additional education is low, close to zero, so the rate of return to education from...
improved economic efficiency is high, and the added years of education may have additional benefits. This conforms to J. Mellor’s argument that investment in education in rural areas should be considered as a central ingredient in a strategy designed to improve agricultural productivity when technology is dynamic. Investments in rural education in the currently changing political and economic environment in Ghana will provide farmers with skills essential in increasing economic efficiency.44

The finding of the relationship between inefficiency and access to credit also suggests that improving farmers’ access to institutional credit will improve production efficiency. The marginal value of reducing credit restraints on rice-producing farmers is 24,135 cedis per farm per year, evaluated at the mean of the data. This amount is significant and is somewhat larger than the impact of an additional year of education. Of course, with the low schooling levels that exist in farm households in Ghana, increases in education are not constrained to a single year; for example, average education would need to be increased by 4.4 years to achieve elementary school competency among household heads.

Improving the efficiency of resources will require streamlining the acquisition of credit among small farmers. However, allocating public expenditure to urban areas or large farmers who are politically vocal does not help the rural poor gain access to credit. Instead, it undermines their ability to operate as family farmers, therefore increasing inequality, and it also reduces efficiency and long-run growth. Specialization, as measured by the share of total cultivated land devoted to rice production, also tends to lower inefficiency, indicating that channeling relatively scarce resources (e.g., labor and capital) into rice production will improve efficiency.

The results for district effects suggest that policy makers need to consider improving the access of farmers who are located in remote areas to extension services and agricultural information. As shown empirically by Lockheed, Jamison, and Lau, the effects of education in a modernizing environment—availability of capital inputs such fertilizers and machines and exposure to extension services—are substantially greater than under traditional conditions.45

Overall, our results suggest that rice producers in Northern Ghana are highly responsive to market prices for rice and for inputs, including family labor. These are important findings, supporting the structural adjustment policies for agriculture that have already been implemented, because they have the goal of making farmers more market oriented and to reduce the direct role of the government in production decisions.

Notes
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Economic Development and Cultural Change

Station, Ames, Iowa, project no. 3077, and was supported by Hatch Act and State of Iowa funds.


11. Ibid.

12. Bindlish and Evenson (n. 4 above); Moock (n. 1 above).


17. Although competitive input and output markets are assumed, what is essential is the fact that all output and input prices be exogenous to the agricultural household and farm. This applies fully in the case of inputs used in rice production and price of rice in the country.

18. This implies that the profit function is nonincreasing in input prices and nondecreasing in output prices, homogenous of degree zero in input and output prices, and convex in input and output prices.

19. Farrell (n. 10 above).


21. We have chosen to separate the representation of the frontier function and profit inefficiency. Separation is reasonable when the factors affecting profit inefficiency are fixed or currently exogenous factors.

22. See n. 17 above.

23. Kumbhaker has recently argued that because the mean and variance of cost inefficiency are farm-specific, one cannot assume that cost inefficiency has constant mean and variance. Consequently, the standard Aigner et al. model cannot be applied to a translog cost function, and it cannot be assumed that cost inefficiency is distributed independently and identically across firms with constant mean and variance (see n. 14 above).

24. This is an attempt to identify sources of apparent inefficiency, and it does not imply that the choice of factors is an exhaustive list of potential factors. For example, risk aversion that may influence efficiency is not considered in the analysis.

25. Environmental variables in the four districts are relatively homogeneous, with the same annual rainfall intensity and little variation in soil types, particularly those used for rice cultivation.


27. While the average wage for male agricultural labor was 590 cedis per day, that of female and children’s agricultural labor was 300 cedis per day in the survey region.


33. The simplifying assumption of perfect information and rationality in the neoclassical economic theory precludes allocative ability from being a valuable skill to farms and households.

36. In the interest of brevity, the full results of the estimation are not presented but are available from us on request.
38. Ali and Flinn (n. 5 above).
41. Lockheed et al. (n. 31 above).
42. Ali and Flinn; Kumbhakar and Bhattacharyya (n. 15 above).
43. Wozniak (n. 29 above).
45. Lockheed et al.