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Profit Efficiency Among Bangladeshi Rice Farmers

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Sanzidur Rahman

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PROFIT EFFICIENCY AMONG BANGLADESHI RICE FARMERS

Sanzidur Rahman[1]

Address for Correspondence:

Sanzidur Rahman
School of Economic Studies
The University of Manchester
Oxford Road
Manchester, M13 9PL
England, UK
Phone: (0161) 275 4865
Fax: (0161) 275 4812
E-mail: Sanzidur.Rahman@man.ac.uk

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[1] Research Fellow, School of Economic Studies, University of Manchester, Manchester, UK.

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Abstract: *Production inefficiency is usually analysed by its two components – technical efficiency and allocative efficiency. In this study we provide a direct measure of production efficiency of the Bangladeshi rice farmers using a stochastic profit frontier and inefficiency effects model. The data, which is for 1996, includes seven conventional inputs and several other background factors affecting production. It covers modern/high yielding varieties (HYVs), in both Aman and Aus/Boro seasons, spread across 21 villages in three agro-ecological regions of Bangladesh, giving a total of 829 observations. The results show that there are high levels of inefficiency in modern rice cultivation. The mean level of profit efficiency is 64% (60% in Aman season and 64% in Aus/Boro season) suggesting that an estimated 36% of the profit is lost due to a combination of both technical and allocative inefficiency in modern rice production. The efficiency differences are explained largely by infrastructure, extension services, tenancy* and *share of non-agricultural income.*

JEL Classification: O33, Q18, and C21.

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PROFIT EFFICIENCY AMONG BANGLADESHI RICE FARMERS

1. Introduction

Bangladesh agriculture, dominated by rice production, is already operating at its land frontier and has very little or no scope to increase the supply of land to meet the growing demand for food required for its ever-increasing population. The expansion in crop area, which was a major source of production growth till the 1980s, has been exhausted and the area under rice started to decline thereafter (Husain et al., 2001). The observed growth in rice production, at an annual rate of 2.34% for the period 1973 – 1999, has been largely attributed to conversion of traditional rice to modern varieties rather than to increases in yields of modern rice varieties (Baffes and Gautam, 2001). Furthermore, the conversion potential from local to modern varieties seems to be limited as the ceiling adoption level of modern varieties in Bangladesh appears to be reached (Bera and Kelly, 1990). Currently, 61% of total rice area is allocated to modern varieties and the upper bound of conversion, set at 85% by Baffes and Gautam (2001), already seems to be optimistic as it assumes a minor increase in gross rice area while past experience revealed a stagnancy and/or minor decline in land under rice. Therefore, the principal solution to increasing food production lies in raising the productivity of land by closing the existing yield gaps and developing varieties with higher yield potential. On the other end of the spectrum, the United Nations projects that farmers will have to generate large marketable surplus to feed the growing urban population (estimated at 46% of total population of 173 million) by 2020 (Husain et al., 2001). This implies that Bangladeshi farmers not only need to be more efficient in their production activities, but also to be responsive to market indicators, so that the scarce resources are utilized efficiently to increase productivity as well as profitability, and ensure supply to the urban market.

Given this backdrop, the present study sets out to analyse the profit efficiency of the modern rice farmers and to identify farm-specific characteristics that explain variation in efficiency of individual farmers. The relationships between efficiency, market indicators and household characteristics have not been well studied in Bangladesh. An understanding of these relationships could provide the policymakers with information to design programmes that can contribute to measures needed to expand the food production potential of the nation.

The paper proceeds as follows. The next section outlines the concept of profit efficiency and the use of a stochastic profit frontier, and the inefficiency effects model for its measurement. Section three describes the data. The fourth reports and interprets the results. The fifth section begins with the farm level efficiency measures and tests for the significance of the policy-relevant inefficiency variables and sixth section concludes.

2. Measuring efficiency using frontier profit function

Production inefficiency is usually analysed by its two component – technical and allocative efficiency. Recent developments combine both measures into one system, which enables more efficient estimates to be obtained by simultaneous estimation of the system (e.g., Ali and Flinn, 1989; and Wang, et al., 1996). The popular approach to measure efficiency, the technical efficiency component, is the use of frontier production function[2] (e.g., Tzouvelekas et al., 2001; Wadud and White, 2000; Sharma et al., 1999; Sharif and Dar, 1996; Battesse and Coelli, 1995, Battesse, 1992; Russell and Young, 1983). However, Yotopolous and others argue that a production function approach to measure efficiency may not be appropriate when farmers face different prices and have different factor endowments (Ali and Flinn, 1989). This led to the

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[2] The measurement of firm level efficiency has become commonplace with the development of frontier production functions. The approach can be deterministic, where all deviations from the frontier are attributed to inefficiency, or stochastic, which is a considerable improvement, since it is possible to discriminate between random errors and differences in inefficiency.

application of stochastic profit function models to estimate farm specific efficiency directly[3] (e.g., Ali and Flinn, 1989; Kumbhakar and Bhattacharya, 1992; Ali et al., 1994; and Wang et al., 1996). The profit function approach combines the concepts of technical and allocative efficiency in the profit relationship and any errors in the production decision are assumed to be translated into lower profits or revenue for the producer (Ali et al., 1994). Profit efficiency, therefore, is defined as the ability of a farm to achieve highest possible profit given the prices and levels of fixed factors of that farm and profit inefficiency in this context is defined as loss of profit from not operating on the frontier (Ali and Flinn, 1989).

Also, in a number of studies on efficiency measurement (e.g., Sharif and Dar, 1996; Wang et al., 1996), the predicted efficiency indices were regressed against a number of household characteristics, in an attempt to explain the observed differences in efficiency among farms, using a two-stage procedure. Although this exercise has been recognized as a useful one, the two-stage estimation procedure utilized for this exercise has also been recognised as one which is inconsistent in its assumptions regarding the independence of the inefficiency effects in the two estimation stages[4] (Coelli, 1996). Battesse and Coelli (1995) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics. The advantage of the Battesse and Coelli (1995) model is that it allows the estimation of farm specific efficiency

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[3] In contrast with the widespread use of frontier production functions to estimate efficiency, use of profit frontier approach is highly limited.

[4] In this commonly used two-stage approach, the first stage involves the specification and estimation of the stochastic frontier function and the prediction of inefficiency effects, under the assumption that these inefficiency effects are identically distributed with one-sided error terms. The second stage involves the specification of a regression model for predicted inefficiency effects, which contradicts the assumption of an identically distributed one-sided error term in the stochastic frontier (Kumbhakar et al., 1991; Battesse and Coelli, 1995).

scores and the factors explaining the efficiency differentials among farmers in a single stage estimation procedure. The present paper utilises this Battesse and Coelli (1995) model by postulating a profit function, which is assumed to behave in a manner consistent with the stochastic frontier concept. This model is applied to a large sample of rice producers in three agro-ecological regions of Bangladesh, differentiated by variety and by season.

The stochastic profit function is defined as

$$\pi_i = f(P_{ij}, Z_{ik}).\ exp\ (\xi_i) \qquad (1)$$

where π_i is normalized profit of the ith farm defined as gross revenue less variable cost, divided by farm-specific output price; P_{ij} is the price of jth variable input faced by the ith farm divided by output price; Z_{ik} is level of the kth fixed factor on the ith farm; ξ_i is an error term; and i = 1, ….., n, is the number of farms in the sample.

The error term ξ_i is assumed to behave in a manner consistent with the frontier concept (Ali and Flinn, 1989), i.e.,

$$\xi_i = v_i - u_i \qquad (1a)$$

It is assumed that v_i is an independently and identically distributed two sided error term representing the random effects, measurement errors, omitted explanatory variables, and statistical noise. The component u_i is a non-negative one-sided error term representing the inefficiency of the farm.

In the inefficiency effects model, the u_i terms in equation (1) are assumed to be a function of a set of non-negative random variables that reflect the efficiency of the farm. They are assumed to be independently distributed, such that efficiency measures are obtained by truncation of the normal distribution with mean, $\mu_i = \delta_0 + \sum_d \delta_d W_{di}$ and variance σ_μ^2, where W_{di} is the dth explanatory variable associated with inefficiencies on farm i and δ_0 and δ_d are the unknown parameters.

The production/profit efficiency of farm *i* in the context of the stochastic frontier profit function is defined as

$$EFF_i = E[\exp(-u_i) \mid \xi_i] = E[\exp(-\delta_0 - \sum_{d=1}^{D} \delta_d W_{di}) \mid \xi_i] \qquad (2)$$

where *E* is the expectation operator. The method of maximum likelihood is used to estimate the unknown parameters, with the stochastic frontier and the inefficiency effects functions estimated simultaneously. The likelihood function is expressed in term of the variance parameters, $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma^2$ (Battesse and Coelli, 1995).

3. Data and the Empirical Model

Data

Primary data for the study pertains to an intensive farm-survey of rice producers conducted during February to April 1997 in three agro-ecological regions of Bangladesh. Samples were collected from eight villages of the Jamalpur Sadar sub-district of Jamalpur, representing wet agro-ecology, six villages of the Manirampur sub-district of Jessore, representing dry agro-ecology, and seven villages of the Matlab sub-district of Chandpur, representing wet agro-ecology in an agriculturally advanced area. A total of 406 farm households from these 21 villages were selected following a multistage stratified random sampling procedure.

Rice occupies about 70% of the cultivated land and is grown in all three seasons, Aus, Aman, and Boro. Aman is the monsoon season while Boro and Aus fall in the dry season and overlap each other. Moreover, the modern Boro rice competes with modern Aus rice and has similar characteristics. These modern varieties are grown by substituting land from traditional Aus rice, jute, traditional broadcast Aman rice and minor dry season crops such as pulses and oilseeds (Hossain et al., 1990). This is also evident in data of the present study where modern

Boro rice areas are extensive, covering about 35% of gross cropped area. Therefore, in this study, Aus and Boro season are merged together and named Aus/Boro. Considering the seasons covered in one crop year, the total number of observations stands at 829 (i.e., 355 modern Aman rice and 474 modern Aus/Boro rice observations, respectively).

In analysing crop production, it is often the case that data is only available for the major inputs, such as land, labour, fertiliser, and animal power. However, crop production is affected by many other variables that play significant roles in explaining performance. In this study, an attempt was made to collect information on almost all the inputs used for rice production. Thus, information on the use of seeds, pesticides, and farm capital assets was collected. This is expected to increase the explanatory power of the analyses significantly. It is often argued that seeds and animal power services are more or less used in fixed proportions, so their omission is not important (Hossain, 1989 and Hossain et al., 1990), but results here suggest that this is not the case.

Empirical Model

The general form of the translog profit frontier[5] is defined as:

$$\ln \pi' = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln P'_i + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \tau_{ij} \ln P'_i \ln P'_j + \sum_{i=1}^{n}\sum_{k=1}^{m} \phi_{ik} \ln P'_i \ln Z_k$$

$$+ \sum_{k=1}^{m} \beta_k \ln Z_k + \tfrac{1}{2}\sum_{k=1}^{m}\sum_{l=1}^{m} \varphi_{kl} \ln Z_k \ln Z_l + v_i - u_i \qquad (3a)$$

where

$$u_i = \delta_0 + \sum_{d=1}^{D} \delta_d W_{di} + \omega_i \qquad (3b)$$

where $\tau_{ij} = \tau_{ji}$ for all *j, i,* and the function is homogenous of degree one in prices of all variable inputs and output. π' is the restricted profit – total revenue less total cost of variable

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[5] The use of a translog profit function permits returns to scale to be variable (Ali et al., 1994).

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inputs normalised by P_y, the price of output; P'_i is the price of variable input X_i, normalized by the output price P_y; Z_k is the kth fixed input; $i = j = 1,2,3,\ldots,n = l = 1,2,3,\ldots,m$; W_d is the dth farm specific efficiency related variable; *ln* is the natural logarithm; and $\alpha_0, \alpha_i, \tau_{ij}, \beta_k, \phi_{ik}, \varphi_{kl}, \delta_0, \delta_{di}$ are the parameters.

Restricted profit is defined as the total revenue less total variable costs of labour, animal power services, seeds, fertilizers and pesticides normalized by the price of rice. The money prices of all five inputs were normalized by the price of rice[6]. The fixed inputs included in the profit frontier are area planted to rice by the farmer and stock of farm capital equipment measured in thousands of taka.

To explain the extent of any inefficiency, the following variables were used. The list included – index of underdevelopment of infrastructure[7], index of soil fertility[8], tenancy (dummy variable for tenurial status. The value is 1 if the farmer is an owner operator, and 0 otherwise), experience (number of years producing rice), age (years), education (completed years of schooling), number of working persons in the family (used to pick up possible

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[6] The prices are computed by dividing the total expenditure by total quantities of relevant inputs. The cost of home supplied inputs was imputed by market prices.

[7] A composite index of underdevelopment of infrastructure was constructed using the cost of access approach. A total of 13 elements are considered for its construction. These are, primary market, secondary market, storage facility, rice mill, paved road, bus stop, bank, union office, agricultural extension office, high school, college, thana (sub-district) headquarter, and post office. Note that a high index value indicates a highly underdeveloped infrastructure.

[8] The soil fertility index is constructed from test results of soil samples collected from the study villages during the field survey. Ten soil fertility parameters were tested. These are: soil pH, available nitrogen, available potassium, available phosphorus, available sulphur, available zinc, soil texture, soil organic matter content, cation exchange capacity (CEC) of soil, and electrical conductivity of soil. A high index value refers to better soil fertility.

disguised unemployment), extension contact (dummy variable to measure the influence of agricultural extension on efficiency. Value is 1 if the farmer has had contact with an Agricultural Extension Officer in the past year, 0 otherwise), and non-agricultural income share (proportion of total household income obtained from non-agricultural sources).

4. Results

The summary statistics of the variables used appears in Table 1. A number of points can be noted from Table 1. First, we note that these farms are quite small, with average sizes of only one third of a hectare. We also observe that the mean profit is much higher for modern varieties of rice grown in Aus/Boro season[9]. Fertilizer price is slightly higher during the modern Aus/Boro season mainly due to a push effect arising from high demand during the peak growing season.

The summary statistics on the farm-specific variables in Table 1 provide one with a summary of the characteristics of these farms. We see that the average level of education is less than four years; the average age of the farmer is 47 years; the average duration of involvement in rice farming is 25 years, average number of working persons is two; 17% of income is derived from off-farm; approximately 53% of farms are owner-operated; and only 11% of farmers have had contact with extension officers during the past year.

[Insert Table 1 here]

The maximum-likelihood estimates (MLE) of the parameters of translog stochastic frontier profit functions defined by equation (3a), given the specifications for the inefficiency

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[9] The per hectare yield levels of modern rice varieties is estimated at 4.2 tons/ha (4.79 ton/ha for modern Aus/Boro rice and 3.51 ton/ha for modern Aman rice, respectively). The profit per hectare of modern rice is estimated at Tk. 12,826 (Tk. 14,157 for modern Aus/Boro rice and Tk. 11,310 for modern Aman rice, respectively). Exchange rate: 1 US dollar = 42.7 Taka (approximately) during 1996-97 (BBS, 1997).

effects defined by (3b), were obtained using FRONTIER 4.1 (Coelli, 1996). First, modern Aman rice and modern Aus/Boro rice profit functions were individually estimated and then data for the two seasons were pooled to provide estimates of a modern rice function for all seasons. The results are presented in Table 2.

The lower section of Table 2 reports the results of hypothesis test that the efficiency effects are not simply random errors. The key parameter is $\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$, which is the ratio of the errors in equation (1) and is bounded between zero and one, where if $\gamma = 0$, inefficiency is not present, and if $\gamma = 1$, there is no random noise[10]. For all the functions, γ is close to 1 and is significantly different from zero, thereby, establishing the fact that high level of inefficiencies exist in rice farming. Moreover, the corresponding variance-ratio parameter[11] γ^* implies that 87.6% (69.7% for modern Aman rice and 91.0% for modern Aus/Boro rice) of the differences between observed and the maximum frontier profits for modern rice farming is due to the existing differences in efficiency levels among farmers.

[Insert Table 2 here]

Further, a set of hypothesis on different inefficiency specifications using Likelihood Ratio test statistic[12] was tested and the results are presented in Table 3. The null hypothesis that $\gamma = 0$ is rejected at the 5% level of significance confirming that inefficiencies exist and

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[10] If γ is not significantly different from zero, the variance of the inefficiency effects (ω_i in equation 3) is zero and the model reduces to a mean response function in which the inefficiency variables enter directly (Battese and Coelli, 1995).

[11] The parameter γ is not equal to the ratio of the variance of the efficiency effects to the total residual variance because the variance of u_i is equal to $[(\pi-2)/\pi]\sigma^2$ not σ^2. The relative contribution of the inefficiency effect to the total variance term (γ^*) is equal to $\gamma^* = \gamma/[\gamma+(1-\gamma)\pi/(\pi-2)]$ (Coelli et al., 1998).

[12] The likelihood-ratio test statistic, $\lambda = -2\{\log[\text{Likelihood } (H_0)] - \log[\text{Likelihood } (H_1)]\}$ has approximately χ^2_v distribution with ν equal to the number of parameters assumed to be zero in the null hypothesis.

are indeed stochastic. In addition, the null hypothesis that $\gamma = \delta_0 = \delta_d = 0 \; \forall_d$, which means that the inefficiency effects are not present in the model, is also rejected at the 5% level of significance. Thus, a significant part of the variability in profits among farms is explained by the existing differences in the level of technical and allocative inefficiencies.

[Insert Table 3 here]

The summary statistics for the measures of profit efficiency of modern rice farming are listed in Table 4 and histograms of these scores is presented in Figure 1. The modern Aus/Boro rice producers are relatively more efficient. Efficiency of the modern Aman rice producers is a few points lower. The average profit efficiency scores are 0.60 and 0.64 for modern Aman and modern Aus/Boro rice, respectively. This indicates, for example, that the average farm producing modern rice could increase profits 40% in the Aman season and 36% in the Aus/Boro season by improving their technical and allocative efficiency. Farmers exhibit wide range of profit inefficiency in both seasons, ranging from 93.7% (92.2%) less than maximum profit to 3.3% (11.5%) less than maximum profit in modern Aman (modern Aus/Boro) season. Observation of wide variation in profit efficiency is not surprising and similar to the results of Ali and Flinn, (1989), Ali et al., (1994), and Wang et al., (1996) for Pakistan Punjab, North-west Pakistan, and China, respectively[13]. Despite wide variation in efficiency range, about 45% of modern rice farmers seem to be skewed towards profit efficiency level of 70% and above (Figure 1). Nevertheless, the results imply that a considerable amount of profit can be obtained by improving technical and allocative efficiency in Bangladeshi rice production.

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[13] Ali and Flinn (1989) reported mean profit efficiency level of 0.69 (range 13 to 95%) for Basmati rice producers of Pakistan Punjab. Ali et al., (1994) reported mean profit efficiency level of 0.75 (range 4 to 90%) for rice producers in North-West Frontier province of Pakistan. Wang et al., (1996) reported mean profit efficiency level of 0.62 (range 6 to 93%) for rural farm households in China.

[Insert Table 4 and Figure 1 here]

Estimation of profit-loss[14] given prices and fixed factor endowments reveals that modern rice farmers are losing to the tune of Tk. 6853.5 per ha in Aman season and Tk. 6775.6 per ha in the Aus/Boro season which could be recovered by eliminating technical and allocative efficiency (Table 5).

[Insert Table 5 here]

5. Factors explaining inefficiency

Results thus far indicate that efficiency scores vary substantially across farms and that the average level of inefficiency is significant. In an attempt to explain some of these between-farm efficiency differentials, a number of farm-level characteristics were included and regressed simultaneously with the profit function and the results are listed in Table 6.

[Insert Table 6 here]

Before discussing the results in Table 6, we should first clearly state our prior expectations regarding the signs on these variables. We expected that *tenancy, education, age, experience, soil fertility,* and *extension* would all be positively related to efficiency[15], while *infrastructure* (lack of), *working adults,* and *percentage of non-farm income* would be associated with lower efficiency levels.

Results show that *owner operators* perform better than the *tenants*. This is perhaps due to relatively higher input intensive nature of modern rice farming where owner-operators have incentives to invest more in terms of irrigation and other capital equipment compared to

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[14] Profit-loss is defined as the amount that have been lost due to inefficiency in production given prices and fixed factor endowments and is calculated by multiplying maximum profit by (1 – PE). Maximum profit per hectare is computed by dividing the actual profit per hectare of individual farms by its efficiency score.

[15] A negative sign on the coefficient indicates positive impact on efficiency except for the infrastructure variable.

tenants. The input sensitivity of modern rice production, therefore, may result in lower efficiency when less than optimal level of investment is made as with the case of tenants. It was observed that tenants made significantly higher profit-loss due to lower level of profit efficiency, particularly during Aman season, when they mainly rely on monsoon rain instead of incurring the large cost for supplemental irrigation (Table 5).

The poor effect of *age, education* and *experience* in modern rice farming is not surprising. Similar results have been reported in past analyses of technical efficiency in Bangladeshi agriculture (for example see Wadud and White, 2000; Deb, 1995). The average education levels of less than four years (see Table 1) help explain the education result. Also, education pulls away households from farming as its opens up opportunities to engage in off-farm work that are often more rewarding than farming on small pieces of land. The age and experience results are most likely a consequence of older farmers having more knowledge of their land and traditional practices, but also being less willing to adopt new ideas.

The *working adults* variable did not pick up the disguised unemployment effect although it has consistent signs in all the functions.

The variables that have worked well in explaining inefficiency are *infrastructure, extension contact* and *non-farm income*. The modern rice producer benefits significantly from better *infrastructure*. It is evident that badly developed infrastructure has negative effects on both technical and allocative inefficiency. Technical efficiency would be adversely affected by not having inputs to use at the correct time, or not at all, and allocative efficiency would be affected by these constraints as well. This intuition is confirmed in Table 5, which clearly reveals that the incidence of incurring higher profit-loss subject to lower efficiency as well as low actual profit among the farmers in underdeveloped regions is significant.

The *percentage of income earned off-farm* was included to reflect the relative importance of non-agricultural work in the household. The positive sign on the estimated coefficient points towards a situation where those households who have higher opportunity to engage in off-farm work fail to pay much attention to their crops relative to other farmers. Table 5 clearly shows that households with high share of off-farm income in total household income have significantly lower levels of efficiency and hence earn less actual profit and incur high profit-loss.

The *extension service*, which is particularly aimed at diffusing modern rice technology to the farmers, seemed to play its part in increasing efficiency in modern rice production although it reached only a fraction of the total farming population (see Table 1). Table 5 again clearly reveals that farmers who have access to extension services perform significantly better and the result is similar for both the seasons.

The *soil fertility* variable with consistent sign and weakly significant at the 15% level of significance, indicates that this variable has little influence upon the observed efficiency differentials. This lends support to the assertion that much of the efficiency differences between these farms may be put down to management issues.

6. Conclusions and policy implications

The study used stochastic profit frontier functions to analyse the efficiency of Bangladeshi rice farmers. Using detailed survey data obtained from 406 rice farms spread over 21 villages in 1997 we obtain measures of profit inefficiency with wide variation among farmers. The mean level of efficiency for modern rice farming is 0.64 (0.60 in Aman season and 0.64 in Aus/Boro season), indicating that there remains considerable scope to increase profits by improving technical and allocative efficiency. The relatively lower level of efficiency during Aman season is perhaps due to the variation in irrigation support. Farmers tend to rely on monsoon rain to a large extent for irrigation in order to save large expenses incurred for mechanical irrigation, which runs up to 9.4% of gross value of output during the Aman season[16] (Rahman, 1998). On the other hand, the Aus/Boro season is a dry season and a pre-requisite to decide on producing modern Aus/Boro rice is the availability of mechanical irrigation. Locations where facilities for mechanical irrigation are uncertain, farmers opt to choose wheat (Morris et al., 1996), which was also observed in this study.

The farm-specific variables used to explain inefficiencies indicate that those farmers who have better access to input markets, and those who do less off-farm work tend to be more efficient. Owner operators are relatively more efficient than the tenants. Extension services have a positive influence in increasing efficiency in modern rice farming. The policy implications are clear. Inefficiency in farming can be reduced significantly by improving the infrastructure and strengthening extension services. Also, land reform measures aimed at promoting land ownership will have a positive role in increasing efficiency of these modern rice producers who will ultimately be put under pressure to provide food for the rapidly growing urban population in the coming years in Bangladesh.

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[16] The overall cost of mechanical irrigation for the study farmers are 10.4% of gross value of output (9.4% in Aman season and 11.4% in Aus/Boro season).

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Table 1. Summary statistics

Variables	Modern Aman rice (monsoon)		Modern Aus/Boro rice (dry season)		Modern rice (all season)	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Output, profits and prices						
Rice output (kg)	1226.15	1348.64	1475.56	1526.04	1368.76	1457.12
Profit (taka[a])	4134.84	5380.86	4439.36	5499.00	4308.96	5447.54
Rice price (taka/kg)	5.60	0.57	5.66	0.46	5.64	0.51
Fertilizer price (taka/kg)	5.75	1.34	6.76	1.40	6.33	1.46
Labour wage (taka/day)	45.98	7.77	46.00	9.21	45.99	8.62
Animal power (taka/pair-day)	84.98	18.41	85.26	18.52	85.14	18.46
Seed price (taka/kg)	9.86	1.52	9.88	1.25	9.87	1.37
Pesticide price (taka/100 gm or ml)	84.19	15.34	83.93	14.84	84.04	15.05
Land cultivated (ha)	0.36	0.38	0.32	0.34	0.34	0.36
Farm capital (‘000 taka)	13.59	18.51	14.70	23.04	14.22	21.22
Farm-specific variables						
Tenancy (%)	0.56	0.50	0.51	0.50	0.53	0.50
Education of the farmer (years)	3.74	4.38	3.75	4.37	3.75	4.37
Age (years)	47.34	14.95	47.19	14.99	47.25	14.96
Experience (years)	25.34	14.67	25.88	14.67	25.65	14.66
Working member (number)	2.15	1.29	2.10	1.32	2.12	1.31
Extension contact (%)	0.12	0.32	0.11	0.31	0.11	0.32
Infrastructure index (number)	37.39	14.84	34.53	14.80	35.75	14.88
Soil fertility index (number)	1.69	0.19	1.69	0.19	1.69	0.19
Non-agricultural income share (%)	0.16	0.26	0.17	0.28	0.17	0.28
Number of observations	355		474		829	

Note: [a] Exchange rate: 1 US dollar = 42.7 Taka (approximately) during 1996-97 (BBS, 1997).

Table 2. Maximum likelihood estimates of profit frontier functions

Variables	**Parameters**	**Modern Aman rice (monsoon)**		**Modern Aus/Boro rice (dry season)**		**Modern rice (all season)**	
		Coefficients	**t-ratio**	**Coefficients**	**t-ratio**	**Coefficients**	**t-ratio**
Profit function							
Constant	α_0	1.7246	0.245	6.9409	3.278 ***	9.9692	3.145 ***
$\ln P'_F$	α_F	-7.4537	-2.789 ***	3.3399	1.928 *	2.1386	1.700 *
$\ln P'_W$	α_W	2.4133	0.637	0.4699	0.278	-2.1215	-1.354
$\ln P'_M$	α_M	-2.0525	-0.772	-0.7576	-0.531	-0.5768	-0.466
$\ln P'_S$	α_S	-0.2774	-0.084	1.1039	0.443	-0.4578	-0.258
$\ln P'_P$	α_P	3.5043	1.662 *	1.8588	1.299	1.1010	0.953
$\frac{1}{2}\ln P'_F \times \ln P'_F$	τ_{FF}	0.6359	0.409	0.0767	0.051	0.3006	0.273
$\frac{1}{2}\ln P'_W \times \ln P'_W$	τ_{WW}	0.2572	0.174	-2.1473	-2.214 **	-0.3782	-0.447
$\frac{1}{2}\ln P'_M \times \ln P'_M$	τ_{MM}	-0.2183	-0.274	-0.6154	-1.045	-0.3495	-0.693
$\frac{1}{2}\ln P'_S \times \ln P'_S$	τ_{SS}	-1.6451	-1.823 *	-0.4470	-0.416	-1.5227	-2.370 ***
$\frac{1}{2}\ln P'_P \times \ln P'_P$	τ_{PP}	-1.8097	-3.594 ***	-1.1219	-2.691 ***	-0.9781	-3.440 ***
$\ln P'_F \times \ln P'_W$	τ_{FF}	1.9712	1.912 *	0.1212	0.195	0.3461	0.673
$\ln P'_F \times \ln P'_M$	τ_{WW}	-1.5748	-2.441 ***	-0.9856	-2.070 **	-0.9893	-2.599 ***
$\ln P'_F \times \ln P'_S$	τ_{MM}	0.7181	0.997	1.4340	1.854 *	0.6690	1.283
$\ln P'_F \times \ln P'_P$	τ_{FP}	2.5104	3.744 ***	-0.7068	-1.306	-0.2548	-0.869
$\ln P'_W \times \ln P'_M$	τ_{WM}	0.1041	0.111	0.9823	1.663 *	0.6542	1.162
$\ln P'_W \times \ln P'_S$	τ_{WS}	0.6198	0.502	-0.1814	-0.214	-0.2833	-0.425
$\ln P'_W \times \ln P'_P$	τ_{WP}	-0.8131	-0.939	0.5342	0.987	0.5555	1.213
$\ln P'_M \times \ln P'_S$	τ_{MS}	-0.1902	-0.228	0.5418	0.875	0.7185	1.480
$\ln P'_M \times \ln P'_P$	τ_{MP}	1.1688	1.812 *	0.0560	0.130	0.0451	0.134
$\ln P'_S \times \ln P'_P$	τ_{SP}	-0.3768	-0.578	-1.1343	-1.720 *	-0.4090	-0.889
$\ln P'_F \times \ln Z_L$	ϕ_{FL}	-0.0209	-0.148	0.0330	0.217	0.0285	0.276
$\ln P'_F \times \ln Z_A$	ϕ_{FA}	0.0618	0.746	0.0368	0.423	0.0618	1.048
$\ln P'_W \times \ln Z_L$	ϕ_{WL}	0.7146	2.762 ***	0.1031	0.687	0.1951	1.435

Variables	**Parameters**	**Modern Aman rice (monsoon)**		**Modern Aus/Boro rice (dry season)**		**Modern rice (all season)**	
		Coefficients	**t-ratio**	**Coefficients**	**t-ratio**	**Coefficients**	**t-ratio**
lnP'_W x lnZ_A	ϕ_{WA}	-0.0877	-0.860	0.0317	0.445	0.0345	0.564
lnP'_M x lnZ_L	ϕ_{ML}	0.1871	1.093	0.0196	0.169	0.1095	1.102
lnP'_M x lnZ_A	ϕ_{MA}	-0.1624	-1.693 *	0.0006	0.008	-0.0806	-1.363
lnP'_S x lnZ_L	ϕ_{SL}	-0.5280	-2.896 ***	-0.1594	-0.873	-0.2554	-2.077 **
lnP'_S x lnZ_A	ϕ_{SA}	0.1646	1.922 *	0.0661	0.832	0.0418	0.782
lnP'_P x lnZ_L	ϕ_{PL}	0.7877	1.021	-0.3348	-0.471	-0.1351	-0.261
lnP'_P x lnZ_A	ϕ_{PA}	-1.6107	-3.031 ***	-0.2230	-0.539	-0.5250	-1.693 *
lnZ_L	β_L	-0.9544	-1.688 *	0.7835	2.119 **	0.3595	1.092
lnZ_A	β_A	0.6096	2.450 ***	-0.0967	-0.588	0.1548	1.157
½lnZ_L x lnZ_L	φ_{LL}	-0.0837	-1.558	-0.0700	-1.417	-0.0651	-1.749 *
½lnZ_A x lnZ_A	φ_{AA}	0.0104	0.550	0.0000	0.000	-0.0044	-0.347
lnZ_l x lnZ_A	φ_{LA}	-0.0107	-1.339	0.0015	0.152	0.0007	0.110
Variance Parameters							
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	σ^2	1.6978	2.043 **	0.5999	2.663 ***	2.0192	2.091 **
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$	γ	0.9655	63.040 ***	0.8633	18.528 ***	0.9511	43.202 ***
Log likelihood		-289.1301		-322.9081		-672.6438	
Number of obs.	N	355		474		829	

Note: *** significant at 1 percent level ($p<0.01$)
** significant at 5 percent level ($p<0.05$)
* significant at 10 percent level ($p<0.10$)
F = fertilizer, W = labour, M = animal power, S = seed, P = pesticide, L = land, A = stock of farm capital asset.

Table 3. Model specification tests

Null hypothesis	Calculated Likelihood Ratio statistics			Critical value[a] of $\chi^2_{v,\,0.95}$
	Modern Aman rice	Modern Aus/Boro rice	Modern Rice	
H_0: $\gamma = 0$	56.81	30.46	92.89	$\chi^2_{1,0.95} = 3.84$
H_0: $\gamma = \delta_0 = \delta_d = 0, \forall d$	85.13	63.30	139.36	$\chi^2_{11,0.95} = 21.27$
H_0: $\delta_0 = \delta_d = 0, \forall d$	28.32	32.84	46.48	$\chi^2_{10,0.95} = 19.82$

Note: [a] The corresponding critical values were obtained from Kodde and Palm (1986, Table 1).

Table 4. Farm specific profit efficiency estimates

	Modern Aman rice (monsoon)	Modern Aus/Boro rice (dry season)	Modern rice (all season)
Mean	0.595	0.640	0.641
Standard deviation	0.227	0.182	0.198
Minimum	0.033	0.115	0.042
Maximum	0.937	0.922	0.927
<50%	33.24	23.42	22.95
50 – 59%	12.96	13.29	11.47
60 – 69%	11.83	19.41	17.03
70 – 79%	17.75	21.52	23.79
80 – 89%	22.54	21.10	23.55
90 – 100%	1.69	1.27	1.21
Number of observation	355	474	829

Table 5. Profit-loss in modern rice farming and key constraints

Selected policy variables	Estimate of profit-loss in taka per hectare											
	Modern Aman rice				Modern Aus/Boro rice				Modern rice (all season)			
	N	Actual profit	Profit loss[a]	Efficiency	N	Actual profit	Profit loss[a]	Efficiency	N	Actual profit	Profit loss[a]	Efficiency
Profit loss by tenurial status												
Owner operator	198	11709.15	6142.47	0.63	241	13582.70	6687.25	0.64	439	12737.68	5782.23	0.65
Tenants	157	10829.17	7750.12	0.55	233	14245.85	6866.90	0.64	390	12870.42	6246.17	0.63
t-ratio (Owner vs. tenants)		1.15	-3.63***	3.25***		-0.93	-0.64	0.41		-0.25	-2.48***	1.41
Profit loss by extension services												
Farmers having extension contacts	42	14181.10	5875.78	0.68	52	15328.05	5437.05	0.71	94	14815.59	4778.67	0.72
Farmers not having extension contacts	313	10936.06	6984.65	0.58	422	13733.78	6940.50	0.63	735	12542.37	6156.75	0.63
t-ratio (Extension vs. no extension)		2.85***	-1.65*	2.51***		1.40	-3.39***	2.89***		2.76***	-4.72***	4.12***
Profit loss by level of infrastructure[b]												
Developed infrastructure	141	11754.19	5905.83	0.64	240	14959.99	6835.84	0.65	381	13773.59	5764.90	0.67
Underdeveloped infrastructure	214	11033.88	7477.83	0.56	234	12830.41	6713.74	0.63	448	11972.25	6200.84	0.62
t-ratio (Developed vs. underdeveloped)		0.95	-3.60***	3.22***		3.02***	0.44	1.70*		3.45***	-2.32**	3.75***
Profit loss by level of off-farm income												
None or < 50% of off farm income share	302	11823.20	6840.11	0.61	391	13928.44	6660.16	0.65	693	13011.00	5891.84	0.65
Off farm income share of ≥ 50%	53	8452.58	6929.51	0.53	83	13815.58	7319.20	0.60	136	11725.59	6554.13	0.59
t-ratio (Low vs. high off-farm share)		3.27***	-0.15	2.34**		0.12	-1.79*	2.14**		1.82*	-2.63***	3.57***
All farms	355	11319.98	6853.46	0.60	474	13908.68	6775.56	0.64	829	12800.13	6000.49	0.64

Note: [a] Estimate of loss from maximum profit obtainable given prices and fixed factor endowments. Maximum profit per hectare is computed by dividing the actual profit per hectare of individual farms by its efficiency score.

[b] Developed infrastructure refers to score below the mean index value.

*** significant at 1 percent level ($p<0.01$)

** significant at 5 percent level ($p<0.05$)

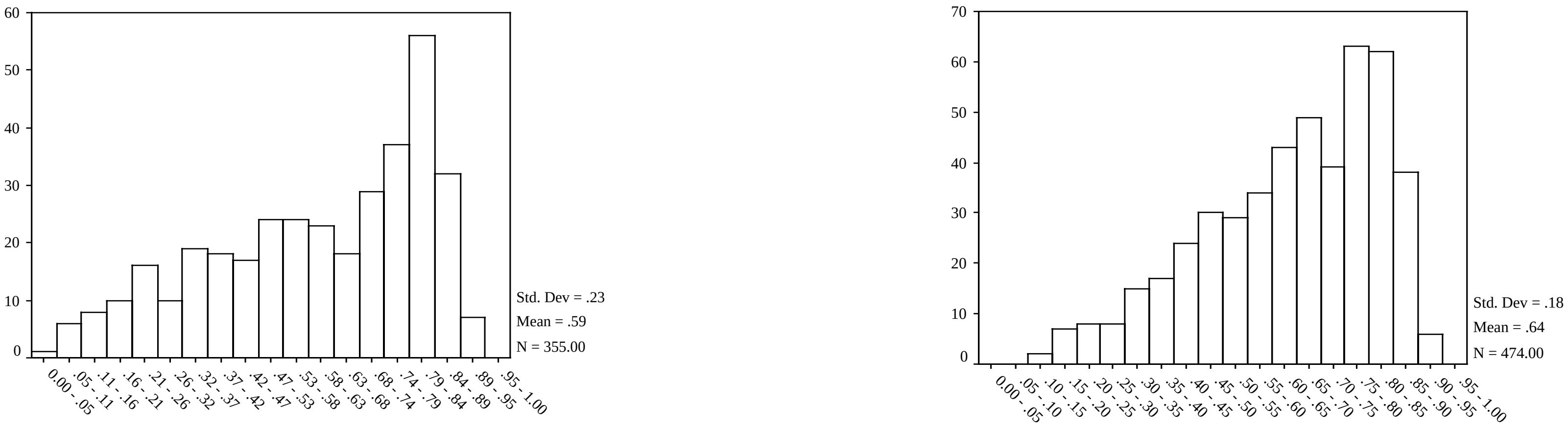
* significant at 10 percent level ($p<0.10$)

Table 6. Factors explaining inefficiency

Variables	Parameters	Modern Aman rice (monsoon)		Modern Aus/Boro rice (dry season)		Modern rice (all season)	
		Coefficients	t-ratio	Coefficients	t-ratio	Coefficients	t-ratio
Constant	δ_0	-0.3605	-0.223	0.1329	0.150	-1.8697	-0.786
Tenancy	δ_1	-0.9136	-1.891 *	0.1164	0.738	-0.2914	-1.669 *
Education	δ_2	0.0335	0.852	0.0088	0.462	0.0427	1.676 *
Age	δ_3	0.0112	0.700	-0.0212	-1.634	-0.0115	-0.969
Experience	δ_4	-0.0074	-0.414	0.0394	2.041 **	0.0296	1.961 *
Working member	δ_5	0.1093	0.770	0.0319	0.529	0.1004	1.457
Extension contact	δ_6	-0.9026	-1.170	-0.5570	-1.331	-1.6256	-1.933 *
Infrastructure	δ_7	0.0334	1.808 *	0.0104	1.639	0.0391	2.253 **
Soil fertility	δ_8	-1.6056	-1.556	-0.5509	-1.097	-1.6222	-1.592
Non-farm income	δ_9	1.1162	1.781 *	0.6163	1.790 *	1.5594	2.248 **
Number of obs.		355		474		829	

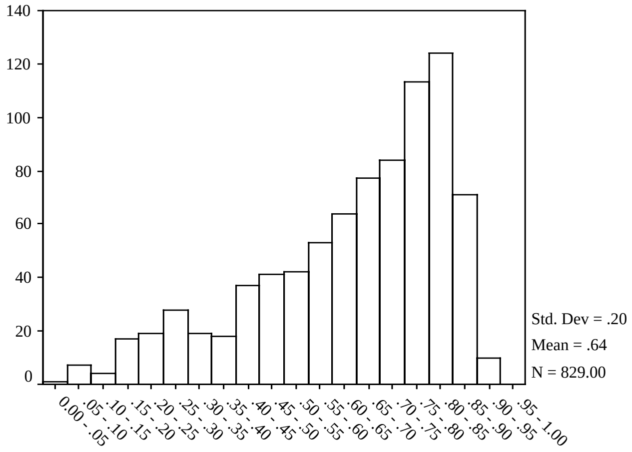
Note: *** significant at 1 percent level ($p<0.01$)
** significant at 5 percent level ($p<0.05$)
* significant at 10 percent level ($p<0.10$)

Figure 1. Profit efficiency of modern rice production



Modern Aman rice

Modern Boro rice



Modern rice (all season)

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