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Impact of resource ownership and input market access on Bangladeshi paddy growers' efficiency

ASIF REZA ANIK[1] and SIEGFRIED BAUER[2]

ABSTRACT

Through a translog stochastic frontier model this study analyzes technical efficiency of Bangladeshi paddy growers and identifies factors explaining farm level inefficiency. A farmer can significantly raise production by increasing quantity of land, total labour and fertilizer in the paddy production. Use of organic manure also significantly contributes in paddy production. Among all the production inputs land has the most dominant impact on production. The estimated mean technical efficiency score of 78% implies that there are substantial scopes to increase paddy production through enhancing farm efficiency. The important efficiency influencing factors are ownership of land and machinery, farm location, access to credit, share of own supplied labour and seed to total requirement and capital constraint. The small farmers are more efficient than the marginal, medium and large farmers. Among different categories of households, higher mean technical efficiency scores are found with the food secured households, households having no earning from outside agriculture, households belonging to lower expenditure group and farmers cultivating paddy only in own land. Finally, the article offers some explanations for these results and suggests some policy options for improving farm efficiency.

KEYWORDS: translog stochastic frontier model; technical efficiency; ownership; input market; Bangladesh

1. Introduction

Enhanced efficiency enables farmers to make judicious use of different resources and thus contribute to farm production and hence income. This is especially important for a country like Bangladesh which has one of the world's lowest land person ratios. A major challenge for the country's policy makers is to feed her large population with limited resources. Until now the country has some notable success in this regard. During her independence in 1971, the country was struggling to produce enough food for her citizens. Since then though the population has almost doubled, the food production has almost tripled. Now the country has achieved near self-sufficiency at least in rice production (FPMU, 2014).

Until the 1980s, the major source of the country's production growth was the expansion in crop area. But this source dried out due to increasing population pressure and nonfarm demand for farmland. The quantity of agricultural land has been declining over the last three decades of previous century (Husain, Hossain and Janaiah, 2001). The country's rice sector is operating at its land frontier, leaving very little or no scope to meet the growing demand of the increasing population by increasing land supply (Rahman, 2003). Replacing traditional varieties by modern varieties was another important source of production growth. But there remains limited scope to increase adoption of modern rice varieties as the ceiling adoption level was almost reached two decades ago (Bera and Kelly, 1990). Furthermore, productivity in modern rice farming declined whereas the production cost increased and the output price remained almost constant. All these contributed to an 18% fall in real income from rice farming (Rahman, 2003). The most likely policy options in such a situation should be to increase production efficiency. Available literature analysing Bangladeshi rice farmers' efficiency shows considerable scope to increase production through farm efficiency (Wadud and White, 2000; Coelli, Rahman and Thirtle, 2002; Rahman, 2003; Asadullah and Rahman, 2009; Selim, 2010). Although the existing literature gives important insight about farm level efficiency and factors explaining efficiency, several crucial factors require further investigation. Ownership of different farm resources, access to market and tenancy are crucial factors explaining efficiency. In existing literature, efforts are mainly concentrated with land ownership and efficiency. It is generally hypothesized that ownership positively contributes to production by ensuring timely and adequate supply of quality inputs at low cost. But an alternative relationship is possible. The market may supply machinery at affordable cost especially when investment, maintenance and operational costs are high. Some of the farm owned inputs

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[1] Corresponding author. Department of Agricultural Economics, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur 1706, Bangladesh. anikbd1979@gmail.com.
[2] Institute of Farm and Agribusiness Management, Justus Liebig University Giessen, Senckenbergstr. 3, Germany.

(e.g. seeds) might be of lower quality than those available in the market. Hence market access may contribute in farm efficiency, particularly in the case of small and poor farmers who own few of the production inputs.

The literature has witnessed a long debate regarding farm size and efficiency. The debate becomes especially crucial while arguing for land reform and farm restructuring. Perhaps the most prominent hypothesis here is the Schultz's (1964) 'poor-but-efficient' hypothesis. The hypothesis is theoretically and empirically supported in the works of Cornia (1985); Stiglitz (1989); Nerlove (1999); Ruttan (2003) and Abler and Sukhatme (2006); though some researchers challenged this hypothesis (Myrdal, 1968; Shapiro, 1983; Ball and Pounder, 1996; Ray, 2006). In general, larger farms in developed countries are more technically efficient, and/or more allocatively efficient; whereas the findings in developing countries mostly support Schultz's hypothesis (Gorton and Davidova, 2004). The most commonly cited explanation for the inverse relationship between farm size and efficiency is labour market dualism. Compared to the large commercial farms, the small farms have lower opportunity cost of labour. Ultimately the small farms apply own labour in such quantities that the marginal value product of family labour is less than the opportunity cost of labour measured using market wage (Carter and Wiebe, 1990). Efficiency levels between small and large farmers may also vary depending on several other socio-economic characteristics. For instance as the small farmers are generally poor they may face more financial difficulties to manage their required inputs than medium and large farmers, and the small farmers may become comparatively inefficient.

Efficiency may also depend on the household's income sources. Rahman (2003) and Asadullah & Rahman (2009) found situations where households with higher opportunity to engage in non-agricultural activities pay less attention to their rice production activities and hence tend to be less efficient. Alternatively Haggblade *et al.* (1989) and Hazell and Hojjati (1995) found that due to poorly functioning capital markets in Africa, the non-farm earnings are stimulating farm investments and improve agricultural productivity. Off-farm income opportunities are generally higher with richer households who own large farms than the poor households. An efficient farm may not be efficient in all the crops, particularly if the crop does not match its core objective function. Due to commercial motive the large farms are characterized to do more crop diversification and may become less efficient in paddy cultivation. Paddy is generally produced for food security purposes and has less profit potential particularly compared to fruit and vegetables and other cash crops. Alternatively as the marginal and small farms operate at subsistence and semi-subsistence level, they are more likely to be efficient in paddy production compared to the large commercial farms. The relationship between farm efficiency and household's food security is another issue which is not still addressed in literature. Analysing these factors is important as this will open a new dimension for the farmers and policy makers to increase farm production by reducing the effect of the inefficiency variables at the existing resource base and available technology.

This paper is organized in four sections. This introductory section is followed by the methodology section where along with the survey procedure, the conceptual model and specification of the stochastic frontier translog production function are presented. The results and discussion are presented in the third section. This is followed by conclusions and policy implications derived from the empirical results.

2. Methodology

Survey and data

The study explores the data collected by Anik (2012). Anik (2012) collected data from 210 Bangladeshi paddy growers through a multistage sampling technique. The major focus of the survey was to estimate impact of farm level corruption on paddy growers' production and their food security. The survey covered six villages belonging to six different districts in the country. At the first stage all the 64 districts were ranked according to the quantity of rice produced during 2008-09 and from the list the above median rice producing districts were selected. These districts were then ranked based on the proportion of households experienced corruption in the service sectors.[3] The top and bottom three districts from this ranking were selected. Then, from each district, the highest rice producing sub district and from each sub district the village producing most were selected. The villages selected are namely: Enayetpur (Naogaon district), South Sordubi (Lalmonirhat district), Mosjidpara (Nilphamary district), Mukimpur (Sirajgong district), Rajapara (Comilla district), and Char Belabo (Narsingdi district). In the final stage, 35 paddy growing farm households from each village were randomly selected using the lists of farmers available with the local agricultural extension office.

Conceptual model and estimation procedure

The impact of different inefficiency factors on farm production is estimated through a stochastic frontier model. Among different approaches of efficiency the stochastic frontier approach is the most prominent due to its theoretical reasonability and empirical competitiveness (Russell and Young, 1983; Battese, 1992; Battese and Coelli, 1995; Sharif and Dar, 1996a; Sharif and Dar, 1996b; Sharma and Leung 1999; Wadud and White, 2000; Tzouvelekas, Pantzios and Fotopoulos, 2001). The specific model for the i^{th} farm can be defined as:

$$ln\ y_i = \alpha_0 + \sum_{j=1}^{5} \alpha_j\ lnx_{ij} + \frac{1}{2}\sum_{j=1}^{5} \beta_{jj}\left(lnx_{ji}\right)^2 + \sum_{j=1}^{5}\sum_{k=1}^{5} \beta_{jk}\ lnx_{ij_k}\ lnx_{ijk} + \tau_{OM}OM + \tau_{Pest}Pest + v_i - u_i \quad (1)$$

and,

$$u_i = \delta_0 + \sum_{d=1}^{4} z_{ij} + \omega_i \quad (2)$$

[3] The proportion was estimated from the Transparency International Bangladesh's (TIB) database of 'National Household Survey 2007 on Corruption in Bangladesh'. The survey followed a three stage stratified cluster sampling method and interviewed 5,000 households (60% from rural areas and the rest from urban areas) about their corruption experiences in different service sectors.

where the dependent variable y_i is the quantity of paddy production in the *Boro*[4] season (kg. per farm); x_i are the different production inputs; OM and Pest are the dummy variables of using organic manure and pesticides, respectively; v_i is the two sided symmetric, normally distributed error term; u_i is a non-negative random variable, associated with the technical inefficiency in paddy production those presented by z_i. All the variables used in the translog production function are measured at farm level. The list of the input variables include: cost of seed (BDT)[5], quantity of chemical fertilizers (kg.), quantity of total labour (includes both family and hired labour and measured in man-days) and quantity of land under paddy production (hectare). The input variables are mean corrected $(x_{ik} - \overline{x_k})$ prior to estimation. This is because the coefficients of the interaction variables multiplied by the same variable at the sample mean will be zero and the coefficients on the first order term can read directly as elasticity.

The inefficiency variables representing farm level ownership are: share of own land to total land, share of family labour to total labour, share of own seed to total seed, ownership dummy for major agricultural machineries, dummy for capital constrained farmer, dummy for marginal farmers, dummy for small farmers. The two dummy variables used to represent farmer's market access to credit (dummy for access to formal credit facilities) and input market (dummy for input restricted farmers). Two other variables used in the inefficiency model are the dummy for improved peri-urban infrastructure and share of off farm income to household's total annual income. Details description of the variables used in the inefficiency analysis appear in Table 2.

Technical efficiency (TE_i) of the i^{th} farm is the ratio of the observed output for the farm, relative to the potential output defined by the frontier function, where the input vector x_i is given. Given the specifications of the stochastic frontier model, the technical efficiency of the ith farm, is equal to:

$$TE_i = \frac{y_i}{\exp(x_i\beta)} = \frac{\exp(x_i\beta - u_i)}{\exp(x_i\beta)} = \exp(-u_i) \qquad (3)$$

The technical efficiency of a farm lies between zero and one and is inversely related to the inefficiency effect. The maximum likelihood estimate (MLE) method is used to estimate the unknown parameters. The stochastic frontier and the inefficiency effects functions are estimated simultaneously. The likelihood function is expressed in terms of the variance parameters, $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 + \sigma$ (Battese and Coelli, 1995).

3. Results

Descriptive statistics of the variables used in the translog production function

The summary statistics of the variables used in the translog production function are presented in Table 1. The sampled farmers were classified into three categories following the classification of Department of Agricultural Extension (DAE). The groups are: marginal (less than 0.99 acre of land), small (1 to 2.49 acre of land), and medium and large (more than 2.50 acre of land). On an average a farm produces 4079.6 kg of paddy in 0.6 hectare of land using 77.3 man days of labour and 237.9 kg of different chemical fertilizers. The cost of seed incurred with this amount of production is 1177.2 BDT. Nearly one out of every four paddy growers applied organic manure. This practice is mostly common among the farmers who have cows at their backyards. Among the sampled farmers, 82.4% uses pesticides.

The small farmers cultivated paddy in more land than the other categories (marginal, medium and large farmers) (Table 1). Compared to other categories, the medium and large farms can be assumed to practice more crop diversification. They are likely to cultivate paddy only to meet their family requirement. As *Boro* is grown in winter season, which is most suitable for growing vegetables in Bangladesh, the medium and large farmers may find better use of their land with different high value added vegetables. Alternatively ensuring food security through staples might be the major objective for the small and marginal farmers. After growing paddy these farmers may have little land available to produce in sufficient volume for the market.

Descriptive statistics of the variables used in the inefficiency effect model

The largest group in term of the proportion of farmers belonging is the group of marginal farmers (40%), followed by the small (37%) and medium and large (23%) farmer's groups. The farmers cultivated paddy mostly on their own land. Rented land is around one fifth (21%) of the total paddy land. Farmers' family labour fulfils 40% of total labour requirement. Farmers mostly rely on market for seed. The private traders are the major suppliers in the seed market. Seed from farmer's own source meet only 9% of the total seed requirement. About 6.42% of the sampled farmers own major agricultural machinery. From formal sources 22.46% farmers took agricultural credit. Around one out of every ten respondents was capital constrained, i.e. these farmers failed to manage enough capital to meet expenses related to paddy production. Due to poor functioning of the seed and fertilizer market, 5.35% of the farmers could not collect their required quantity of inputs from the market even though they had enough money. Nearly two out of every three farms were living in rural areas. Off farm income contributed nearly 33% of household's total annual income (Table 2).

Parameter estimates of the stochastic production frontier

The MLE estimates of the translog stochastic production frontier model are presented in upper part of Table 3. The signs associated with all the non-cross production inputs are positive, as expected. Land, labour and fertilizer have significant effect on production. Both the dummy variables used in the model have positive coefficients, but the impact is significant only for organic manure.

The lower section of the table present estimates of different test statistics related to the model specification.

[4] There are three specific rice growing seasons in Bangladesh: *Aus* (mid-March to August), *Aman* (end June to early January) and *Boro* (mid-November to June). *Boro* is the major season in the country in terms of area and production.

[5] In the *Boro* season many of the farmers use different modern seed varieties, which are generally of high price than the traditional and local varieties. To capture the quality difference between modern and traditional varieties, cost is used instead of quantity.

Table 1: Summary statistics of the variables used in the translog production function by different categories of farmers (per farm basis)

Variables	Marginal farmers	Small farmers	Medium and large farmers	All farmers
Total paddy production (kg.)	3495.6	4849.7	3862.6	4079.6
Cost of seed (BDT[1])	104.7	1317.5	1190.0	1177.2
Quantity of fertilizer (kg.)	194.0	274.2	256.4	237.9
Quantity of total labour (man-days)	68.6	88.7	74.4	77.3
Cost of irrigation (BDT)	4884.0	6532.9	5236.6	5573.5
Quantity of land under paddy production (hectare)	0.51	0.89	0.58	0.67
% of farmers using organic manure	20.0	21.7	34.9	24.1
% of farmers using pesticides	80.0	81.2	88.4	82.4

[1] BDT is local Bangladeshi currency known as Bangladeshi Taka. One euro is approximately 85 BDT (http://www.google.co.uk/finance/converter Accessed April 20th 2015)

The estimated value of γ is almost near to 1 and significantly different from zero. Consequently, this argues for presence of high level of inefficiency in the production process. Other related hypothesis tests conducted argue for the translog stochastic production frontier model to represent paddy production structure in Bangladesh. The generalized likelihood ratio (LR) test ($H_0 : \beta_{jk} = 0$, for all j and k) confirmed that the translog production function was a better choice over the Cobb–Douglas functional form. The rejected null hypothesis of no technical inefficiency effect in paddy production implies that significant technical inefficiency effects exist in paddy production. The p-value of the hypothesis of no inefficiency present in the model indicates that significant level of inefficiency is present in the model.

Furthermore, following Sauer *et al.* (2006) two different regularity conditions were checked. These are: (i) monotonicity, i.e. positive marginal products, with respect to all inputs ($\partial_y / \partial x_i > 0$) and thus non negative production elasticities; and (ii) diminishing marginal productivity ($\partial^2 y / \partial x^2 < 0$) with respect to all inputs (i.e. the marginal products, apart from being positive should be decreasing in inputs). Both these conditions were fulfilled for all the input variables used in the production function.

Among all the inputs used in paddy production, land has the most dominant effect on production. The estimated output elasticity for land is 0.629, implying that a 1% increase in land area will result in 0.629% increase in paddy production (Table 3). Relatively higher output elasticity of land compared to other inputs is in line with earlier studies in Bangladesh (Wadud and White, 2000; Rahman, 2003; Asadullah and Rahman, 2009; Selim, 2010) and also in the Asian context (Lau and Yotopulos, 1971; Bardhan, 1973; Ohkawa, 1972; Cornia, 1985; Battese and Broca, 1997). The sum of mean output elasticities for all the inputs are almost unitary.

Determinants of technical efficiency

Results of the technical inefficiency effect models are presented in the lower section of Table 3. Farmer's own land share has a negative significant impact on farm inefficiency. The negative sign here implies that with increasing own land share farmers become efficient. This is in line with the findings of Coelli, Rahman and Thirtle (2003) and Rahman (2003). Both the studies observed tenants to operate at relatively lower level of efficiency than the owner operators. According to Rahman (2003) the reason might be due to relatively poor quality of land that is generally rented to tenants.

The estimated inverse relationship between family labour share and farm inefficiency indicates that farms with higher share of family labour to total labour are more efficient. Compared to hired labour, family labour

Table 2: Summary statistics of the variables used in the inefficiency model

Variables	Description	Mean
Own land share	Share of own land to total land	0.79
Family labour share	Share of family labour to total labour	0.40
Own seed share	Share of own seed to total seed	0.09
Ownership of major machinery	Dummy of ownership of major agricultural machineries used for tillage, irrigation and threshing (1 for owners; 0 otherwise).	0.64
Credit	Dummy for agricultural credit recipient farmers from formal sources (1 for credit recipients, 0 otherwise)	0.23
Capital constrained farmers	Dummy of capital constrained farmer (1 = Capital constrained, 0 = Not constrained). Capital constrained farmers are those who failed to purchase their required quantity of inputs (e.g. seed/seedlings, fertilizer and pesticides) as they did not have sufficient capital.	0.10
Input restricted farmers	Dummy of input restricted farmer (1 = Input restricted, 0 = Not restricted). Input restricted farmers are those who were not capital constrained but failed to collect their required quantity of input (i.e. seed/seedlings, fertilizer and pesticides) as the inputs were not available in the market.	0.54
Infrastructure	Dummy for improved infrastructure (1 = Improved peri-urban infrastructure, 0 = Less developed rural infrastructure)	0.37
Dummy for marginal farmers	1 for the marginal farmers, 0 otherwise	0.40
Dummy for small farmers	1 for the small farmers, 0 otherwise	0.37
Off farm income share	Share of off farm income to household's total annual income	0.33

Table 3: Maximum likelihood estimates of stochastic translog production frontier for the sample farmers

Variables	Coefficient	SE
Production function		
Seed	0.029	0.026
Fertilizer	0.164***	0.034
Labour	0.189***	0.031
Land	0.629***	0.052
Irrigation	0.011	0.026
0.5 X Seed X Seed	0.012	0.041
Seed X Fertilizer	– 0.040	0.042
Seed X Labour	0.058	0.076
Seed X Land	0.036	0.103
Seed X Irrigation	– 0.085*	0.047
0.5 X Fertilizer X Fertilizer	– 0.066	0.122
Fertilizer X Labour	0.023	0.148
Fertilizer X Land	– 0.023	0.172
Fertilizer X Irrigation	0.101	0.082
0.5 X Labor X Labor	– 0.475	0.320
Labor X Land	0.359	0.265
Labor X Irrigation	0.079	0.111
0.5 X Land X Land	– 0.541***	0.178
Land X Irrigation	0.191**	0.105
0.5 X Irrigation X Irrigation	– 0.311	0.085
Pesticides	0.024	0.019
Organic manure	0.088***	0.020
Constant	8.287***	0.022
Technical inefficiency predictors		
Own land share	– 0.085**	0.044
Family labour share	– 0.237***	0.087
Own seed share	0.100**	0.049
Ownership of major machinery	0.237***	0.042
Credit	– 0.119**	0.064
Capital constrained farmers	0.103***	0.048
Input restricted farmers	0.076	0.058
Infrastructure	0.125***	0.033
Dummy for marginal farmers	– 0.056	0.035
Dummy for small farmers	– 0.085***	0.037
Off-farm income share	0.009	0.024
Constant	0.318***	0.076
Variance parameters		
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.0218***	0.001
$\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$	0.99998***	0.00001
Hypotheses tests (p-value of the null hypothesis are reported)		
Functional form test: Cobb Douglas versus translog ($H_0 : \beta_{jk} = 0$, for all j and k)	0.000	
No inefficiency effect ($H_0 = \delta_0 = \delta_1 = \ldots = \delta_{11}$)	0.000	
No inefficiency present in the model ($H_0 : \mu = \gamma = 0$)[a]	0.000	
log likelihood function	141.85	
Total number of observations	187	

Notes: All the input variables were mean-differenced prior to estimation and therefore the coefficients on the first order term can be read directly as elasticities at the sample mean. *, **, and *** indicate significant at 10%, 5% and 1% levels, respectively.
[a] Since the test involves testing of γ parameter, it has a mixed χ^2 distribution. The value of χ^2 is taken from Kodde and Palm (1986).

work more sincerely and laboriously and they are better manager of the farm resources. Ultimately the marginal physical productivity of family labour is higher than that of hired labour. Furthermore, farms able to use more family labour can loosen their burden on budget. All these may contribute to higher efficiency level.

The owner operators of agricultural machinery are more efficient than the tenant operators. The cost of machinery is higher for the tenants than the owners. The owners bear only operating and maintenance cost, whereas along with these costs the tenants pay some additional charges for hiring. Furthermore, owners can use machineries whenever they need, whereas the tenants may not always get machinery at time of their need.

Unlike the variables indicating ownership of land, machinery and labour, efficiency is lower for the farmers with higher own seed share. Quality degradation of the seed preserved in farmer's own storage facilities might be responsible for lower efficiency level.

Inability to manage enough capital for farming makes capital constrained farmers less efficient. This is evident from the positive relationship between inefficiency and dummy variable representing farmer's capital constrained situation. As a farmer who is not capital constrained operates with relatively higher level of input bundle than his counterpart who is capital constrained, the former is more likely to make proper adjustment of his input bundles and hence achieve higher efficiency level.

The estimated negative and significant relationship between inefficiency and credit means farmers with access to formal credit facilities are more efficient. Access to credit facilities may help even the capital constrained farmers to operate nearer to their optimal input bundles and operate at higher level of efficiency.

The positive sign for the peri-urban infrastructure coefficient implies that rural paddy farms are more efficient than the peri-urban farms. This relationship contradicts with the existing literature. Ahmed and Hossain (1990) identified poor rural infrastructure as one of the major obstacles to agricultural development in Bangladesh. Improved infrastructure ensures better access to input and output markets by reducing cost and time. Ali and Flinn (1989), Coelli, Rahman and Thirtle (2002) and (Rahman, 2003) also found farmers in remote villages are less efficient. But due to better communication and infrastructure off farm employment opportunities are relatively more in peri-urban areas compared to rural areas. Hence, the rural farmers may devote more effort in farming and ultimately operate at higher efficiency level compared to their counterparts who are in peri-urban areas. Furthermore, differences in number of dealers and distance from the input market between peri-urban and rural areas are not substantial. Moreover, none of the sampled rural areas have typical remote settings, e.g. no access through road, non-availability of mechanized or semi mechanized transportation vehicle, *etc.* Hence the differences in cost, effort and time of marketing between peri-urban and rural farmers may not be substantially high.

The negative sign associated with the dummy for small farmers mean that the small farmers operate with higher level of efficiency compared to the marginal, medium and large farmers. The relationship here is in line with the Schultz's (1964) hypothesis. Two possible explanations can be offered here. Firstly, in *Boro* season the competing crops with paddy in the season are wheat and different high value vegetables. As the small farmers mostly operate at the subsistence or semi-subsistence level, meeting household's calorie requirement through staple production is the top priority for these farmers. After producing paddy the quantity of land remaining available for the small farmers may not be sufficient for commercial production of different high value crops. Consequently a small farmer tries to maximizing paddy production and earnings through sell of surplus paddy. Ultimately they attain higher level of efficiency in paddy production. Alternatively, the medium and large farmers have more commercial vision. They produce paddy only to fulfil family requirement and maximize farming income through production of different high value crops. For limited access to different production inputs, compared to the small farmers the marginal farmers operate far below their optimal input bundle level and become less efficient. Secondly, the small farmers earn nearly one-fourth of their total household earnings from different non-agricultural sources, whereas it contributes more than one-third of other farmer's total annual income. Relatively more contribution of farming to total income may work as an incentive for the small farmers to be more efficient in paddy production.

The dummy of input restricted farmer has a negative, but insignificant effect on farm efficiency (Table 3). The relationship is insignificant as only 5.35% of the farmers are input restricted (Table 2). But the relationship here demands some attention. Market failure may restrict farmers' access to their required quantity of inputs, even if they can afford the cost. Farmers who are input restricted may operate at relatively lower level of input bundle than their optimal input bundle compared to their counterparts who are not input restricted. In Bangladesh unavailability of inputs is not always due to supply demand disequilibrium. Insufficient monitoring and supervision from the part of government often allows the dealers to create artificial crisis through hoarding (Anik, 2012).

Technical efficiency in rice production

The summary statistics of technical efficiency scores for the rice farmers are presented in Table 4. The mean technical efficiency for the sample farmers is 78% and this is almost similar to earlier studies conducted with the Bangladeshi rice farmers (Wadud and White, 2000, Rahman, 2003; Asadullah and Rahman, 2009; Selim, 2010). The estimated mean efficiency indicates that a substantial 28% [(100-78)/78] of the rice production is lost due to technical inefficiency alone and a farm can increase production by 28% by improving its technical efficiency. Farmers exhibit wide range of variation in technical efficiency. Farmers' efficiency ranges from 48% to 99%. Wide variation in efficiency level is also observed in previous studies on rice production in Bangladesh (Wadud and White, 2000; Coelli, Rahman and Thirtle, 2002; Rahman, 2003; Rahman and Rahman, 2008).

Table 5 presents distribution of technical efficiency scores by different farm and household level characteristics. Mean efficiency score for the households with off-farm earnings is significantly higher compared to the score of the households having no income from outside agriculture. In the inefficiency effect model the variable off-farm income share do not have significant affect, though it is positively associated with inefficiency.

Households were divided into five equal quintiles based on their annual expenditure. The bottom two quintiles have higher mean efficiency scores than the top quintiles. Efficiency score declines while moving upward from the 2nd quintile. The difference in mean technical efficiency scores among the groups is significant. The explanation for this pattern is similar to those offered in case of negative association between technical inefficiency and the dummy for small farmers, i.e. farmer's crop diversification practices and contribution of different income sources. The households belonging to the top expenditure quintiles are likely to be the medium and large farmers practicing relatively higher level of crop diversification than the bottom quintiles. The top

Table 4: Technical efficiency in rice production

Efficiency levels	Proportion of farmers
Up to 70%	36.02
70-80%	20.97
80-90%	19.35
90% and above	23.66
Efficiency scores	
Mean	0.78
SD	0.13
Min	0.48
Max	0.99

Table 5: Distribution of technical efficiency scores by different farm characteristics

Farm characteristics	Mean efficiency score	P value of mean difference
Off farm income		
Households with off farm income	0.76	0.004
Households with no off farm income	0.82	
Expenditure group[1]		
1st quintile	0.84	0.000
2nd quintile	0.86	
3rd quintile	0.80	
4th quintile	0.72	
Top quintile	0.70	
Food security[2]		
Secured	0.69	0.003
In-secured	0.82	
Tenancy		
Tenant	0.72	0.066
Owner-operator cum tenant	0.77	
Owner operator	0.79	

[1] During the survey the households were asked about their consumption of different food items in last seven days. Food quantities consumed at the household level were converted to calories using the locally available food composition table (BIRDEM 2013). The variable was converted into adult equivalent (AE) ratio.
[2] A household with calorie consumption above 2122 kcal/day/AE was considered to be food secure.

expenditure quintile earned half of their income from non-farm sources. Contribution of off-farm income sources reduces as moving from top quintile to bottom quintile. Off farm income contributes less than one fourth of total annual income for the bottom three quintiles. As low expenditure quintile groups have few off farm employment opportunities they devote their full effort in farming and ultimately operate at upper level of efficiency.

The food secured households have significantly higher technical efficiency scores than the in-secured households. It is quite impossible for a food in-secured household to operate somewhere near their optimal input bundle, whereas the distance between optimal and actual input bundle is relatively lower for the food secured households. In extreme cases a member of a food in-secured household may not be physically capable to work efficient even provided with optimal input bundle.

The sample farmers were divided into three categories based on ownership of cultivated land. The groups are: tenant (farmers cultivating paddy only in rented in land), owner-operator cum tenant (farmers cultivating paddy in both own and rented in land) and owner-operator (farmers cultivating paddy only in own land). Among the three groups the group of owner-operators is the most efficient. The group is followed by the owner-operator cum tenant. The tenants are the most inefficient. The tenants are mostly the marginal farmers who cultivated paddy in only rented in land. These farmers own some farm land but the land are not suitable to cultivate paddy. The owner operators are mostly large and medium farmers who have sufficient quantity of land to meet their family's requirement of paddy. Only few farmers in the group (nearly 6% of the owner-operators) are marginal and small farmers and may have failed to access the land market due to financial constraints. They belong to the bottom two expenditure quintiles. The mean technical efficiency for the owner-operators who are marginal and small farmers is 9% lower than the group's mean score.

4. Conclusions and policy implications

Through a stochastic frontier model the present study analyzes technical efficiency of the Bangladeshi paddy growers in the *Boro* season. The estimated mean technical efficiency for the farmers is 78% and this indicates that there remains considerable scope to increase production by improving farm efficiency. The farmers exhibit wide range of variation in technical efficiency scores.

By increasing the quantity of fertilizer, labour and land, farmers can significantly increase their paddy production. Application of organic manure will also significantly increase paddy production. Among all the production inputs land has highest effect on production.

The farm specific variables used to explain farm inefficiency show that the small farmers are most efficient compared to the other categories of farmers. Efficiency level is higher with the owner-operators of land and agricultural machineries. Farm efficiency increases with increasing family labour share to total labour. Farmers collecting seed from the market are efficient than the farmers who use own seed. Farmers become less efficient when they are in capital constrained situations, i.e. they cannot manage their required quantity of input as they do not have enough capital. Access to formal credit facilities contributes in farm efficiency. Rural farms are more efficient than the peri-urban ones.

These econometric results offer some policy interventions. Farm inefficiency can be reduced significantly by ensuring farm level ownership of land and machinery. For the earlier mentioned input major reform initiatives are needed. The issue of absentee ownership of agricultural land should be addressed. Transfer of agricultural land to non-agricultural purposes should be discouraged by taxation. For fertile land government may plan for restricting by law. Distribution of government-owned land is another issue to address. Here, it is noteworthy to mention that since independence no government in the country has initiated the land reform programme. For ownership of agricultural machinery government may consider reducing import tax. Simultaneously initiatives should be taken to encourage innovation and production of different agricultural machineries at the local level. For this, agricultural research institutions should be encouraged through incentives and especial budgetary allocation. The financial institutes may provide medium and long term credit to the farmers for land and machinery. Short term credit might help a farmer to overcome capital constrained situation and purchase their required variable inputs. Strong monitoring is required to control misallocation of agricultural credit at the farm level and increase recovery rate.

But since all the farms cannot be ensured with ownership, an effective approach may be ways of improving service provisions, especially mechanization services. Service provisions are especially crucial for the food insecured and tenant farms as they have significantly lower level of efficiency. A detailed study at farm level on service availability and constraints is much needed. Strong monitoring is also needed in the input market to make sure that the dealers do not create any artificial crisis. Government may think for more competitive input market by allowing more market actors and dealers. Competition among sellers can alone tackle several marketing problems including corruption.

These interventions may make paddy farming attractive for the farmers. Even the peri-urban farmers and households with higher off-farm income may regain their interest in paddy farming. Inverse relationships between farm efficiency and expenditure and off-farm income are two important issues for further investigation.

About the authors

Asif Reza Anik is a member of the academic staff of the Department of Agricultural Economics at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh. Prior to this he was a member of Patuakhali Science and Technology University (PSTU), Bangladesh. He holds a doctoral degree from Justus-Liebig-Universität, Giessen, Germany and a Master's degree from the Bangladesh Agricultural University, Bangladesh.

Siegfried Bauer obtained his Ph.D. in 1977 and habilitation in the subject of agricultural policy and agrarian economics in the year 1984. From 1985 to 1987 he held a professorship for agricultural policy at the University of Kiel and at the University of Bonn. Since 1991 he has been professor of project and regional planning at the faculty of Agriculture and Environmental Management at Justus Liebig University Giessen, Germany. He has contributed to various studies and projects in developing countries.

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