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RESEARCH PAPER

Profit Efficiency and Technology Adoption of Boro Rice Production in Bangladesh

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Abstract
This study aims to find out the profit efficiency and determinants of profit efficiency in Boro rice cultivation in Manikganj and Dhaka districts of Bangladesh. It also focuses on technology adoption and the effect of technology adoption on the profit efficiency of Boro rice cultivation in Bangladesh. Face-to-face interviews with one set of structured questions were used to get the information from 300 households that grew Boro rice. The findings showed that the profit efficiency of the farmer varied between 23% and 97%, with a mean of 76%, which implies that 24% of the profit is lost due to a combination of technical and allocative inefficiencies in Boro rice cultivation in the study area. The inefficiency model revealed that the education level of the farmer, farm size, variety of seed, and training& extension service influence the profit inefficiency significantly. The study also explained that the level of technology adoption index affects profit efficiency. The technology adoption in Boro rice cultivation is influenced by the education level of the farmer, farm size, and farm capital.
Keywords: Farmer, Maximum Likelihood Estimation, Profit Efficiency, Rice.
JEL Classification: Q10, Q13, Q14, Q16.

Introduction

Rice is the staple food of about 162.7 million people of Bangladesh. It is the source of about two-thirds of the total calorie supply and about one-half of the total protein intakes of an average person in the country. In addition, rice contributes to 50 percent of the agricultural GDP and one-sixth of the national income in Bangladesh (BRRI, 2011). Due to the favorable agro-climatic environment and the necessity of food supply for a huge population, about 75% of the total crop area is used to grow rice all over the country throughout the year (BBS, 2016-17). Besides food supply, rice is also used as raw material for the agri-food processing industry; feed for cattle, poultry, fish, etc., whereas rice bran is used to produce edible oil. Although rice production has increased by more than three times, we have failed to achieve food security for a continuously increasing large number of people for the last 48 years. In order to meet an additional demand for rice, the country needs to import rice every year. For instance, Bangladesh imported 1,100,000 metric tonnes of rice in the fiscal years 2017–18 (BBS, 2018). A few experts opined that Bangladesh would not have to import rice if productivity could be enlarged through increasing technical efficiency in rice production

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(Hossain and Rahman, 2012). Furthermore, real income from modern rice cultivating households has fallen by 18% over the last decade as a result of stagnant output prices and rapid increases in labour and input prices, resulting in higher production costs (Rahman, 2002). Given this fact, it has encouraged many researchers to study technical efficiency and determine what factors affect the technical inefficiency of rice farming in Bangladesh (Hasan, 2008; Theodoridis et al., 2009; Khan et al., 2010; Haider et al., 2011; Rahman et al., 2012; Hasnain et al., 2015; Regmi et al., 2016). These studies employed the stochastic production frontier model to measure technical efficiency and suggested some policies to increase rice production by improving technical efficiency. Some researchers also recommended technology adoption in rice cultivation, which can ensure efficient use of resources and increase farm productivity (Hossain et al., 2003; Verma, 2005; Hossain et al., 2006; Adekambi et al., 2009; Goswami and Chatterjee, 2009; Olagunju and Salimonu, 2010; Dontsop Nguezet et al., 2011; Islam, 2012; Hiroyuki Takeshima et al., 2016; Khatun and Haider, 2016). Nonetheless, the rice cultivating farmers want to maximize their farm profit by increasing the production of rice. Farmers are not becoming profitable due to the rising cost of farm inputs (labor, seed, fertilizers, pesticides, etc.) and a static output price in spite of increasing the production of rice more than three times since 1971.

While reducing input use must reduce rice farming productivity, farmers should not only be technically efficient during the production phase, but also be well responsive to market conditions. Therefore, they can utilize their scarce resources efficiently to increase productivity as well as be financially profitable. That’s why, many researchers employed the stochastic profit frontier model to measure profit efficiency and to determine what factors were affecting the profit inefficiency in rice cultivation around the world (Hyuha et al., 2007; Adamu and Bakari, 2015; Trong and Napasintuwong, 2015; Kaka et al., 2016; Saysay et al., 2016). These studies found that household size, level of education, the extension service, training, and adoption of modern varieties have positively influenced the profit efficiency in rice production. Rahman (2002) assessed the profit efficiency and determinants of profit inefficiency of rice farming in Bangladesh. However, his study did not specify the type of rice and did not analyze the impact of technology adoption in rice farming. Furthermore, Rahman (2002) did not consider some variables such as farm size, source of funds, access to credit, harvesting method, distance from farm to market, and market condition, whereas these variables play a vital role in determining profitability. Given this gap in the literature, this study aims to measure the profit efficiency of Boro rice and examine the effect of technology adoption on rice cultivation in Bangladesh. This is important because it can provide useful information to policymakers in designing policies to achieve the ultimate goal of food security.

Theoretical Framework

Theoretical Framework of Stochastic Frontier Analysis (SFA)

The efficiency of the firm is essentially measured by comparing observed performance with some specified standard performance. Farrell (1957) defines efficiency as the ability to produce a given level of output at the lowest cost. Production inefficiency is normally measured by using two components: technical and allocative efficiency. Technical efficiency refers to the degree to which a farmer produces the maximum feasible output from a given input set and technology (an output-oriented estimation) or uses the least feasible input set and technology to produce a given level of output (an input-oriented estimation). Allocative efficiency, on the other hand, reflects the level to which a farmer uses inputs on an optimal scale given observed input prices (Coelli et al., 2002).

A blend of technical efficiency and allocative efficiency measures into a single system has been developed recently, which enables more efficient estimation through simultaneous system estimation (Ali and Flinn, 1989; Wang et al., 1996).

The technical efficiency is the most popular component for measuring efficiency by using the production frontier function (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 et al. (1973); Ali and Flinn (1989), argued that a production frontier function approach to measuring technical efficiency may not be suitable when a farmer faces different prices of inputs and output and has different resource endowments.

On the other hand, the profit function technique combines both technical and allocative efficiency in the profit relationship. Any mistakes in the production decision are thought to lead to lower profits or less revenue for the producer (Ali et al., 1994). That's why it is wise to apply the stochastic profit frontier for measuring farm-specific efficiency (Ali and Flinn, 1989; Kumbhakar and Bhattacharya, 1992; Ali et al., 1994; and Wang et al., 1996). Profit efficiency refers to the ability of the farmer to earn the maximum possible profit at the given prices of the variable inputs and levels of fixed factors used in rice cultivation. Profit inefficiency denotes a loss of profit and the farm is not going on a profit frontier (Ali and Flinn, 1989). Battese 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 benefit of the Battesse and Coelli (1995) model is that it helps in the estimation of the farm-specific efficiency score and the determinants describing efficiency differentials among farmers in a single-stage estimation technique.

Following Ogundari et al. (2006) and Rahman (2002), these studies used the Battesse and Coelli (1995) model by assuming a profit function that behaves in a way that is consistent with the stochastic frontier concept. The stochastic frontier approach says that a farmer (farm) makes less than the maximum feasible profit frontier from the proposed due to the degree of inefficiency. A stochastic profit function can be written by adding an error term for inefficiency as:

$$\Pi_i = f\left(P_{ij}, Z_{ik}\right) \cdot exp(\varepsilon_i) \quad (1)$$

where π_i is the normalized profit for the i-th rice farm obtained as profit (Revenue less Variable cost) divided by the price of output. P_{ij} is the price of j-th variable input divided by the ith farm output price. Z_{ik} is the level of the k-th fixed factor on the i-th farm. $\boldsymbol{\varepsilon_i}$ is an error term and i= 1, 2,…,n denotes the number of the rice farm under study.

The error term $\boldsymbol{\varepsilon_i}$ is assumed to behave in a manner consistent with the frontier concept (Ali and Flinn,1989)

$$\varepsilon_i = v_i - u_i \quad (2)$$

v_i is independently and identically and normally, N (0, σ^2_v), distributed two-sided random errors, independent of u_i. The v_i accounts for random variation in profit attributed to factors outside the farmer's control (random effects, measurement errors, omitted explanatory variables, and statistical noise). The u_i is a one-sided, non-negative error term that is assumed to be independently and identically distributed with the half-normal truncated distribution as as $N^+(0, \sigma_u^2)$, also independent of v_i (Kumbhakar & Lovell,2000).

The Maximum Likelihood Estimation (MLE) technique is employed to estimate the parameters ($\boldsymbol{\beta}$,σ , γ) of the stochastic frontier. The variance of the parameters can be estimated in the following way:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad ; \quad \gamma = \frac{\sigma_u^2}{\sigma^2} = \frac{\sigma_u^2}{(\sigma_u^2+\sigma_v^2)}$$

FRONTIER version 4.1software can be used to estimate all parameters of the SFA of the maximum likelihood function (Coelli, 1996b). This software estimates the $\gamma = \sigma^2_u/\sigma_s^2$ parameter, which takes a value between zero (0) and one (1). When, γ = 0 denotes those deviations from the profit frontier are due to noise. Whereas γ =1 represents that deviation from the frontier is due to profit inefficiency.

Profit Efficiency of the rice cultivating farmer is defined as the ratio of actual profit (π_i) to the highest possible profit (π_i^*). We can express it mathematically following Sunday, et al. (2013)

$$Profit\ Efficiency\ (E_{\Pi}) = \frac{Actual\ Profit\ (\pi_i)}{MaximumPossible\ Profit\ (\pi_i^*)} \tag{3}$$

$$Profit\ Efficiency\ (E_{\Pi}) = \frac{exp(v_i - u_i)}{exp(v_i)} = exp(-u_i) \tag{4}$$

E_π has a value between 0 and 1. If u_i = 0; the farm is going on the profit frontier and will receive the highest possible profit. If u_i > 0, the farm is operating under the profit frontier and losing profit because of inefficiency. The MLE strategy is followed to calculate the parameters of the profit function by employing the FRONTIER version 4.1 software (Coelli, 1996b).

Materials & Method

Material

The study was carried out in two regions, namely Manikganj and Dhaka, Bangladesh. These districts were selected because they cover about 61.895% of rice cropped area and 78.218% of Boro rice of the total production of rice (BBS-2018). A structured questionnaire was used to get information from 150 farmers in each district. The questions focused on the amounts of inputs and outputs, the prices of inputs and outputs, and the farmers' social and economic situations. A total of 300 farmers were used as a sample for the analysis.

The collected data was subsequently encoded, grouped, and analyzed for the purpose of the study. The stochastic profit function with an inefficiency model assuming a Cobb-Douglass function was applied to measure the efficiency and determinants of the inefficiency of rice-growing households. The stochastic profit frontier was assessed using the MLE strategy by Frontier Version 4.1(Coelli, 1996).

Stochastic Profit Frontier Model

The stochastic profit frontier used in this study is defined as below:

$$\pi_i^* = \frac{\pi}{P_{iy}} = f\left(P_{ij}^*, Z_{iq}\right) exp(v_i - u_i) \tag{5}$$

where, π_i^*=Normalized profit of *i-th* farmer (Tk);

P_{ij}^* = Normalized price of the jth variable input; Z_{iq} = Quasi fixed input of the *q-th* input; P_{iy} = Unit price of output (Tk); and $exp(v_i - u_i)$ = Composite error term.

Following Coelli (1996), the stochastic profit frontier with a Cobb-Douglas functional form was employed to estimate all parameters in single step maximum likelihood estimation. Following Ifeanyi and Onyenweaku (2007); Nganga et al. (2011) and Sunday et al. (2013), the model is defined as

$$ln\pi_i^* = \beta_0 + \beta_1 ln\, P_{1i}^* + \beta_2 ln\, P_{2i}^* + \beta_3 ln\, P_{3i}^* + \beta_4 ln\, P_{4i}^* + \beta_5 ln\, P_{5i}^* + \beta_6 ln\, P_{6i}^* + \beta_7 ln\, Z_{1i} + \beta_8 ln\, Z_{2i} + exp(v_i - u_i) \quad (6)$$

where, π_i^* = Profit of the *i-th* rice farm normalized by the price of output (P_{iy})

P_{1i}^*= Price of labor (Tk/ Man day) used in *i-th* rice farm and normalized by the price of output (P_{iy}); P_{2i}^*= Price of seedling (Tk/ 100 bundles) used in *i-th* rice farm and normalized by the price of output (P_{iy}); P_{3i}^*= Cost of tillage (Tk/ per plot) used in *i-th* rice farm and normalized by the price of output (P_{iy}); P_{4i}^*= Price Index of fertilizer (Tk/ Kg) used in *i-th* rice farm and normalized by the price of output (P_{iy});P_{5i}^*= Price Index of pesticides (Tk/kg or 100ml) used in *i-th* rice farm and normalized by the price of output (P_{iy}); P_{6i}^* = Cost of irrigation (Tk/ plot) used in *i-th* rice farm and normalized by the price of output (P_{iy}); Z_{1i} = The survey plot size of i-th rice farm ;Z_{2i}= Capital used in the i-th rice farm. β_0,$\beta_1, \beta_2, \beta_3, \ldots, \beta_8$ are parameters to be estimated,

The inefficiency model (u_i) is defined by:

$$U_i = \delta_0 + +\delta_1 R_{1i} + \delta_2 R_{2i} + \delta_3 R_{3i} + \delta_4 R_{4i} + \delta_5 R_{5i} + \delta_6 R_{6i} + \delta_7 R_{7i} + \delta_8 R_{8i} + \varepsilon_i \quad (7)$$

where, U_i =Profit inefficiency score; R_1 =Age (years); R_2 = Education (Schooling years); R_3 = Household size(nuclear family =1, Large family =2, Joint family =3); R_4 = Access to input and output market Information (yes=1, otherwise = 0); R_5 = Training & extension advisory service (yes=1, otherwise = 0); R_6 = Source of fund (self-financed =1, otherwise = 0); R_7 = Farm Size (Small =1, Medium=2, Large =3); R_8 = Variety (High Yield Variety =1, Local variety =0).

Determinants of Technology Adoption in Boro Rice Cultivation

Both quantitative and qualitative analyses were applied to solve the impact of technology usage on farming. Firstly, qualitative analysis was applied to compare technology adoption among Bangladesh and other rice-growing countries in the world. Secondly, following Khatun and Haider (2016), a multiple regression model was applied to investigate the determinants affecting technology adoption in rice cultivation. The dependent variable is defined as the technology adoption index. The index is constructed from the responses of a five-point Likert scale on the degree of technology usage in the seven stages of the production process, such as land preparation, variety seed, weed management, fertilizer application, irrigation facilities, pest management, and harvesting methods. The value of the index is transformed into a scale of 0–5 by assuming the responses on considering seven phases of production. The independent variables include age (A), education (E), capital availability (K), experience (X), and land (L). The technology adoption model used in this study is defined as,

$$D_i = \beta_0 + \beta_1 A_i + \beta_2 E_i + \beta_3 X_i + \beta_4 L_i + \beta_5 C_i + u_i \quad (8)$$

where, β_0 = Intercept, β_i = Coefficients of the independent variables, D_i = Level of technology adoption measured from household survey, u_i= error term.

Results & Discussion

Table 1. Maximum Likelihood Estimates (MLE) of the Cobb Douglas Stochastic Profit Frontier

	Coefficient	S. E	t-ratio
Constant	-0.110	0.020	-5.500***
Normalized Wage of Labor	-0.471	0.160	-2.941***
Normalized Price of Seedling	0.260	0.117	2.223**
Normalized cost of Tillage	0.024	0.291	0.082
Normalized Price Index of Fertilizers	0.531	0.231	2.296**
Normalized Price Index of Pesticides	-0.238	0.736	-0.323
Normalized cost of Irrigation	0.498	0.161	3.090***
Plot Size	0.428	0.263	1.627*
Capital used	-0.516	0.365	-1.414*
Inefficiency Model			
Constant	2.018	0.383	5.265***
Age	0.128	0.052	2.474**
Education	-0.136	0.024	-5.585***
Household Size	0.041	0.178	0.228
Access to Market Information	-1.105	0.325	-3.404***
Training & extension service	-0.735	0.23	-3.195***
Source of fund	0.209	0.273	0.768
Farm size	-0.13	0.207	-0.628
Variety of Seed	-0.156	0.068	-2.264**
Sigma Squared (σ^2)	0.449	0.066	6.777***
Gamma (γ)	0.936	0.08	11.341***
Log Likelihood Value: -106.38			
LR Value: 309.28			
No of Observation: 300			

Source: Computer print-out of FRONTIER 4.1
Note: Significance level: *** for 1 %, ** for 5 % and * for 10 %

Table 1 showed the estimation of the Cobb-Douglass profit frontier through MLE for a total of 300 respondents in the study area. The estimated sigma-squared (σ2) was found to be 0.449 and statistically significant at the 1%probability level. Again, the estimated value of the gamma parameter (γ) was found to be 0.968 and was significant at a 1 % probability level. It means that a 93.6 % deviation in actual profit from the profit frontier among the farms happened because of farm-specific characteristics rather than random variability.

The coefficient of seedling was 0.260 and significant at the 5 % probability level. It means that the higher price of seedlings promotes higher profitability and vice versa. Farmers who buy better quality seeds or improved seeds are more likely to make money because they get a higher crop yield and less crop damage than farmers who use local variety seeds or seeds of lower quality. The result is consistent with the following studies Saysay et al., 2016; Dang, 2017; Kaka et al., 2018; Rahman, 2002; Sunday et al., 2013; Zahid & Ahmed, 2018.

Similarly, the coefficient of the price index of fertilizer carried a positive value of 0.531 and was significant at the 1 % probability level. It implies that the higher price of the fertilizer increases profitability and vice-versa. A higher price for fertilizer means better quality fertilizers in terms of nutrient content, its effectiveness, which ensures higher crop production by fulfilling the required nutrients in the soil. Hence, farmers who use higher-priced fertilizer earn more profit than farmers using low-priced fertilizer in their rice fields (Rahman, 2002; Oladeebo and Oluwaranti, 2012; Kaka et al., 2018).

Again, the coefficient plot size was 0.428 and affected the profit efficiency at a 10 % level of significance. Similar outcomes are reported by Kaka et al., 2018; Dang, 2017; Sunday et al., 2013; Ifeanyi and Onyenweaku, 2007. This means that farmers cultivating the Boro rice in larger plots gain more gross margin and run at a significantly higher level of farm profitability than those cultivating it in smaller plots. They can procure the larger volume of input material at a discounted price, which reduces the production cost and can reduce wastage of the farm inputs by appropriate allocation. Conversely, farmers possessing the bigger plots sell the larger volume of rice, and they can sell it for a higher price and reduce the marketing/ transportation expense, which directly increases the profit.

Finally, the coefficient of irrigation cost was positively related to profit in Boro rice cultivation and significant at 1% level. This means higher costs in irrigation lead to a higher level of profit in Boro rice cultivation and vice-versa. The irrigation facility is one of the basic elements in rice cultivation because it improves water conditions in the soil, controls soil temperature and acidity level, dissolves nutrients and makes them available to plants. So, a shortage of irrigation facilities directly affects crop yield as it is required from land preparation to a few days before harvesting (Rahman et al., 2012; Hasnain et al., 2015).

Labor costs, on the other hand, were found to have a negative impact on profitability and to be statistically significant at the 1% level. The finding suggests if labor is hired at a higher wage, it decreases the profit in Boro rice cultivation and vice versa. This similar result was found by Rahman, 2002; Oladeebo and Oluwaranti, 2012; Ogunniyi, 2011; Zahid & Ahmed, 2018. Boro rice cultivation is a labor-intensive activity that requires a huge number of labors from land preparation to harvesting, and labor costs cover 30–40% of the total production cost. As a result, a per-unit wage increase raises a significant portion of the total production cost, lowering the farm's income.

Lastly, the coefficient of the capital was -0.516, which affected the normalised profit with a 10% level of significance. As profit is found in total revenue minus total cost (capital used in production), higher capital means lower profit. More capital used in rice production affects the farm's profit negatively (Rahman 2002). This implies that farmers cultivating Boro rice with a higher cost of production equivalent to higher capital used are less profit efficient than farmers cultivating with less farm capital.

Determinants of Profit Inefficiency

The determinants of profit inefficiency have been illustrated in table 1 The objective of estimating the inefficiency model was to identify the sources for the policy recommendation. Galawat and Yabe (2012) opined that the direction of the coefficient in the inefficiency model is noteworthy in describing the obtained level of profit efficiency of the farm. A coefficient with a negative sign indicates that the factor minimizes profit inefficiency, while a coefficient with a positive sign means that it accelerates profit inefficiency. The coefficients of education, variety of seedlings, training and advisory service, farm size, and access to market information had a negative sign. Conversely, the coefficients were positive for age, household size, and source of funds.

The age of the farmer was found to affect the profit inefficiency positively at a 10 % level of significance, which implies that the younger farmer is more efficient than the older farmer. According to Nwaru (2004); Ajibefun and Aderinola (2003); and Sunday et al. (2013), younger farmers are more efficient because they follow modern farming practices, are innovative, and are willing to bear the risk of adopting the latest technology. In addition, younger farmers keep updated information on input or output markets and are physically stronger to work manually, which is required in Boro rice production. On the other hand, aged farmers are more efficient due to having more practical experience in farming activities and can minimize crop damage through efficient farm management during natural disasters like floods, droughts, and infestations of insects and pests (Effiong, 2005; Idiong and Iko, 2019).

The estimated result suggests that the education of the farmer affected the profit inefficiency negatively with a 1 % level of significance. This implies that if the schooling year of the farmer increases, the farmer's profit inefficiency declines. Because education improves farmers' skills and changes their attitudes towards farming practices, it encourages them to participate in various training and extension services sponsored by the government and non-governmental organizations (NGOs) in order to adopt modern technologies such as high yield variety (HYV) seed, fertilizers, pesticide farm machinery, and so on. In addition, farmers having more schooling years can easily access information on agricultural markets, which helps them to purchase the right quality farm inputs at a reasonable price and sell their output at a fair price. Finally, educated farmers can avoid some seasonal natural calamities to some extent by following the crop calendar. This outcome is supported by the findings of Ogunniyi, 2011; Nganga et al., 2010; Wallace, 1980; Rahman, 2003, Kaka et al., 2018; Kumbhakar and Bhattacharya, 1992; Abdulail and Huffman, 1988.

The coefficient of seedling variety was -0.156 and significant at a 5% probability level, which indicates that the households cultivating Boro rice through a high yield variety of seedling earn more profit than the households employing the local variety of seedling. High yield varieties of seed perform better in terms of disease resistance, stress tolerance, better vegetative growth, early flowering and harvesting in the least possible period, which reduces the crop damage and ultimately higher yield (Ali et al., 2014; Hoque et al., 2020). Hence, the variety has a significant effect on profit inefficiency (Kaka et al., 2018).

The coefficient of training and extension service was -0.35 and influenced the profit inefficiency with a 5 % level of significance. The findings suggest that farmers who have attended the training and received the extension services are more efficient than farmers who have not attended the training and received extension services because training and extension services introduce farmers to advanced technologies and modern farming practices, which ultimately increase productivity and efficiency (Kaka et al., 2018; Dang, 2017; Schreinemacher et al., 2016; Ogunniyi, 2011). Therefore, training and extension services reduce profit inefficiency. The Department of Agricultural Extension (DAE) organizes a training program for farmers to learn about modern farming practices such as technology adoption, the use of modern variety seeds, the application of chemical fertilizer and bio-fertilizer, and how to reduce crop damage from natural disasters such as plant diseases, floods, droughts, cyclones, and tornados, among others (MoA, 2018). The DAE provides suggestions to farmers based on their needs through online services conducted by an agricultural information service application.

The estimated coefficient of access to market information had a negative relationship with profit inefficiency at a 1% level of significance, which means that greater access to market information reduces profit inefficiency. Adequate access to market information supports farmers to identify the proper markets from where they can purchase the better quality of farm inputs at a reasonable price and can sell their output at a fair price, which ultimately ensures a reasonable profit. That's why market information affects profit efficiency significantly. The identical findings were reported by a few studies (Wadud and Rashid, 2011; Dwi et al., 2014; Saysay et al., 2016). DAM provides farmers with information on the input-output market, guiding them in purchasing the right quality of farm input and disposing of their produce in the proper location. Further, DAM monitors the agricultural market of Bangladesh by setting the price for farm commodities and farm inputs to protect the interests of stakeholders like farmers, consumers, society, and the government (MoA, 2018).

Table 2. Efficiency Level

Range	Frequency	Percentage	Cumulative Percentage
0.00- 0 .10	0	0	0
0.11- 0.20	0	0	0
0.21-0.30	12	4	4
0.31-0.40	16	5.33	9.33
0.41-0.50	11	3.67	13
0.51-0.60	14	4.67	17.67
0.61-0.70	39	13	30.67
0.71- 0.80	25	8.33	39
0.81-0.9	89	29.67	68.67
0.91-1.00	94	31.33	100
Total	300	100	
Maximum	0.97		
Minimum	0.23		
Standard Deviation	0.21		
Mean	0.76		

Source: Computer print-out of FRONTIER 4.1

The frequency distribution of the farm-specific efficiency score of Boro rice cultivating households in Bangladesh is presented in table 2. The estimated result shows that the profit efficiency ranges from 23 percent to 97 percent, with a mean efficiency of 76 percent. It is clear from the result that a considerable amount of profit loss is occurred in Boro rice cultivation because of the existence of profit inefficiency in resource use. Through technical and allocative efficiencies, a Boro household that grows rice can increase its profit efficiency by 24%. However, to achieve the profit efficiency of the best farmer in the study area, the least profit efficient Boro rice growing household requires a profit efficiency gain of 76.29% [(1.00 - 0.23/0.97) *100] in the use of specified farm resources, and a profit efficiency gain of 91% [(1.00-0.23/1.00) *100] to be on the frontier. Furthermore, to be on the frontier, the most profitably efficient farmer requires a profit efficiency gain of 3% [(1.00-0.97/1.00) *100].

Table 3. Determinants of Technology Adoption in Boro Rice Cultivation

Technology Adoption	Coeff.	S.E	t-statistic
constant***	0.280	0.050	5.606
Age	-0.055	0.074	-0.741
Education**	0.026	0.011	2.419
Capital*	0.290	0.140	2.071
Farm Size**	0.126	0.059	2.117
Farming Experience	0.054	0.033	1.196

F-Value= 465.34; Prob> F=0.00; R^2=0.905

Significance level: *** for 1 %, ** for 5 % and * for 10 %

Source: Computer print-out of STATA.

The estimated results of the Ordinary Least Square (OLS) method denoted that the model fitted well according to R^2 and F-Value. The coefficient of determination (R^2) was 0.905, indicating that the independent variables mentioned in the model explained approximately 90.5 percent of the variation in technology adoption. The F-value of 465.34 of the equation was significant at the one percent probability level, implying that the variation in technology adoption depended upon the explanatory variables such as age, education, capital, farming experience, and farm size included in the model.

The coefficient of education was found to affect the technology adoption in Boro rice cultivation at a 5%level of significance. This means that more educated farmers keep information on the latest technological developments and are aware of the cost-benefit of farming. Hence, they prefer to adopt the latest technology, which can ensure more profitability and reduce the cost of production by replacing manual activities with mechanized procedures (Khatun and Haider, 2016).

The capital had a positive effect on technology adoption and was statistically significant at a 10% probability level. This indicates that farmers who are financially sound and have more funds to invest in farming adopt the latest technologies available on the market than farmers with less capital. As we know, some technologies, such as combine harvesters, deep tube wells, power tillers, and wheelers, are too expensive to purchase for small and medium farmers.

The estimated result showed that farm size influenced technology adoption in Boro rice cultivation significantly at a 5% level. This implies that farmers having larger farm sizes use more technologies than farmers having smaller farm sizes. There are some technologies such as power tillers, wheelers, combine harvesters, drum seeders, deep tube wells, etc. that are not possible to operate profitably on smaller sized farms. Hence, the larger farm size encourages the adoption of more technologies in Boro rice cultivation in the study area (Khatun and Haider, 2016).

On the other hand, it was found that the age of the farmers and how long they had been farming didn't have much of an effect on how they used technology when growing Boro rice in Bangladesh.

Table 4. Impact of Technology Adoption in Profit Efficiency

Profit Efficiency	Coefficient	Standard error	t-statistic	Probability Level
Intercept	0.218	0.069	3.150	0.002
Technology Adoption Index	0.156	0.023	6.770	0.000
F-Value= 45.89; Prob> F=0.00; R2=0.2305				

Source: Computer print-out of STATA.

According to table 5, the R^2 value of 0.3905, which stated that around 39.05% of the fluctuation in profit efficiency, was defined by the explanatory variable mentioned in the framework. The F-value of 45.89 proves the equation statistically significant with a one percent probability level, denoting that the change in profit efficiency relied on the independent variable technology adoption index in Boro rice cultivation. The coefficient of the technology adoption index was found to have a statistically significant effect on profit efficiency at a 1% level of significance. This means a 1% rise in the technology adoption index. The profit efficiency of Boro rice cultivation will increase by 0.87%.

According to a few studies, technology adoption had a positive and significant impact on farm productivity and efficiency around the world (Verma, 2006; Goswami and Chatterjee, 2009; Asfaw et al., 2010; Adofu et al., 2011; Islam, 2012; Khatun and Haider, 2016).

Conclusion

Rice is the leading crop in the agriculture of Bangladesh. There is no alternative to increasing the production of rice by ensuring a rational profit to encourage the farmers towards rice farming, which ultimately will contribute to achieving national food security. The study obtained an average profit efficiency score of 0.76, ranging from 0.23 to 0.97. The estimated results from the maximum likelihood estimation show that farmers did not operate at the profit frontier. The findings indicate that efficiency might still be developed by 24% utilizing the available resources and technologies for the households cultivating Boro rice. Next, the inefficiency model identified as the schooling of the farmer, farm holding size, variety of seedlings, access to market information, and training and extension service, has a negative impact on the profit inefficiency significantly. In contrast, the household size and age of the farmer were found to influence the profit inefficiency positively. These findings show that farmers can improve the profitability efficiency of Boro rice production by actively participating in training and receiving extension services, selecting improved varieties of seed, and having better access to market information. In addition, the authorities must make policies to upgrade the socio-economic conditions of the study area, such as increasing the education level of the farmers and motivating them to form a cooperative society to make a larger sized plot. The study also shows that the status of technology reception influences farm-level profitability. The education of the farmer, farm holding size, and available farm capital influence technology adoption. Finally, the government should supply some technologies to farmers at a subsidized price, which are too expensive to purchase for the farmers.

Limitation of the Study

Although the quality of output and input are homogenous in Boro rice farming, the study did not adjust the quality of output and input during estimating the profit efficiency. The study only evaluated the quality by the price of the item, assuming the higher price was for better quality and vice versa. Further estimation can be carried out by considering the adjustment of the input and output quality in rice production as discussed in Ball et al. (2010); Fuglie et al. (2016), which can motivate the future study to be carried out. Moreover, this study estimates the profit efficiency by pooling the data from the Dhaka and Manikganj regions.

Given the regional differences, whether farmers in different districts operate under their own technologies is an important topic for future investigation, which can be carried out by applying the meta frontier analysis as discussed in Wang and Rungsuriyawiboon (2010). In addition, this study figured out the socio-economic determinants of technology adoption, but it did not study how technology is adopted following any Technology Adoption Model (TAM), such as the Zero-Inflated Poisson and Negative Binomial count data models discussed in Isgin et al. (2008). This can motivate further research on TAM in Boro rice cultivation.

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