RESEARCH ARTICLE

Do credit constraints affect the technical efficiency of Boro rice growers? Evidence from the District Pabna in Bangladesh

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Abstract
This study analyzes the effects of credit constraints on technical efficiency of Boro rice growers in the district of Pabna in Bangladesh. Using a simple random sampling technique, the data was collected from 570 Boro rice growers from the Pabna district of Bangladesh. Before conducting a field survey, a theoretical model was designed to identify credit-constrained and non-constrained rice growers. We have analyzed the collected data in two phases: first, we investigated the technical efficiency of Boro rice growers using the stochastic frontier model (SFA); and second, we used an inefficiency effect model to estimate the influence of credit constraints on technical efficiency. Findings indicate that credit-constrained rice growers (CCRG) are 6.7% less technically efficient than credit non-constrained rice growers (CNRG). Findings further indicate that the education level of the household head, family size, certified seed, sowing time, access to extension services, off-farm income, and household savings have significant effects on the technical efficiency of both groups of rice growers. Furthermore, credit size has a significantly positive impact, whereas the interest rate imposed on the principal amount has a significantly negative impact.

Keywords Bangladesh · Credit constraints · Financial institution · Rice growers · Technical efficiency

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Introduction

Adequate access to credit is considered as a comprehensive tool for agricultural growth and rural development (Li et al. 2016; Lin et al. 2019; Amanullah et al. 2020). In recent years, the capital requirements of the farming communities, on the one hand, have increased tremendously. On the other hand, formal financial institutions are reluctant to allocate funds for agriculture, considering the nature of uncertainties in this sector (Arshad et al. 2017a, b). Farmers in developing countries heavily depend on formal and informal credit sectors due to insufficient savings. The production and financial structure theory note that if financially constrained farm households have opportunities to get credit, overall productivity performance can be enhanced (Elahi et al. 2018).

Existing literature (von Cramon-Taubadel and Saldias 2014; Chandio et al. 2019; Attipoe et al. 2020; Ekinci and Omay 2020; Long et al. 2020; Kattel et al. 2020) has posited that farmers' credit constraints along with environmental factors influence farmers' performance in different ways and may decrease farm productivity. In developing countries, the financial market is fragmented. Its failure arises from asymmetric information, the influence of informal lenders, strict terms and conditions of loan disbursement, controlled monitoring, etc. (Bhattacharya et al. 2020). Although globally, financial experts are working on sustainable rural development programs by offering different financial services on subsidized rates; real farming communities in most of the developing countries are deprived of adequate access to formal credit (Dong et al. 2012; Li et al. 2018; Jin et al. 2019; Ma et al. 2019; Cao and Leung 2020; Okoruwa et al. 2020).

The present rural financial market in Bangladesh is highly imperfect, mainly impacted by knowledge scarcity, information complexity, restricting credit volumes, monitoring, non-performing portfolio ratios (NPPs), and most importantly, stimulating private money lenders. In addition, loan applicants have to provide several kinds of legal and supporting documents depending on the amount of the loan and the cash facility the borrowers are requested to avail (Ma et al. 2019). These hurdles create a rigorous credit environment which may result in low agricultural productivity (Bashir and Mehmood 2010; Mehmood et al. 2018).

Bangladesh is the fourth largest rice producer (Roy et al. 2014) and the third-largest rice consumer in the world (Shew et al. 2019). Rice farming employs 48% of the total labor force and contributes 70% to the national agricultural gross domestic product (GDP). According to an estimate, around 13 million farmers in Bangladesh grow the rice crop that covers around 10 million hectares of land (Hossain et al. 2012). Farmers usually grow three varieties of rice, i.e., Aus, Amon, and Boro, and among these three varieties, 42% of the rice growers grow the Boro variety (Hasnain et al. 2016). Boro rice is widely known as an irrigated rice crop planted during December and early February and harvested during the dry season between April and June. Compared to other rice varieties, Boro rice contributes the highest production, at 4.03 t/ha (BER 2019), but this is much lower than other Asian countries, like Japan, Indonesia, Vietnam, China, and South Korea. In Vietnam, the average rice production is 5.63 t/ha, Thailand 3.0 t/ha, India 3.59 t/ha, and Bangladesh 2.93 t/ha (FAO 2012). This lower production compared to other Asian players indicates a massive economic loss. To enhance productivity and ensure food security, it is significantly important to understand how to allocate the resources and increase farm efficiency technically and develop a new production technique to reduce costs and maximize resource utilization (Charnes et al. 1978; Fatemi and Atefatdoost 2020; Kumar et al. 2020; Li et al. 2020). This is the reason why a study on technical efficiency of rice growers will be of great significance toward increasing overall farm efficiency.

Despite the significant contribution of rice crops to national GDP, Bangladesh's farming community is facing several challenges, like lack of advanced production technologies, shortage of water, poor soil salinity, and insect or pest attack (Ahmed et al. 2021; Rana and Moniruzzaman 2021; Sarkar et al. 2021). The annual rice production statistics in Bangladesh show that the industry is still in its embryonic stage. Nonetheless, there is a significant gap between rice demand and supply in Bangladesh and this gap is widening at an alarming rate (Timsina et al. 2018; Shew et al. 2019). This existing disequilibrium in the rice market can be reduced if the government focuses on the financial issues, controls the farm input prices, and implements effective policies and regulations. Mehmood et al. (2018) and Zhao and Barry (2014) evinced that credit constraints restrict farmers from purchasing key inputs that indirectly can affect farm productivity.

Credit constraints could have both direct and indirect impacts: directly, they can influence farmers' purchasing ability; and indirectly, they can affect farmers' risk averting behavior that restricts them from taking risks, such as investment in advanced technologies (Boucher et al. 2008; Diana et al. 2010; Shew et al. 2019; Duong and Thanh 2019; Carrer et al. 2020; Kattel et al. 2020). Thus, farmers with insufficient funds or who are financially constrained have not been able to achieve the maximum production level. Like in other developing countries, in Bangladesh, farmers are trapped in a vicious cycle of poverty and debt. From one aspect, they need finance to help them purchase basic farm inputs (Bidisha et al. 2018; Long et al. 2020), while on the other, financial institutions are reluctant to disburse the loan to them, considering the risks involved in the agriculture sector (Arshad et al. 2017b; Mehmood et al. 2017).

In most cases, financial institutions reject loan applications or disburse lesser amounts than requested. Financial institutions in rural Bangladesh evaluate farmers' net worth, years of experience, property they offer as mortgage, their loan history,

etc. If farmers fulfill all these requirements, banks approve loans at different interest rates by applying an equity ratio.

To the best of the authors' knowledge, very few studies are available on credit constraints and the technical efficiency of rice growers in Bangladesh, while the available studies have ignored several key variables in the empirical analysis. So far, extant studies have addressed several issues and analyzed both demand-side credit constraints and supply-side credit constraints. Moreover, these studies have ignored the impact of diversified income sources on the technical efficiency of rice growers. Thus, we identified all these gaps and evaluated the farm households' technical efficiency by considering demand and supply-side credit constraints. Following the method of several researchers (Komicha and Öhlmer 2008; Cabrera et al. 2010; Koirala et al. 2013; Haryanto et al. 2016), we used the stochastic frontier model (SFA) and inefficiency effects model to analyze rice growers' technical efficiency. Considering the importance of technical efficiency and farmers' credit constraints, we mainly addressed two questions:

a) Do credit constraints affect the technical sefficiency of Boro rice growers?
b) Does access to credit affect the technical efficiency of Boro rice farmers?

A theoretical framework to identify credit-constrained households

Prior to the field survey, the authors designed a theoretical framework and identified credit constrained and credit non-constrained rice growers (see Fig. 1). The issues of credit constraints appear from both supply and demand-sides as noted by scholars (Boucher et al. 2008; Diana et al. 2010; Chiu et al. 2014; Mehmood et al. 2017; Beyhaghi et al. 2020). The demand-side credit constraints arise from inadequate household income, past bad credit records, absence of collateral and guarantee, etc. In contrast, supply-side credit constraints arise when lenders offer insufficient loans to household farmers (Mehmood et al. 2017). If the loan provider recognizes that the farmers will be incapable of repaying the principal or the interest, there is a huge chance that the loan application will be rejected. These fundamental factors take preference when financial markets are imperfect or interest rates are exceptionally high (Jana 2015). Particularly, we identified credit constraints by focusing on the non-price restricting mechanism, which could arise in two situations. Firstly, the farm households which applied for a loan at current interest rates but were rejected by the financial institutions; and secondly, farm households do not want to borrow due to various risks and demand crises (Beyhaghi et al. 2020).

Based on the theoretical model, if the rice growers received the total amount as requested from the financial institutions, they were classified as credit non-constrained rice growers (CNRG), and if they received a partial amount or their loan applications were rejected by the financial institutions, they were classified as credit-constrained rice growers (CCRG). It was also hypothesized that if farmers received the total amount from the financial institutions as requested, they would have been in a position to purchase farm inputs and invest in advanced technologies that result in higher efficiency. On the contrary, farmers who did not receive a sufficient fund would not have been able to access the maximum inputs for production, thus resulting in lower efficiency. Fig. 1 also shows that farmers who rely on credit are split into two groups: (1) farmers who have not applied for credit; and (2) farmers who have applied for credit. Farmers who have not applied for credit could have been due to several reasons, including risk rationing and cost operation rationing as a result of risk aversion or some other reasons (Diana et al. 2010; Zhao and Barry 2014; Bond et al. 2015; Kjenstad et al. 2015; Beyhaghi et al. 2020; Galema 2020; Long et al. 2020). Boro rice growers who applied for credit are divided into three subcategories: (i) Farmers who applied for credit and were granted the full amount (as they had submitted all the requirements and in-demand and supply-sides show there is no presence of quantity rationing) are known as CNRG; (ii) farmers whose applications were not accepted for a reasonable sum of credit (i.e., less than 100%), and some of them were rejected directly; and (iii) some farmers applied for the credit by contacting private lenders directly, and most of them managed to get the loan, although some farmers have not received the loan. The situation of quantity rationing usually arises from asymmetric information (Zhao and Barry 2014). Finally, the authors identified three categories of farmers: (i) credit-constrained farmers; (ii) credit non-constrained farmers; and (iii) farmers who have not applied for credit because of sufficient funds. Notably, the last category was excluded from the dataset.

Materials and methods

Study population and place

The study was conducted in the District of Pabna in Bangladesh. The Pabna District is located in the southeast boundary of the Rajshahi Division. Its temperature ranges from 9.6 to 36.8 °C, with an annual rainfall of 1872 mm. The soil of the district is highly fertile and divided into four categories: the flood plains of the Baring Tracts, Karatoya, Ganges, and Jamuna. This district was selected as the scope of the study, considering its share in the national agricultural GDP, i.e., around 15%. Moreover, the selection of rice crops
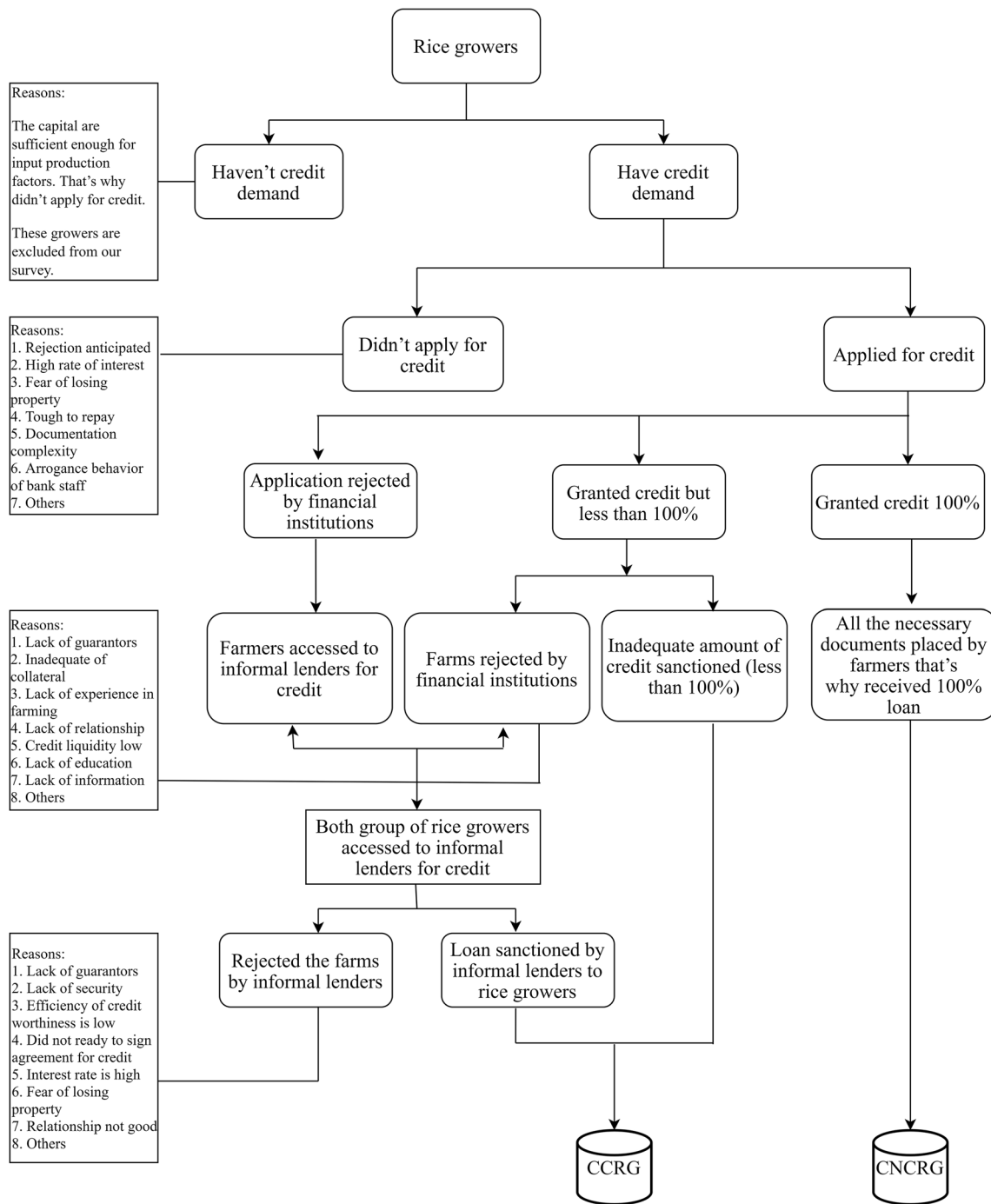
Fig. 1 Theoretical model of credit constraints rice growers (CCRG) and credit non-constraints rice growers (CNRG)

was based on two primary reasons: firstly, rice is the leading food crop in Bangladesh; and secondly, in the agriculture industry, rice contributes around 70% of the added value.

Survey design and data collection

A simple random sampling technique was adopted and 570 rice growers from 10 Union Councils of Pabna District were selected (Fig. 2). A pilot survey was conducted and

information from 50 farm households was collected using a pre-tested and well-structured questionnaire. Necessary amendments were made to the questionnaire before conducting the final field survey. The farm households were identified as credit constrained and credit non-constrained using a direct elicitation approach.

Notably, farm households who had neither applied for a loan nor faced credit issues in both categories were removed from the database because their loan demand from financial

Fig. 2 Study area in Pabna
District, Bangladesh
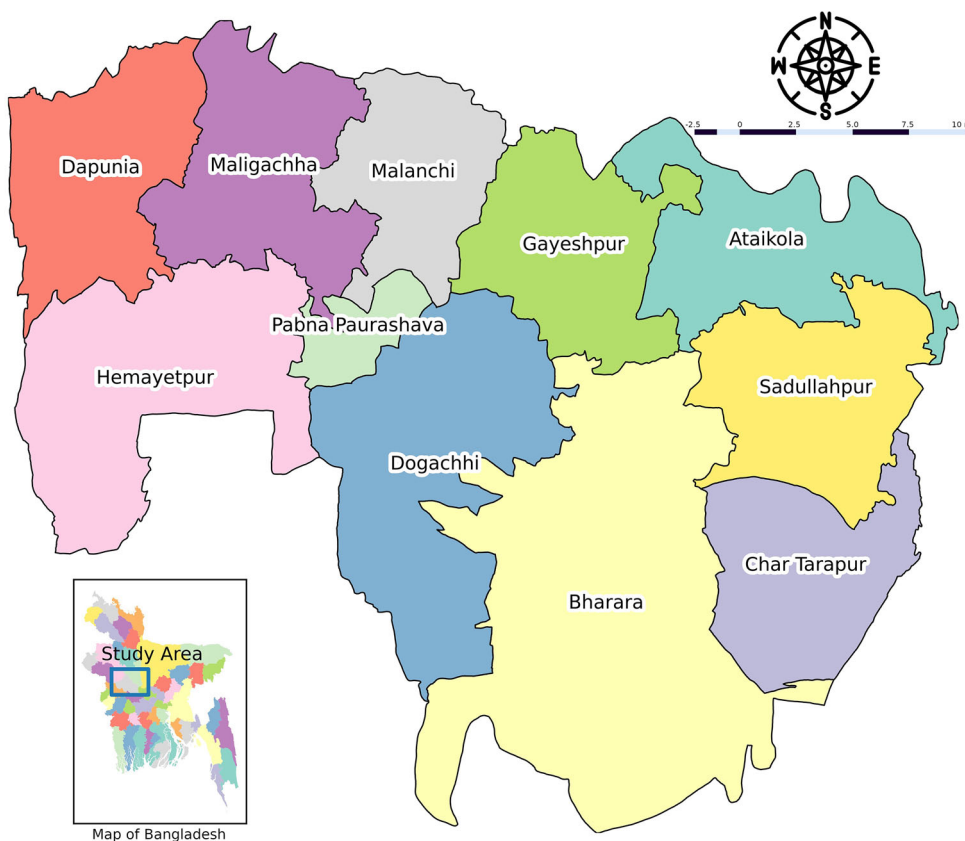
institutions was zero. A list of rice growers was obtained from
the Agricultural Department of Bangladesh, and a total of 597
rice growers were interviewed. The total response rate was
96%, while 4% of respondents were unavailable or refused
to provide the information. Thus, the total sample size is
570, including 200 CNRG and 370 CCRG.

Econometric estimation

Stochastic frontier analysis

The SFA, developed by Aigner et al. (1977), was used to
analyze the technical efficiency of rice growers. This model
has been widely used in earlier studies (Tipi et al. 2009;
Cabrera et al. 2010; Heriqbaldi et al. 2015; Bhattacharyya
and Mandal 2016; Hasnain et al. 2016). The basic equation
is given below:

$$Y_i = f(X_i; \beta) \exp(v_i - u_i) \tag{1}$$

In Eq. (1), Y_i represents the expected output of ith rice
growers, X_i denotes an observed function of inputs or de-
scriptive variables, while $(X_i; \beta)$ specifies the framework's
production frontier. The random deviation of output is
known as v_i, which is an asymmetric random error and mea-
sured empirically as $N(0, \sigma_v^2)$, while (u_i) denotes a set of

non-negative random variables allied with the inefficiency
model for rice growers in production with a mean (u) vari-
ance (σ_μ^2) (which is $| N(u, \sigma_u^2 |)$, as well as treated as a half-
normal distribution (Kumbhakar and Lovell 2000). The var-
iance constraints of the framework are $\sigma^2 = \sigma_v^2 + \sigma_\mu^2; \lambda = \sigma_\mu^2 / \sigma^2$
and $0 \leq \lambda \leq 1$. Considering the distribution assumption of
variance (v_i) and (u_i), we generated an assessment of (u_i),
from its restrictive probability by generating the standard
integral:

$$E(u_i|\varepsilon_i) = \mu_i^* + \sigma_i^* \left[\frac{\phi\left(-\frac{u_i}{\sigma_i^*}\right)}{1 - \phi\left(-u_i / \sigma_i^*\right)} \right] \tag{2}$$

In Eq. (2), $u_i^* = \left(u\sigma_v^2 + \varepsilon_i \sigma_\mu^2 \right) / \sigma_v^2 + \sigma_\mu^2$,

$\sigma_v^{*2} \equiv \sigma_v^2 \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ and $^\phi(.)$ and $^\phi(.)$ denote accumula-
tive distribution and likelihood density functions. We obtain-
ed the value of variance from Eq. (1), (v_i) and (u_i) by swapping
the estimation of $\varepsilon_i \sigma_i$ and l, which is associated with output-
related (TE_i) of ith Boro rice growers. The output level is
explained as the proportion of perceived output to uppermost
attainable production, symbolized by $\exp - v_i$ and expressed
as follows:

$$TE_i \frac{y_i}{f(X_i;\beta)e\,(v_i)} \exp\{-(u_i|\varepsilon_i)\} \qquad (3)$$
$$TI_i = 1 - TE_i$$

The distribution of (u_i) from Eq. (3) confined the estimated TE of Boro rice growers between 0 and 1. Therefore, we obtained the efficiency score from diverse groups of rice growers for our study. We defined it as $1 - exp\{(-u_i|\varepsilon_i)\}$. Besides, we treated it as a dependent variable whereas assessing inefficiency models (CNRG, CCRG and total sample). Finally, to assess the TE of rice growers, the overall form of the SFA framework is mentioned below:

$$InY_i = \beta_0 + \sum_{K=i}^{\sigma} \beta_{ij}lnX_{ij} + v_i - u_i \qquad (4)$$

where the aggregate output for the rice growers is Y_i, measured in kilograms, and X_{ij} is the selected input variables explained as farmland area, cost of seedling, farm labor cost, the cost of fertilizer application, cost of pesticides, irrigation cost (as stated earlier); the β_0 are the coefficients of descriptive variables that need to be projected and (v_i) and (u_i) have already been explained in Eq. 1.

In the second stage of the unified analysis, the authors applied the inefficiency effects model to determine the technical efficiency of rice growers. Battese and Coelli (1995) extended the work of Aigner et al. (1977) and introduced the inefficiency effects model with the SFA. We used the inefficiency effects model by applying the maximum likelihood estimation method.

$$IE_i = \delta Z_i + \eta_i \qquad (5)$$

In Eq. (5), IE_i represents the inefficiency scores, in which Z_i is a vector of designated variables that impacts inefficiency within different classified groups of Boro rice growers, and η_i is a random error term in the database set, which is distributed with a zero mean and variance normally and independently.

Data description

The dependent variable Y_i was measured as a total yield for ith rice growers in a cropping session on a per-acre basis (measured in kilograms). Six independent variables were included in the model to measure technical efficiency (TE). These include farmland area X_1 indicating the total area used to cultivate the rice crop (measured in acres); cost of seedling X_2 indicates the cost of seed-applied on acre basis (analyzed in per 100 bundles); farm labor cost X_3 reflects the required typical number (No.) of labor (equal to the adult male) during the cropping session; the cost of fertilizer used X_4 is the cost of fertilizer used on an acre (as analyzed in kilograms), that is, urea and potash; cost of pesticides X_5 used for plant

protection procedures indicates the aggregate application of pesticides, weedicides, etc., in a cropping season (analyzed in kilograms); irrigation cost X_6 symbolizes the cost of irrigation in a cropping season analyzed in number on an acre basis. Descriptive statistics related to outputs and input variables were chosen for technical efficiency analysis are portrayed in Annexure 4 in the Appendix.

In the second stage, the inefficiency effects model was used to estimate the determinants of farmers' technical efficiency. The variable age of the household head Z_1 represents the total age of the household head (estimated in years); Z_2 represents the schooling level of the head of household (measured in years); household size Z_3 represents the household family size (estimated as total number of family members in a household); seed quality Z_4 is the dummy variable which stands for certified seed (if certified seed is used, then 1, otherwise, 0); Z_5 represents the dummy variable for the time of seed sowing (if the rice seed is sown in time, then 1, otherwise, 0); as a dummy variable, Z_6 is for own tube-well (if tube-well is owned, then 1, otherwise, 0); access to extension services, Z_7 is represented as a dummy variable (if taken extension services facility, then 1, otherwise, 0); for livestock, Z_8 is represented as a dummy variable (if own livestock, then 1, otherwise, 0); for off-farm income, Z_9 is represented as a dummy variable (if there is opportunity for off-farm earning option, then 1, otherwise, 0); Z_{10} is chosen as a dummy variable for the household head's annual savings (projected in 1000 BDT); Z_{11} is represented as a dummy for credit size (calculated in 1000 BDT); Z_{12} is chosen as a dummy variable for the interest rate imposed on the loan amount (calculated in percentage); Z_{13} reflects credit availability as a dummy variable (if yes=1; otherwise=0). Descriptive statistics of all explanatory variables used in the inefficiency effects model are presented in Annexure 5 in the Appendix.

Results and discussion

Maximum likelihood estimates of the production frontier

The results show that for both CNRG and CCRG, the coefficients of farmland area variables are 0.028 and 0.093, respectively (see Table 1). This coefficient value explains that 1% increase in the unit of farmland area results in an estimated increase in the Boro rice yield by 0.02% for the CNRG and 0.09% for CCRG. For cost of seedling, we find the highest input consequence on Boro rice production, and the calculated elasticities are 0.60 for CNRG and 0.454 for CCRG. One reason for this is that most farmers in the study area used better quality seed for the Boro rice cultivation, which significantly and positively patronage Boro rice yield. The CCRG farm

Table 1 Maximum likelihood estimates of production frontier

Variables	CNRG No. (200)	CCRG No. (370)	Full sample No. (570)
Intercept	0.577 (0.070)***	0.731 (0.094)***	0.785 (0.063)***
Ln farm land area	0.028 (0.009)**	0.093 (0.011)**	0.082 (0.008)***
Ln cost of seedling	0.600 (0.050)***	0.454 (0.064)***	0.491 (0.044)**
Ln farm labor cost	0.010 (0.008)	0.042 (0.011)**	0.039 (0.010)
Ln cost of fertilizer	0.119 (0.029)***	0.141 (0.040)	0.056 (0.008)*
Ln cost of pesticides	0.090 (0.015)**	0.058 (0.017)**	0.048 (0.010)***
Ln irrigation cost	0.060 (0.023)**	0.060 (0.035)	0.023 (0.013)
Ln σ^2	−10.828 (0.184)***	−8.358 (0.112)***	−7.969 (0.095)***

Notes: The values in parenthesis specify standard errors. Significant level at ***$p< 0.01$; **$p< 0.05$, and *$p< 0.10$

Variance parameters

Credit unconstrained: log likelihood = 538, Wald χ^2 = 1426, $\lambda = \sigma_\mu/\sigma_v$ = 1.08, σ^2 =0.0013

Credit constrained: log likelihood = 619, Wald χ^2 = 561, $\lambda = \sigma_\mu/\sigma_v$ = 0.112, σ^2 = 0.0017

Full sample: log likelihood = 946, Wald χ^2 = 1081, $\lambda = \sigma_\mu/\sigma_v$ =0.008, σ^2 = 0.0009

labor cost coefficient value is 0.042 and significant at the 5% level of probability. The coefficient values of the cost of fertilizer for CNRG and CCRG are 0.119 and 0.141, respectively. CNRG and CCRG, respectively, have 0.090 and 0.058 coefficients for the cost of pesticides values. For CNRG, the coefficient value of the irrigation cost is 0.060 and significant at the 5% level of probability, while for CCRG, the same coefficient value is insignificant.

Scale effect

The scale elasticity shows declining returns to scale (DRS) in all our models. The calculated figure of the scale effect is lesser than one. It indicates no significant connection between the farm inputs and the amount of products produced for the sample of Boro rice growers. This study indicates that farmers in the surveyed areas might not be managing their land effectively or introducing appropriate innovation. We successfully proved that farm households, at least by statute, have obtained enough income to afford their most basic needs or requirements. This study indicates that farm households' productivity can be improved by capacity building rather than by expanding their size.

Range of technical efficiency

The results show that the mean technical efficiency of CNRG is 88.76% and 82.06% for CCRG (Table 2). The difference in the mean technical efficiency is 6.70%, which indicates technical efficiency gaps between CNRG and CCRG. Therefore, in both cases, the rice growers can increase the efficiency level by 11.24% for CNRG and 17.94% for CCRG, by employing their existing level of resources. Findings further show that around 75% of CNRG and 46% of CCRG attained more than 80% of technical efficiency scores. Findings are in line with

the studies by Min et al. (2020) and Wang et al. (2020), who obtained technical efficiency scores of 88.76% for CNRG and 82.06% for CCRG in China. Findings also support the earlier studies of Balcombe et al. (2007) and Jalilov et al. (2019) conducted in Bangladesh. Furthermore, in South Asia, technical efficiency ranged from 0.82 to 0.97% (Bibi et al. 2020).

Technical inefficiency effects estimate

Table 3 presents the factors affecting the technical inefficiency of rice growers. Following the methods of Cabrera et al. (2010) and Mehmood et al. (2017), the authors explained the findings of the inefficiency effects model concerning technical efficiency. This indicates that a negative impact on technical inefficiency has a positive impact on technical efficiency.

The calculated parameters suggest that household's head age (considered as agricultural farming experience) has a significant but negative effect on CNRG. The negative sign signifies that old farmers in the area surveyed are less productive than their younger counterparts. The coefficients of the education level in both groups of growers are positive and significant, but the impact seems stronger on CNRG. Komicha and Öhlmer (2008) noted that education, as a source of human capital, improves management efficiency and increases farmers' understanding on handling complex issues, like loan acquisition. The coefficient of household size is significant and positive for both groups of growers. This indicates that the technical efficiency of growers increases with increases in household size. This may be due to the fact that more family members are involved in farming practices and help farmers to manage farm activities.

The coefficients of certified seed for both CNRG and CCRG are positive and significant. Findings evince that the seed can generate higher output if it is sowed on time. These

Table 2   Efficiency estimates of credit constrained, credit non-constrained, and full sample size

Efficiency range	CNRG (N=200)		CCRG (N=370)		Full sample (N=570)	
	Numbers	Percentage	Numbers	Percentage	Numbers	Percentage
<80%	51	25.50	198	53.51	235	41.22
81–85%	28	14.00	72	19.45	108	18.94
86–90%	35	17.50	28	7.56	53	9.29
91–95%	47	23.50	41	11.08	98	17.19
>95%	39	19.50	31	8.37	76	13.33
Total	200	100	370	100	570	100
Mean	0.8876	88.76%	0.8206	82.06%	0.8581	85.81%
Std. Dev.	0.097	----	0.0874	----	0.096	----

Source: author' calculation

results concur with Musaba and Bwacha's (2014) analytical work. The coefficient of own irrigation system for CCRG is significant at 10% probability level, with a positive impact on rice producers' technical efficiency, while for CNRG, it is vice versa and insignificant. The presence of severe electricity issues in rural areas of Bangladesh is always a challenge, and diesel and petrol prices are extremely costly. As a result, most farmers in rural areas rely on external irrigation sources. Therefore, logically, we should not conclude that the CNRG community of rice growers with their irrigation system are less efficient than those who did not.

Awareness of the role of production and proper distribution is vital to accelerate the current level of productivity at the farm level, as well as to impact the growth of the agricultural sector (Das et al. 2017). The value of the extension services coefficient for both CNRG and CCRG is positive and

significant, which indicates the success of Bangladesh's agricultural development corporation (Afrad et al. 2019). Similarly, the wing of traction facilities and the availability of compost for livestock agriculture in rural Bangladesh have greatly improved farmers' productivity and helped minimize overall production costs. The coefficient value of livestock is significant and positive for CNRG, pointing out that those who have livestock facilities are typically more efficient than other farmers.

Diversified sources of income play a role as a benchmark for pull or push factors (Escobal 2001; Mariyono 2018) among farm households. Diversified income sources in rural Bangladesh are not substantially seen or very limited due to many factors, such as demographic characteristics, lack of sufficient credit facilities, and lack of technical personnel (Reardon et al. 2000; Kabir et al. 2019; Kabir et al. 2020).

Table 3   Parameter estimates of inefficiency effects model

Variables	CNRG No. (200)	CCRG No. (370)	Full sample No. (570)
Constant	−6.551 (0.858)***	−3.995 (0.580) ***	−4.957 (0.446) ***
Household head age(years)	0.027 (0.018)**	0.008 (0.008)	0.016 (0.007)
Household head education (years)	−0.101 (0.034)***	−0.076 (0.034) **	−0.083 (0.028) **
Household family size (numbers)	−0.076 (0.021)**	−0.060 (0.028) **	−0.064 (0.021) **
Certified seed (yes=1; otherwise=0)	−0.741 (0.585)**	−0.670 (0.335)	−0.663 (0.260)**
Sowing time (yes=1; otherwise=0)	−0.986 (0.267)***	−0.784 (0.367)*	−0.453 (0.271)**
Owned tube-well (yes=1; otherwise=0)	0.523 (0.336)	−0.682 (0.396)	−0.075 (0.314)
Extension services (yes=1; otherwise=0)	−0.878 (0.258) **	−0.790 (0.345)**	−0.784 (0.251)**
Livestock holding (yes=1; otherwise=0)	−1.422 (0.425)**	−0.512 (0.338)*	−0.909 (0.260)**
Off-farm income (yes=1; otherwise=0)	−0.790 (0.495)**	−1.074 (0.472)**	−0.876 (0.343) *
Household savings (1000 BDT)	−0.002 (0.027)**	−0.002 (0.001)**	−0.002 (0.001)**
Credit size	−0.0002 (0.0002)**	−0.0003 (0.0001)**	−0.003 (0.0001)*
Interest rates (percentage)	0.016 (0.013)**	0.035 (0.010) **	0.024 (0.008) *
Credit availability (yes=1)	--	--	−0.453 −0.271**

Notes: The values in parenthesis specify standard errors

Significant degree at ***p< 0.01; **p< 0.05, and *p< 0.10

According to our results, the value of off-farm income coefficients is significant and positive for both the CNRG and CCRG categories. These results are somewhat similar to Tipi et al.'s (2009) work. Furthermore, the household saving coefficients for both the CNRG and CCRG classes are positive and significant at 5% probability level, suggesting a greater efficiency for households with comparatively higher savings potential.

The credit size indicator has a significant and positive effect on both the CNRG and CCRG categories. The influence of the volume of credit can be easily seen in two separate ways. Initially, increasing the volume of credit would positively affect farm households to implement advanced technologies and help to distribute their resources rationally. Furthermore, it is possible to condense the size of the loan per unit cost of service. At the same time, certain expenses are systemic at the time of loan disbursement (e.g., hiring counsel, third party assessment, mortgage payments), irrespective of the amount of credit. In comparison, the principal interest charges have a major detrimental impact on the technical efficiency of both the CNRG and CCRG classes. (Drehmann et al. 2010; Mallick 2012), showing that higher interest rates are levied by financial institutions in rural Bangladesh, mostly due to credit delinquency.

In a nutshell, the full sample parameter evaluation is close to that of CNRG and CCRG to some degree (see Table 3). The primary objective of the study is to assess the effect of credit constraints on growers' technical efficiency. After reviewing several studies (Komicha and Öhlmer 2008; Afrin et al. 2017; Bidisha et al. 2018), we examined credit availability as a dummy variable (as mentioned earlier). The availability of credit (as a dummy) determines its effect on technical efficiency, but credit constraints were assessed using the direct elicitation process. Generally speaking, the finding shows that the availability of credit has a substantially positive impact on the technical efficiency of Boro rice farmers. In comparison to the hypothesis of economic experts, who believed that the monetary market

in rural Bangladesh does not make a major contribution to improving the livelihood of the rural poor, the results of our study are in tandem with the work carried out by Ayaz et al. (2010) and Kabir et al. (2020). However, risk reluctance mechanisms at the household level must be dramatically reduced by offering subsidy insurance premiums, as indicated by Arshad et al. (2016) and Tuihedur Rahman et al. (2018).

Conclusions and policy implications

The effect of credit constraints on the technical efficiency of rice growers was analyzed using cross-sectional data collected from the district of Pabna in Bangladesh. The authors used the technique of direct elicitation and identified rice growers into two categories: CCRG and CNRG. A simple random sampling was adopted and 570 farm households were recruited to get the necessary information. The technical efficiency of rice growers was estimated using the SFA. The mean technical efficiency of CNRG is 88.76% and CCRG is 82.06%. This indicates that in the area surveyed, CNRG and CCRG, in principle, could increase their technical efficiency by 11.24% and 17.94%, respectively. The difference between the technical efficiency scores of CNRG and CCRG is 6.70%.

Moreover, findings of the inefficiency effects model show that the technical efficiency of both groups of rice growers is affected by the years of schooling, the size of household, sowing time, extension facilities, off-farm income, and savings of the household head. The variable of credit size is positive, and the interest rates on the principal amount have significantly negative effects on the technical efficiency of rice growers. Access to credit on the technical efficiency of farm households is significant and positive. However, while our research reveals a very strong effect of the availability of credit on the technical efficiency of Boro rice farmers, one issue is quite mysterious as to why perfection does not exist in the rural financial market as well as poverty has not been substantially

Table 4 Descriptive statistics of output and inputs variables used in SFA analysis

Variables	(CNRG) No. (200)	CCRG No. (370)	Full sample No. (570)	t-ratios
Yield (kilograms acre-1)	48.55 (8.25)	40.25 (9.82)	45.29 (9.31)	7.361**
Farm land area (acres)	4.50 (3.12)	2.35 (1.75)	3.49 (2.51)	4.891**
Cost of seedling per 100 bundles acre-1	220.00 (30.50)	230.00 (20.65)	229.50 (26.34)	3.943**
Farm labor cost (per day per labor BDT)	450.00 (40.35)	450.00 (45.52)	459.00 (44.22)	−5.251***
Cost of fertilizer per kg (BDT)	23.50 (7.25)	25.60 (6.30)	25.04 (6.98)	3.814**
Cost of pesticides per kg (BDT)	250.00 (65.72)	245.00 (64.77)	252.45 (67.20)	0.892
Irrigation cost per acre (BDT)	7200.00 (1165.50)	6900.00 (1356.00)	7191.00 (1298.57)	9.19***

Notes: Standard deviations are presented in parentheses

Significant degree at ***$p < 0.01$; **$p < 0.05$; and *$p < 0.10$

1 US$ = 85 BDT when the study was conducted

Source: Authors' field survey in 2018

reduced in rural agricultural communities in Bangladesh and elsewhere in low-income nations.

Our findings signify that access to formal credit help can minimize the households' financial constraints and allow them to purchase farm inputs. Therefore, the government and private financial organizations should simplify the loan procedure and reduce the interest rate for agriculture businesses. Moreover, the government must increase the per acre credit limit, considering the financial requirements and input costs. Financial institutions should also open their branches in remote areas of Pabna District to facilitate farmers that would in turn increase their loan portfolio.

Appendix

Table 5 Descriptive statistics of explanatory variables used in the inefficiency effects model

Variables	(CNCRG) No. (200)	CCRG No. (370)	Full sample No. (570)	*t*-ratios
Household head age(years)	43.45 (11.13)	44.56 (13.92)	40.04 (7.36)	−3.65***
Household head education (years)	7.50 (4.67)	5.25 (5.85)	5.80 (3.21)	2.37**
Household family size (numbers)	5.25 (3.12)	6.45 (3.90)	5.32 (2.11)	5.94***
Certified seed (yes=1; otherwise=0)	0.62 (0.35)	0.48 (0.43)	0.50 (0.36)	0.95
Sowing time (yes=1; otherwise=0)	0.58 (0.41)	0.51 (0.51)	0.50 (0.35)	0.36
Owned tube-well (yes=1; otherwise=0)	0.51 (0.26)	0.34 (0.32)	0.39 (0.35)	2.58**
Extension services (yes=1; otherwise=0)	0.57 (0.40)	0.44 (0.50)	0.46 (0.36)	−1.63*
Livestock holding (yes=1; otherwise=0)	0.69 (0.17)	0.39 (0.21)	0.49 (0.32)	2.96**
Off-farm income (yes=1; otherwise=0)	0.324 (0.512)	0.214 (0.252)	0.257 (0.421)	1.02
Household savings (1000 BDT)	88.00 (48.51)	25.00 (16.32)	51.42 (44.06)	0.44
Credit size (1000 BDT)	864.29 565.67	201.42 (723.23)	432.43 (744.53)	5.758***
Interest rates (percentage)	11.50 (1.39)	15.45 (1.74)	12.26 (4.82)	17.47***
Credit availability (yes=1)	…	…	0.48 (0.27)	…

Notes: Standard deviations are specified in parentheses

Significant level at *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$

1 US$ = 85 BDT when the study was conducted

Source: Authors' field survey in 2018

Declarations

Ethics approval This is an observational study. We confirmed that no ethical approval is required.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interest The authors declare no competing interests.

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