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Comparative Advantage and Cost Efficiency of Rice-Producing Farms in Bangladesh: A Policy Analysis

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バングラデシュにおける稲作の比較優位と費用効率性
—政策分析—

モハマド アリフル イスラム^{1)*}

本稿の目的は、バングラデシュ稲作が、肥料補助金を撤廃しても比較優位を持ち続けられるか、費用非効率性の低減により、どの程度比較優位が回復するかを検討することにある。そのため、本稿では、家計調査データを用い、国内資源費用（DRC）と、確率的フロンティアモデルによる費用非効率性とを推計したうえで、肥料補助金の廃止が比較優位指標におよぼす影響と、費用効率性の改善が稲作の比較優位におよぼす影響とを検討する。主要な分析結果

は、1) 乾季稲作は比較優位を持ち雨季稲作はそれを失っていること、2) 肥料補助金が廃止された場合、稲作全体の比較優位は消滅すること、および、3) 費用効率性の改善は、たとえ肥料費補助金が廃止されても、費用効率性の改善により、比較優位を回復し得ること、である。これらの分析結果は、肥料補助金を削減しても費用効率性を高めることにより、バングラデシュ稲作の国際競争力を向上させる可能性を示唆するものである。

Key words: input subsidy, drc, shadow price, rice policy, cost efficiency

1. Introduction

Agriculture is the mainstay of the Bangladesh economy, while rice is considered to be the most important food crop. More than three-fourths of the country's total cropped land is devoted to rice production, which contributes more than 97 percent to the total cereal food supply. Official available statistics show that food grain demand in Bangladesh in 2006/07 FY was estimated at 25.69 million tons while net domestic cereal supply was 25.25 million tons, implying a shortage. With further improvement in domestic production, the net food grain supply in 2014/15 increased to 31.73 million tons while corresponding demand was 29.32 million tons,

indicating that domestic net supply is higher than total food grain demand in Bangladesh (FPMU, 2015). Presently, domestic production of rice is deemed sufficient to meet existing demand due to policies to achieve self-sufficiency for food security. These policies, however, include fertilizer subsidies and price support programs. Implementation of these policies has increased the budget deficit problem and has been criticized by foreign donors and international aid agencies (Ahmed et al., 2009), because such policies are ineffective for achieving the target of sustainable food security.

Bangladesh agriculture is now transforming from a traditional to a modern system. However, in this transformation process, the rice sector has the most

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strategic importance of all sectors, as rice is the staple food source for the whole population and the major source of livelihood for 16 million farm households (Kazal et al., 2013). The dominant issue affecting the rice sector is the inflexibility of collaborating resources in production activities. A major concern for the government is to maintain stability in food prices, which relates to the subsidization policy for agricultural inputs and price support through buying food crops from farmers at higher prices.

Several studies have been conducted to investigate the competitiveness of rice farming in Bangladesh. Shahabuddin et al. (2002) examined the comparative advantage of rice using two indicators: net economic profitability and the domestic resource cost (DRC) ratio. They suggested that Bangladesh had comparative advantage in rice production except for upland *aus* and broadcast *aman*¹ (wet season) rice. Rashid (2009) concluded that Bangladesh had comparative advantage in rice production, as the estimates of the DRC ratio were less than 1 in all the years under investigation. In addition, Kazal et al. (2013) and Miah and Haque (2013) concluded that Bangladesh rice had comparative advantage in both *boro* (dry-season) and *aman* (wet-season) rice production at import substitution.

However, the existence of comparative advantage of the rice sector in Bangladesh continues to be in doubt, as without input subsidies, if the rice sector does not have comparative advantage, then how can the Bangladesh rice sector achieve comparative advantage? To address these issues, first, this study aims to examine whether the Bangladesh rice sector has comparative advantage without subsidies.

To enhance productivity, generally, at least three measures should be adopted: 1) improve technical and allocative efficiency, 2) enlarge farm size to enjoy scale economy, and 3) develop new technologies for enhancing productivity and profitability.

This study mainly focuses on the possibility of the first measure and investigates whether the Bangladesh rice sector could improve technical and

allocative efficiency and obtain comparative advantage by improving efficiency.

Second, this study aims to examine whether cost inefficiency has a negative effect on the comparative advantage of the rice sector; whether decreased cost inefficiency could improve the comparative advantage of rice, and what the determinants of cost inefficiency are.

Given this scope, this study is expected to make two significant contributions. First, to the best of our knowledge, this is the first study that aims to examine the impacts of efficiency improvement on the global competitiveness of the Bangladesh rice sector. Second, this study is the first to measure the cost efficiency of Bangladesh rice farms by applying a stochastic frontier approach instead of a production function model and by applying a cost function model using Bangladesh Integrated Household Survey (BIHS) data.

The rest of this paper is organized as follows. Section 2 describes the data sources of rice production in Bangladesh, focusing on sample size and seasonal differences. Sections 3 and 4 explain the analytical framework of assessing the comparative advantage along with the econometric model used. In addition, this section presents the estimated results of DRC values and cost inefficiency estimates. Section 5 explains the measurement of the DRC ratio, which is an indicator of global competitiveness. Moreover, the estimates on the effects of cost inefficiency on the DRC ratio are added in this section. Finally, Section 6 summarizes the major findings of the study and draws some policy implications.

2. Data

In this study, data are obtained from the BIHS 2011–2012. The International Food Policy Research Institute (IFPRI) conducted a nationwide survey in 2011 and 2012 covering 6,500 sample rural households. In this study, we use only rice farming households for the analysis. Data modification and filtering are performed to ensure that the unit of measurement of each variable is consistent with the study objectives, and

the quality of data is satisfactory. This micro level data would represent the whole of Bangladesh. Although rice production in Bangladesh is practiced in three distinct seasons (namely, aus/pre-monsoon season, aman/wet season, and boro/dry season), for this study, we use only the data for high yielding rice varieties which are commonly being cultivated by transplanted method (this method is popular both in wet and dry seasons in Bangladesh and it gives higher yield than any other methods), both in dry and wet seasons. In fact, more than 96 percent of the total area under rice production in Bangladesh are covered by this transplanted method. Furthermore, out of the three rice growing seasons, the wet (*aman*) season covers the major rice area and it alone shares nearly 38% of the total rice production (FPMU, 2015). In this season, both high yielding modern rice varieties and some indigenous rice varieties are grown implicitly following the transplanted method, except some scanty deep water areas where the broadcast or B. *aman* rice is grown. Virtually, the area under B. *aman* rice is quite limited. As such, considering the area coverage, productivity and share of total rice production we intended to carry out the present study covering the Transplanted Aman varieties in order to achieve the set objectives.

3. Comparative advantage of rice-producing farms in Bangladesh

Economic profitability can be estimated using different methods. In this study, the DRC ratio is used to measure the comparative advantage in growing rice in Bangladesh.

(1) Data requirement for calculating domestic resource cost

To estimate the DRC, a comprehensive dataset is needed. The basic pieces of information needed to constructing the DRC include outputs, inputs, and the market and social prices of inputs and outputs. For this study, we used field survey data along with published and unpublished secondary data from different national and international sources. Inputs are divided into two

categories: (1) traded intermediate inputs and (2) non-traded intermediate inputs.

1) Traded intermediate inputs

Traded intermediate inputs are either imported or exported. In Bangladesh, different types of fertilizers (i.e., Urea, TSP, and MoP), seeds, insecticides/pesticides, and machinery are used usually for rice production. Here, we consider these as traded intermediate inputs. The costs of tradable inputs are measured by border/import parity price². The shadow price of seed is calculated applying a formula used by Hartono and Peneliti (2003) and Antriyandarti et al. (2012), as follows: shadow seed price = {(actual seed cost/actual output) × shadow output price}. The detailed calculations of import-parity border price of fertilizers and rice are presented in Appendix Table A1.

2) Non-traded intermediate inputs

Unskilled agricultural labor, manure, land rent, irrigation³ and interest on operating capital are considered as non-traded intermediate inputs and domestic resources, because these components do not usually enter to the international market. The costs of these inputs are collected through field survey. For social valuation of these costs and prices of non-tradable inputs, the specific conversion factors are used. To construct social budget, we use specific conversion factors of 0.75 and 0.86 for labor and irrigation charges, respectively. However, costs of manure and land rent are used as full social cost in this study (Shahabuddin and Dorosh, 2002; BRF, 2005; Kazal et al., 2013). The opportunity cost of operating capital is calculated at 10% interest for 5 months of the rice production period, both in the dry and wet seasons. The payments for non-traded intermediate inputs and domestic resources are converted from a measurement of “per unit of land” to “per unit of output.” Methodologically, these items are valued considering their opportunity costs. In Bangladesh, factor markets are fairly competitive, and thus, payment for non-traded intermediate inputs and domestic resources represents the opportunity costs

of these resources.

(2) Domestic resource cost

This subsection aims to estimate the global competitiveness of Bangladesh rice. Therefore, we use DRC as an indicator of global competitiveness, as suggested by Bruno (1972). The DRC is the ratio of the cost of domestic resources and non-traded inputs, valued at their shadow prices, in producing the commodity domestically to the net foreign exchange earned or saved by domestically producing the good. $DRC < 1$ indicates that the commodity is more profitable when produced domestically; meanwhile, $DRC > 1$ indicates that it is less profitable to produce domestically. This criterion is used in this study to determine the economic profitability of rice production in Bangladesh, both in the dry and wet seasons, and is estimated by using the following equation:

$$DRC_i = \frac{\sum_{j=k+1}^n a_{ij} p_j^*}{p^b - \sum_{j=1}^k a_{ij} p_j^b} \quad (1)$$

where

$i = i$ -th farms,

$j = 1, \dots, k$ are the traded inputs,

$j = k + 1, \dots, n$ are the domestic resources and the non-traded intermediate inputs, p_j^* is the shadow price of domestic resources and non-traded intermediate inputs, p^b is the border price of the traded output, measured at the shadow exchange rate, and p_j^b is the border price of the traded input j , also measured at the shadow exchange rate.

The results of DRC values are presented in Table 1 for both the dry and wet seasons in Bangladesh. The values of the estimated DRC reveal that Bangladesh has comparative advantage in import substitution of HYV rice production in the dry season. Data in Table 1 shows that DRC values are less than 1 either without (0.80) or with subsidy on chemical fertilizers (0.72). These results accord with the results of some earlier studies by Shahabuddin and Dorosh (2002), BRF (2005); Rashid (2009); and Kazal et al. (2013). A plausible reason for these results are high prices in the international market and higher per unit yield. Furthermore, the present results indicate that the

value of domestic resources used in producing per ton of dry-season rice in Bangladesh is less than the import cost. This means that policies focused on the attainment of self-sufficiency, especially for rice, are economically reasonable. Since the adoption of the dry season's HYV-rice technologies has reached a plateau (Alam and Islam, 2013), further advancement in the growth and supply of rice would require the adoption of newly evolved stress-tolerant varieties in unexploited large stress-prone areas of the country to achieve future food security as well as comparative advantage of growing the crop.

Conversely, the DRC values of HYV-transplanted *aman* rice in the wet season indicate that Bangladesh has no comparative advantage of rice production at import substitution. Data in Table 1 reveal that the DRC values are greater than 1, either without subsidy (1.45) or with subsidy on chemical fertilizers (1.25). This is attributed plausibly to the lower yield of wet-season rice. Therefore, there is no economic ground for producing HYV-transplanted *aman* rice at import substitution, which is similar to the results of Shahabuddin et al. (2002). However, in Bangladesh, the wet-season rice production depends on nature, and is prone to natural calamities, like flashfloods, submergence, salinity, and drought.

In the recent past, few rice varieties have been developed by research institutes that are tolerant to submergence, drought and salinity. Therefore, the government should emphasize the supply of newly evolved stress-tolerant rice seeds to the farmers for proper adoption to enhance the level of productivity.

Overall, DRC values were calculated with and without chemical fertilizer subsidy in Bangladesh. To calculate the overall DRC in Bangladesh, we use data for 2,303 rice-producing farms that cultivate rice in both the dry and wet seasons under the same piece of land. The results show that Bangladesh has an overall comparative advantage ($DRC < 0.97$) at import substitution with the subsidized price of fertilizers (Table 2).

Table 1. DRC for HYV rice production under dry and wet seasons in Bangladesh

Items	Dry season (Import parity)		Wet season (Import parity)	
	Without fertilizer subsidy	With fertilizer subsidy	Without fertilizer subsidy	With fertilizer subsidy
A. Tradable inputs (Tk/ton)	8481.54	7140.10	12401.31	11158.35
Urea	1449.87	631.14	1543.89	960.10
TSP	978.37	590.95	1103.10	682.95
MoP	447.06	311.77	574.75	335.73
Seed	3329.89	3329.89	7309.78	7309.78
Pesticide and insecticide	359.20	359.20	441.59	441.59
Machinery inputs	1917.15	1917.15	1428.20	1428.20
B. Non-tradable inputs and domestic resources (Tk/ton)	9139.51	9139.51	10829.68	10829.68
Labor	3693.17	3693.17	5357.15	5357.15
Manure	637.66	637.66	286.19	286.19
Irrigation	1777.20	1777.20	475.69	475.69
Interest on operating capital	303.95	303.95	385.84	385.84
Land rental value	2727.53	2727.53	4324.80	4324.80
C. Output price (Tk/ton) ¹⁾	19846.22	19846.22	19846.22	19846.22
D. DRC = B/(C-A)	0.80	0.72	1.45	1.25
Number of observations		6,243		3,740

Source: BIHS data (2011–12).

1) Using same border output price of rice in both seasons which is adopted from Appendix Table A1.

Table 2. Overall DRC score of sample rice-producing farms (combined with dry and wet seasons) in Bangladesh

DRC score	Overall ¹⁾			
	Without fertilizer subsidy		With fertilizer subsidy	
	Frequency	% of farms	Frequency	% of farms
0.11–0.30	5	0.22	6	0.26
0.31–0.50	280	12.16	373	16.20
0.51–0.70	479	20.80	524	22.75
0.71–0.99	603	26.18	629	27.31
1.00–2.00	633	27.49	612	26.57
2>	303	13.16	159	6.90
Total	2,303	100.00	2,303	100.00
Minimum		0.257		0.245
Maximum		5.361		3.80
Mean		1.13		0.97

Source: BIHS data (2011–12).

1) indicates that farmers cultivate HYV rice both in the dry and wet seasons under the same plot.

4. Estimates of the stochastic frontier cost function

In estimating the technical inefficiency of rice-producing farms in Bangladesh, we apply a stochastic frontier cost function approach. In the frontier approach, theoretically, the amount by which a farmer lies below the production frontier and that above its cost frontier can be regarded as the measures of inefficiency.

All deviations from the frontier are assumed the result of technical inefficiency (Aigner et al., 1977; Kumbhakar and Lovell, 2000; Coelli et al., 2005).

The few previous studies on the efficiency of Bangladesh rice producers had a narrow focus. Hossain (1989) conducted a Cobb–Douglas profit function analysis of relative economic price efficiency between modern technology adopters and non-adopters. Banik (1994) estimated technical efficiency of modern *boro* (dry season) rice farmers in the central region of Bangladesh. Deb (1995) and Rahman et al. (2013) estimated technical efficiency of rice farmers in the southwestern region of Bangladesh using a Cobb–Douglas production frontier. Alam (2006) estimated technical efficiency of modern rice-producing farms under the flood-prone and flood-free production environments in Bangladesh. However, several efficiency studies have used data envelopment analysis, such as the study of rice-farming households' efficiency in Bangladesh by Wadud and White (2000) and Coelli et al. (2002).

Coelli (1995) compared the two methods and observed that the main strengths of the stochastic frontier approach are its ability to deal with stochastic noise, and the fact that it permits statistical tests of hypotheses pertaining to production structure and the degree of inefficiency. However, since data envelopment analysis (DEA) is deterministic and attributes all the deviations from the frontier to inefficiencies, frontier estimation by DEA is likely to be sensitive to measurement errors or other noise in the data. Nevertheless, this is the first study that uses

a stochastic frontier cost efficiency model as it provides a good statistical fit to the relevant data as well as ease of estimation and interpretation.

(1) Empirical model

This study follows the method of estimating a stochastic frontier cost function as proposed by Aigner et al. (1977), Kumbhakar and Lovell (2000), and Coelli et al. (2005). The cost function is specified as follows:

$$\begin{aligned} \ln C_i = & \beta_0 + \beta_1 \ln P_{x1i} + \beta_2 \ln P_{x2i} + \beta_3 \ln P_{x3i} \\ & + \beta_4 \ln P_{x4i} + \beta_5 \ln P_{x5i} + \beta_6 \ln P_{x6i} + \beta_7 \ln P_{x7i} \\ & + \beta_8 \ln P_{x8i} + \beta_9 \ln P_{x9i} + (V_i + U_i) \end{aligned} \quad (2)$$

where

C_i = total cost of production (Tk),

P_{x1i} = seed cost (Tk/kg),

P_{x2i} = plowing cost (mechanical) (Tk/kg),

P_{x3i} = chemical fertilizer cost (Tk/kg),

P_{x4i} = irrigation cost (Tk/ha),

P_{x5i} = pesticide and insecticide cost (Tk/kg),

P_{x6i} = manure cost (Tk/kg),

P_{x7i} = labor cost (Tk/hour),

P_{x8i} = rental cost of land (Tk/ha),

P_{x9i} = production (kg),

β_0 to β_9 = parameters to be estimated,

V_i = statistical disturbance term, and

U_i = farmer-specific characteristics related to cost inefficiency.

The choice of the Cobb–Douglas specification is because the methodology requires the function to be self-dual as in the case of the cost function on which the analysis is based. To examine the determinants of the cost inefficiency, we use the following regression equation.

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \tau_i \quad (3)$$

where

U_i = cost inefficiency scores,

z_{1i} = farm size (ha),

z_{2i} = age of respondent (year),

z_{3i} = tenancy dummy (D = 1 if the farmer is a tenant,

and 0 otherwise),

z_{4i} = education dummy (D = 1 if the respondent is educated to class 6 and above, and 0 otherwise),

z_{5i} = supplementary irrigation dummy (D = 1 if the farmer used supplementary irrigation, and 0 otherwise) (only for wet-season rice), δ_0 to δ_5 = inefficiency parameters, and τ_i = error term.

These socioeconomic variables are included in the model to determine their possible influence on the cost inefficiency of the farms. We test the presence of cost inefficiency using generalized likelihood-ratio statistics, as follows:

$$\lambda = -\ln\left(\frac{H_0}{H_A}\right) \quad (4)$$

Where H_0 is the value-of-likelihood function in which parameter restriction specified by the null hypothesis, H_0 is imposed, and H_A is the value of the likelihood functions for the general frontier model.

The maximum-likelihood (ML) estimates of the parameters of the stochastic frontier cost function and inefficiency model were obtained using STATA software in two stages. In the first stage, the inefficiency evidence is tested. If evidence of inefficiency is not found, the frontier cost function becomes an ordinary least squares cost function. If there is evidence of cost inefficiency, in the second stage, the inefficiency is regressed on socioeconomic variables to explore the relationship among those variables and the cost efficiency. These two stages of estimation are performed in a single step. The single step estimation of the parameters of equations (2) and (3) are conducted using the aforementioned software.

The results of the Cobb–Douglas stochastic frontier cost function estimated with heteroscedasticity are presented in Table 3. The frontier model allows heteroscedasticity in either error term as a linear function of a set of covariates. We specify covariates for both variance of U_i and V_i . The component of inefficiency and the statistical disturbance term are heteroscedastic (Kumbhakar and Lovell, 2000; Greene, 2005) in Antriyandarti (2015).

The coefficient for cost of seed was significant and

positive, both in the dry and wet seasons, implying that if the cost of seed increases, then the total cost of production would increase substantially. The coefficients of mechanical plowing, chemical fertilizer, labor, and land rent are significantly positive, both in the dry and wet seasons. The coefficient for irrigation cost is significantly positive for dry-season rice farms in Bangladesh, indicating that an increase in irrigation cost would reasonably increase the total cost of production. However, the estimated coefficients of pesticide and insecticide cost, both in the dry and wet seasons, are significantly negative. These results imply that if farmers use better/high-quality pesticides & insecticides, then they could achieve high yields by which the unit cost would decrease.

Similar implications are applicable to the case of manure cost, since the estimated coefficient for manure is also significantly negative. The coefficient of production is significantly positive for both dry- and wet-season rice, implying that an increase in production would reasonably increase the total cost.

However, the estimated results are in line with the theoretical background and are consistent with prior expectations. The results of efficiency analysis show that the mean cost efficiency of rice-producing farms is 0.912 and 0.815 for the dry and wet seasons in Bangladesh, respectively. These findings indicate that rice-producing farms in the dry and wet seasons in Bangladesh are highly cost efficient.

(2) Cost inefficiency analysis

The results of the inefficiency model are depicted in Table 3. The estimated coefficients for different variables included in the inefficiency model show important implications for the cost efficiency of rice production in Bangladesh. The coefficient for farm size is negative and significant, implying that the cost inefficiency of rice-producing farms in the dry season would decrease with the increase in farm size in Bangladesh. Conversely, the coefficient for this variable is positive in the case of wet-season rice production, implying that cost inefficiency would hardly decrease with the increase in farm size.

Table 3. Estimates of Cobb–Douglas frontier cost function of rice-producing farms under dry and wet seasons in Bangladesh

Name of variable	Dry season		Wet season	
	Coefficients ¹⁾	SE	Coefficients ¹⁾	SE
Seed cost (Tk/kg)	0.0644***	0.0025247	0.1007***	0.0080035
Mech. plowing cost (Tk/kg)	0.1752***	0.0049154	0.1215***	0.0135465
Chem. fertilizer cost (Tk/kg)	0.0451***	0.0047858	0.0854***	0.0100231
Irrigation cost (Tk/ha)	0.1555***	0.0045851	—	—
Pesticide and insecticide cost (Tk/kg)	−0.0307***	0.0023728	−0.0611***	0.0069183
Manure cost (Tk/kg)	−0.0054 ^{NS}	0.0041962	−0.0470***	0.0090762
Labor cost (Tk/hour)	0.0925***	0.0095734	0.1386***	0.0238178
Land rent cost (Tk/ha)	0.2206***	0.0116232	0.3581***	0.0269531
Production (Kg)	0.3253***	0.0085819	0.3498***	0.0199715
Constant	4.3721***	0.142221	3.8432***	0.3238543
Mean cost efficiency		0.912		0.815
Inefficiency variables:				
Farm size (ha)	−0.2223***	0.0741192	0.294***	0.0789784
Age of respondent (year)	0.0023 ^{NS}	0.0026883	−0.0043 ^{NS}	0.0033628
Tenancy dummy	−0.2094***	0.0770191	−0.0531 ^{NS}	0.0885919
Education dummy (6 class and above)	0.1155 ^{NS}	0.0758884	0.0046 ^{NS}	0.0901306
Supplementary irrigation dummy	—	—	−0.4241***	0.089318
Constant	−4.33408***	0.2274818	−3.8413***	0.1939462
Diagnostic statistics:				
Log likelihood		4472.745		502.386
Sigma v-square (σ_v^2)	−4.7059***	0.0780671	−3.7787***	0.0743427
Sigma u-square (σ_u^2)	−4.2661***	0.145558	−2.7653***	0.085942
Lamda ($\lambda = \sigma_u/\sigma_v$)	1.2459	0.0121665	1.6598	0.0157403
Likelihood ratio test $H_0: \sigma_u^2 = 0$		25.07***		65.33***
Number of observations		6,243		3,740

Source: BIHS data (2011–12).

1) *** indicates significance at the 1% level of probability and NS = not significant.

Although the positive sign here looks unexpected, it can be explained logically. Wet-season (*aman*) rice is a completely rain-fed crop, and farmers face different natural calamities in most of the years, leading to rice production risk. Moreover, nearly 30% of the wet-season rice area is devoted to growing indigenous/traditional rice varieties with low yield potentiality. Second, wet-season rice is less input-intensive; as a

nature-dependent crop, enhancement in per-unit productivity is hardly feasible. Producers' efficiency is quite unlikely to increase in the case of wet-season rice cultivation. The estimated coefficient for tenancy dummy is negative and highly significant, implying that if the tenurial arrangement (tenant farmers) for dry-season rice production increases, then producers' inefficiency would decrease substantially. The coef-

Table 4. Estimated linear regression models of rice-producing farms in Bangladesh

Variables	Dry season		Wet season	
	Coefficient ¹⁾	SE	Coefficient ¹⁾	SE
Cost efficiency (CE)	-3.7062***	0.1195553	-1.8761***	0.0998533
Barisal divisional dummy	-0.0999***	0.0278439	-0.2998***	0.0662408
Rajshahi divisional dummy	-0.2282***	0.0204611	-0.3685***	0.0476924
Dhaka divisional dummy	-0.0505***	0.0188758	0.1017**	0.0472965
Khulna divisional dummy	-0.1373***	0.0209894	-0.3995***	0.0491704
Chittagong divisional dummy	0.0346 ^{NS}	0.025135	-0.1636***	0.0614535
Rangpur divisional dummy	-0.2030***	0.0233383	-0.3244***	0.0511663
Constant	-0.5843***	0.0193921	-0.1078**	0.045625
F value		174.68***		91.97***
R ²		0.164		0.147
Number of Observations		6,243		3,740

Source: BIHS data (2011–12).

1) *** and ** indicate significance at the 1% and 5% levels of probability, respectively and NS = not significant.

ficient for supplementary irrigation is negative and highly significant, implying that if the level of supplementary irrigation for wet-season rice production increases, then producers' inefficiency would decrease substantially.

5. Estimation of impact of cost efficiency on domestic resource cost

To estimate the relationship between the cost efficiency of rice-producing farms and global competitiveness, this study applies the following multiple linear regression analysis approach:

$$\ln DRC_i = \beta_0 + \beta_1 \ln CE_i + \beta_2 D_{1i} + \beta_3 D_{2i} + \beta_4 D_{3i} + \beta_5 D_{4i} + \beta_6 D_{5i} + \beta_7 D_{6i} + e_i \quad (5)$$

where

DRC_i = domestic resource cost of i -th farms,

CE_i = cost efficiency of i -th farms,

D_{1i} = Barisal divisional dummy of i -th farms,

D_{2i} = Rajshahi divisional dummy of i -th farms,

D_{3i} = Dhaka divisional dummy of i -th farms,

D_{4i} = Khulna divisional dummy of i -th farms,

D_{5i} = Chittagong divisional dummy of i -th farms,

D_{6i} = Rangpur divisional dummy of i -th farms, taking Sylhet division as the base,

β_0 to β_7 are the parameters to be estimated, and e_i = error term in i -th farms.

Here, we use DRC as an indicator of global competitiveness, as suggested by Bruno (1972). To estimate the relationship between the competitiveness of rice production and cost efficiency of rice farms, this study applies regression analysis with the help of a multiple linear regression model. The analysis showed that cost efficiency could negatively influence the DRC value for both the dry- and wet-season rice production, which was significant at the 1% level of probability. If the cost efficiency increases by 10%, DRC would decrease by 37.1% in the dry season and 18.8% in the wet season (Table 4). Conversely, almost all divisions have global competitiveness for rice production, except for Chittagong in the dry season and Dhaka in the wet season. Overall, Bangladesh has the opportunity to increase the cost efficiency of rice-producing farms, which would eventually help accelerate global competitiveness.

6. Conclusions and recommendations

Based on the abovementioned findings, the following conclusions can be drawn. The DRC values indicate that Bangladesh has comparative advantage in import substitution of HYV rice production in the dry season. The estimated DRC values are less than 1, either without subsidy (0.80) or with subsidy on chemical fertilizers (0.72). In the case of the wet season, the DRC values for HYV rice production are more than 1, indicating that Bangladesh has no comparative advantage at import substitution either without or with fertilizer subsidy. Bangladesh has overall comparative advantage of rice production, both in dry- and wet-season rice production under the same piece of land, at import substitution of subsidized price of chemical fertilizers.

It is observed that cost inefficiency prevails among rice farms, both in the dry and wet seasons in Bangladesh. The estimated mean cost efficiency is 0.912 and 0.815 for the dry and wet seasons, respectively, indicating that rice production in these seasons would be highly cost efficient. Production cost is positively influenced by the input prices, especially labor cost, land rent, irrigation cost, and mechanical plowing costs. Therefore, reduction of these costs would be more effective in decreasing the cost of rice production. Moreover, farm size, tenancy arrangement (land renting) in the dry season, and supplementary irrigation in the wet season could increase cost efficiency of rice-producing farms in Bangladesh.

Results of multiple linear regression revealed that cost efficiency reduces the DRC values negatively and significantly both in the dry and wet seasons. In addition, all divisions had global competitiveness for rice production, except the Chittagong division in the dry season and the Dhaka division in the wet season. Moreover, Bangladesh has an opportunity to increase cost efficiency in rice-production to increase global competitiveness by gradually reducing input subsidy.

The following policy implications can be drawn in relation to accelerating comparative advantage in rice

production.

a) To achieve comparative advantage in Bangladesh, the government needs to put into practice policy options that aim not only to increase cost efficiency but also to help rice farmers to undertake proper crop husbandry to boost the level of productivity.

b) The potential yield of rice varieties should be increased focusing on environmental issues, particularly the issue of climate change which is relevant to rice farming activity in Bangladesh. In addition, new cropping patterns should be developed and disseminated to the end users to increase productivity.

c) To improve cost efficiency, the government should expand irrigation facilities both in the dry and wet seasons aiming to enhance the level of productivity.

d) In a situation of self-sufficiency in rice, a change in input subsidy could be considered through adopting the gradual reduction process that could be compensated partly by increasing the cost efficiency of rice-producing farms in Bangladesh.

A limitation of this study is that while Bangladesh rice has comparative advantage in the short-run, owing to the unavailability of time series costs and return data, it is difficult to judge the results of the research in the long-run.

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Notes

¹ Broadcast *aman* rice is otherwise known as deep-water rice in Bangladesh. Broadcast *aman* (B. aman) rice is direct seeded under dry-land preparation during the pre-monsoon period (March–April) in the low lying/deep-water areas (1–6 meter deep). Photoperiod sensitive indigenous/traditional rice

varieties are used for cultivation. B. *aman* rice is harvested during October–December. This method is not common throughout Bangladesh; the area under this rice cultivation is very limited.

² Although the costs of machinery, pesticides and insecticides are considered as tradable inputs, in Bangladesh, no comprehensive dataset exists to calculate border or import parity price for these inputs at farmers' level. Therefore, in our study, we use market price as a border parity price.

³ Irrigation equipment is considered a non-traded intermediate input because detailed costs for irrigation equipment are unavailable. This input cost is collected through field survey.

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Appendix

Table A1. Calculation of import-parity border prices of chemical fertilizers and rice

Items	Urea	TSP	MoP	Rice
A. CIF price at Chittagong (US \$/ton)	410.78	516.08	380.90	520
B. CIF price at Chittagong (Tk/ton)	29235.21	36729.41	27108.65	37008.4
C. Domestic handling cost (from port to wholesale) (Tk/ton)	2441.06	2441.06	2441.06	2278.36
D. Border price at wholesale level (B + C) (Tk/ton)	31676.27	39170.47	29549.71	39286.76
E. Domestic handling cost (from wholesale to farmer) (Tk/ton)	485.68	564.10	564.10	19440.54 ¹⁾
F. Border price of farm produce at farm gate (D + E) (Tk/ton)	32161.95	39734.57	30113.81	19846.22 ²⁾

Source: Adopted from Kazal et al. (2013).

1) Marketing spread between wholesale market and production level.

2) Border price of farm product at farm gate (D–E).

3) 1 US dollar = average 71.17 Bangladeshi taka.