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Original Article

Assessing the Level of Comparative Advantage for the *Boro* Rice Production in Bangladesh: A Time Series Analysis

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ABSTRACT

This study aims to investigate whether Bangladesh has a comparative advantage in producing rice in the long run for the *Boro* season. With that view, we estimated "Domestic Resource Cost (DRC)" as an indicator of comparative advantage using the time series data. Data were obtained from the food situation database, published by the Food Planning and Monitoring Unit, Ministry of Food, Peoples' Republic of Bangladesh. The analyses show that Bangladesh has a comparative advantage in modern rice production in the *Boro* season at import substitution. DRC values for *Boro* season are less than 1 in all the periods (2010/11 to 2019/20) except 2018/19. The sensitivity analysis shows that all the indicators pertinent to this particular analysis strongly influence DRC values. The government and policymakers should focus on price spread between the wholesale to retail levels, the border price of rice at the farm gate level, and the border prices of rice, urea, TSP, and MoP of farm gate level to achieve a long-run comparative advantage. Research efforts need to be prioritized for developing new varieties, especially for the *Boro* season with higher yield potential.

Introduction

Agriculture is the mainstay of the Bangladesh economy, while rice is considered the most important food crop (Islam et al., 2020; Rahaman et al., 2020a; Siddique et al., 2017; Rahman et al., 2015). More than three-fourths of the country's total cropped land is devoted to rice production, contributing more than 83 percent of the total cereal food supply (FPMU, 2020; Rahaman et al., 2020b). Bangladesh agriculture is now transforming from a traditional to a modern system. However, in this transformation process, the rice sector has the most strategic importance, as it is the staple food source for the whole population and the primary source of livelihood for 16 million farm households (Kazal et al., 2013; Rahaman et al., 2020c). Hence it became a key to the political economy of Bangladesh (Rahman et al., 2020). The dominant issue affecting the rice sector is the inflexibility of collaborating resources in production activities. Official available statistics show that food grain demand in Bangladesh in 2006/07 FY (Financial Year) 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 rice supply in 2019/20 FY increased to 36.61 million tons while the food grain demand for the corresponding period was 32.00 million tons, indicating that domestic net supply is higher than the total food grain demand in Bangladesh (FPMU, 2020). Currently, domestic production of rice is considered sufficient even surplus to meet the existing demand having policies to achieve self-sufficiency in food grain supply. These policies, however, include fertilizer subsidies and price support programs. After achieving food self-sufficiency, the government's major concern is to maintain stability in food prices, which relates to the costs of production and behavior of price transmission and market integration across the horizontal and

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vertical movement of the supply chain (Rahman, 2018). The production costs associated with the subsidization policy for agricultural inputs and ensuring fair price at the farm-gate are much influenced by the minimum price support/procurement policy of farmers' food crops. Foreign donors and international aid agencies have criticized implementing these policies because they are subversive to the economy's rationalization and market (Ahmed et al., 2009). The world is like a global village, and the increasing domestic production costs emphasize import with proper justifications, although import is not always possible even with offering higher prices. Bangladesh experienced the difficulties of agricultural import in the 2008 food crisis, and the world faced it during the COVID-19 pandemic in 2020. Therefore, the importance of subsidizing domestic production over import decisions is not only a single matter of analysis. Before deciding on agricultural input subsidies and/or incentives, as one of the ways of investigation, it is essential to justify whether input subsidized domestic production is worthy, or importation is better. To do this, one of the economic tools is to assess the comparative advantage at import substitution.

Several studies have been conducted to investigate the effectiveness of rice farming in Bangladesh. Shahabuddin et al. (2002) examined rice's comparative advantage using two indicators: net economic profitability and the domestic resource cost (DRC) ratio. They suggested that Bangladesh had a comparative advantage in the production of rice in the *Boro* season. In another study, Rashid (2009) concluded that Bangladesh had a comparative advantage in rice production, as the DRC ratio estimates were less than 1 in all the years under investigation. Besides, Kazal et al. (2013) and Miah et al. (2013) concluded that Bangladesh rice had a comparative advantage in *Boro* rice production at import substitution. Islam (2016) examined the comparative advantage of rice production using the DRC ratio. He found that Bangladesh had a comparative advantage at import substitution of high yielding variety (HYV) rice production in the *Boro* (dry) season with and without input subsidy. However, in the wet season, Bangladesh did not have a comparative advantage at import substitution either without or with fertilizer subsidization. Bangladesh had the overall comparative advantage of rice production, both in the dry and wet season under the same piece of land, at import substitution of the subsidized price of chemical fertilizers.

However, some earlier studies' findings remain controversial on whether there is a comparative advantage in *Boro* season rice production in Bangladesh but in the short run. The studies mentioned above only used cross-sectional data to know comparative advantage in the short run. For achieving sustainable rice production, it is essential to investigate whether Bangladesh has a comparative advantage in *Boro* season rice production over the long run at import substitution. Given this scope, this study is expected to make two significant contributions. First, this study maybe the first of its kind that used costs and returns time-series data of Bangladesh in the estimation. *Second*, most of the studies considered only urea, TSP, and MoP as tradable inputs. Additionally, we considered seed cost, pesticide cost, and machinery equipment cost along with urea, TSP, and MoP as tradable inputs. Further, we showed how different input prices and output levels would influence *Boro* season rice production's comparative advantage using a sensitivity analysis. These results will help policymakers to adjust the input subsidy and output decision for estimating the long-run comparative advantage of *Boro* season rice production in Bangladesh.

Methodology

Data

This study used time-series data. Required data obtained from the database on food situation published by Food Planning and Monitoring Unit (FPMU), Ministry of Food, Peoples' Republic of Bangladesh. FPMU published costs of production data for supporting minimum/floor prices of different crops cultivated in Bangladesh. This study used the time series data covering 2010-11 to 2019-20 on rice production costs and return for the *Boro* season. Also, from different secondary sources, the time series data of Free on Board (FOB) and Cost, Insurance and Freight (CIF) price of rice, urea, TSP, and MoP were collected (Table 1). Data modification and filtering are performed to ensure that each variable's measurement is consistent with the study objectives and the quality of data is satisfactory. Rice production in Bangladesh is divided into three distinct seasons [namely, *Aus* (pre-monsoon season), wet *(Aman)* season, and dry (*Boro)* season]. For this study, we use only HYV rice data in the *Boro* season to achieve the set objectives.

Table 1. Selected FOB and CIF price and source

Commodity	FOB/CIF	Source
Rice (Thai 5% broken)	FOB	Food Outlook, 2020, FPMU, 2020
Urea (Ukraine)	FOB	Economic trend, Bangladesh Bank, 2020
TSP (US Gulf port)	FOB	Economic trend, Bangladesh Bank, 2020
MoP (Morocco)	FOB	Economic trend, Bangladesh Bank, 2020

The comparative advantage of rice-producing farms in Bangladesh

Different methods are useful in estimating the economic profitability of specific crops. In this study, the DRC ratio is used to measure the comparative advantage of modern variety (MV) rice production in Bangladesh at import substitution.

Data requirement for calculating DRC

This study has heavily borrowed the methodology of DRC from Islam (2016). A comprehensive dataset is needed to estimate the DRC. The desired information required for constructing the DRC includes inputs, outputs, market, and social prices. For this study, we used time-series data on costs and return of MV *Boro* rice production. Similarly, published and unpublished secondary data from different national and international sources were also used. Inputs are divided into two categories: (1) traded intermediate inputs, and (2) non-traded intermediate inputs.

Traded intermediate inputs

Traded intermediate inputs are either imported or exported. In Bangladesh, different fertilizers (i.e., Urea, TSP, and MoP), seeds, insecticides/pesticides, and machinery are usually used for rice production. Here, we consider these as traded intermediate inputs. The costs of tradable inputs are measured by border/import parity price. Although the costs of machinery, pesticides, and insecticides are considered tradable inputs, no comprehensive dataset is available to calculate border or import parity prices for these inputs at the farmers' level. Therefore, in our study, we used market price as a border parity price.

Use of shadow price for seed

The shadow price of seed is calculated by applying a well-adopted formula that has been used in the relevant analysis by Antriyandarti et al. (2012); Antriyandarti (2015) and Islam (2016). The formula is as follows:

Shadow seed price = {(Actual seed cost/Actual output) × Shadow output price}

The detailed calculations of the import-parity border price of fertilizers and rice are presented in Tables 2 to 5.

Non-traded intermediate inputs

Unskilled agricultural labor, manure, land rent, and interest on operating capital are considered non-traded intermediate inputs and domestic resources because these components of production do not usually enter the international market. Irrigation equipment is regarded as a non-traded intermediate input because detailed costs for irrigation equipment are unavailable. The fees of these inputs were collected from secondary sources (FPMU, 2020). The specific conversion factors are used for the social valuation of these costs and prices of non-tradable inputs. We use particular conversion factors of 0.75 for human labor and 0.86 for irrigation charges to construct a social budget. However, manure and land rent costs are used as full social costs in this study (Shahabuddin and Dorosh, 2002; BRF, 2005; Kazal et al., 2013; Islam, 2016). The opportunity cost of operating capital is calculated at 9% interest for five months of the Boro season's rice production period. The payments for non-traded intermediate inputs and domestic resources are converted from a measurement of "*per unit of the land*" to "*per unit of output*." Methodologically, these items are valued considering their opportunity costs. In Bangladesh, factor markets are reasonably competitive, and thus, payment for non-traded intermediate inputs and domestic resources represent the opportunity costs of these resources.

Estimation of domestic resource cost (DRC)

This subsection describes the methodology of estimating the global comparative advantage of MV rice production in Bangladesh. As such, we use DRC as an indicator of international competitiveness, as Bruno (1972) suggested. 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 through domestically producing the good. DRC measures whether a commodity is more profitable when produced domestically or importation is economical. DRC < 1 indicates that the commodity is more profitable when produced domestically; meanwhile, DRC > 1 suggests 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 in the *Boro* season and is estimated by using the following equation:

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

Where i = i^{th} farms, j = 1, ..., k are the traded inputs, j = k+1, …, 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_i^b is the traded outputs border price, 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.

Table 2. Calculation of import parity border prices of *Boro* season clean rice in Bangladesh from 2010-11 to 2019-20

Items	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
FOB. price at port of exit (US$[1]/mt)	522.00	587.00	568.00	450.00	411.00	375.00	390.00	412.00	383.00	435.00
Freight charge (US$/mt)	50.00	53.12	56.31	59.41	62.35	66.41	70.74	75.30	80.12	85.25
Off. Exchange rate (1 US$=Tk.)	71.17	79.10	79.93	77.72	77.67	78.26	79.12	82.10	84.02	84.78
A. CIF price at Chattogram US$/mt	572.00	640.12	624.31	509.41	473.35	441.41	460.74	487.30	463.12	520.25
B. CIF price at port of entry (Tk./mt)	40710.33	50631.12	49902.72	39592.26	36766.88	34546.38	36452.98	40007.77	38911.71	44106.80
C. Marketing margin from the port of entry to wholesale market (Tk./mt)	2278.36	2476.24	2644.14	2838.38	3020.26	3198.93	3372.94	3567.91	3763.32	3656.16
Import handling cost (Tk./mt)	1110.25	1206.68	1288.50	1383.15	1471.78	1558.85	1643.64	1738.65	1833.87	1695.00
Transport cost (Tk./mt)	1016.00	1104.24	1179.12	1265.73	1346.84	1426.51	1504.11	1591.06	1678.19	1731.16
Domestic trading cost (Tk./mt)	152.11	165.32	176.53	189.50	201.64	213.57	225.19	238.20	251.25	230.00
D. Border price at wholesale (Tk./mt) (B+C)	42988.69	53107.36	52546.86	42430.65	39787.14	37745.31	39825.93	43575.68	42675.03	47762.96
E. Component of marketing spread between the wholesale market to the product level (Tk./mt)	11682.70	12118.90	12869.19	13198.68	13698.11	14374.07	15225.69	17669.99	18186.80	18523.01
Cost from millgate to wholesale (Tk./mt)	994.25	1080.60	1153.87	1238.64	1318.01	1395.98	1471.91	1557.00	1642.27	1504.00
Milling cost (Tk./mt)	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	2000.00	2000.00	2037.50
Adjustment at 66% of milling cost (Tk./mt)	7983.20	8251.80	8840.00	9010.00	9350.00	9860.00	10540.00	12240.00	12586.80	12913.20
Interest cost (Tk./mt)	440.25	455.06	487.50	497.00	516.00	544.00	581.25	675.00	694.13	733.34
Cost from farm gate to mill gate (Tk./mt)	765.00	831.44	887.82	953.04	1014.10	1074.10	1132.53	1197.99	1263.60	1334.98
F. Border price at farmgate (Tk./mt) (D-E)	31305.99	40988.46	39677.67	29231.97	26089.03	23371.24	24600.24	25905.70	24488.23	29239.94
Clean rice price (Tk./kg)	31.31	40.99	39.68	29.23	26.09	23.37	24.60	25.91	24.49	29.24

Source: Authors' estimation based on data from FPMU database and Bangladesh Bank.

Table 3. Calculation of import parity border prices of urea fertilizer in Bangladesh from 2010-11 to 2019-20

Items	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
A. FOB price at port of exit (US$/mt)	288.59	420.96	405.40	340.12	316.00	272.92	199.00	221.40	261.08	228.55
B. Freight charge (US$/mt)	50.00	53.12	56.31	59.41	62.35	66.41	70.74	75.30	80.12	85.25
C. Off. Exchange rate (1 US$= Tk.)	71.17	79.10	79.93	77.72	77.67	78.26	79.12	82.10	84.02	84.78
D. CIF price at port of entry (Tk./mt)	24098.09	37497.97	36905.68	31052.19	29387.80	26557.22	21341.22	24359.34	28667.48	26604.03
E. Domestic handling cost (from port to wholesale) (Tk./mt)	2441.06	2653.07	2832.96	3041.08	3235.94	3427.37	3613.81	3822.70	4032.06	4259.81
F. Border price at wholesale (Tk./mt) (D+E)	26539.15	40151.04	39738.64	34093.27	32623.73	29984.59	24955.03	28182.04	32699.54	30863.84
G. Domestic handling cost (Cost from farmgate to wholesale) (Tk./mt)	485.68	527.86	563.65	605.06	643.83	681.92	719.01	760.58	802.23	847.54
H. Border price at farmgate (Tk./mt) (F+G)	27024.83	40678.90	40302.30	34698.33	33267.56	30666.51	25674.04	28942.61	33501.77	31711.38
I. Border price at farmgate (Tk./kg)	27.02	40.68	40.30	34.70	33.27	30.67	25.67	28.94	33.50	31.71

Source: Authors' estimation based on data from FPMU database and Bangladesh Bank.

Table 4. Calculation of import parity border prices TSP fertilizer in Bangladesh from 2010-11 to 2019-20

Items	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
A. FOB price at port of exit (US$/mt)	381.89	538.26	462.00	382.06	388.34	385.00	290.00	273.20	344.92	255.28
B. Freight charge (US$/mt)	50.00	53.12	56.31	59.41	62.35	66.41	70.74	75.30	80.12	85.25
C. Off. Exchange rate (1 US$= Tk.)	71.17	79.10	79.93	77.72	77.67	78.26	79.12	82.10	84.02	84.78
D. CIF price at port of entry (Tk./mt)	30738.43	46775.97	41429.87	34311.84	35006.78	35329.02	28541.06	28612.16	35711.92	28870.30
E. Domestic handling cost (from port to wholesale) (Tk./mt)	2441.06	2653.07	2832.96	3041.08	3235.94	3427.37	3613.81	3822.70	4032.06	4259.81
F. Border price at wholesale (Tk./mt) (D+E)	33179.49	49429.04	44262.83	37352.92	38242.71	38756.38	32154.87	32434.86	39743.98	33130.11
G. Domestic handling cost (Cost from farmgate to wholesale) (Tk./mt)	564.10	613.09	654.66	702.76	747.79	792.02	835.11	883.38	931.76	984.39
H. Border price at farmgate (Tk./mt) (F+G)	33743.59	50042.13	44917.49	38055.67	38990.50	39548.41	32989.98	33318.25	40675.74	34114.50
I. Border price at farmgate (Tk./kg)	33.74	50.04	44.92	38.06	38.99	39.55	32.99	33.32	40.68	34.11

Source: Authors' estimation based on data from FPMU database and Bangladesh Bank.

[1] 1 US$=84 Taka (15 September 2021)

Table 5. Calculation of import parity border prices of MoP fertilizer in Bangladesh from 2010-11 to 2019-20

Items	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
A. FOB price at port of exit (US$/mt)	368.56	471.31	428.70	345.50	286.32	301.50	220.75	214.81	230.50	249.29
B. Freight charge (US$/mt)	50.00	53.12	56.31	59.41	62.35	66.41	70.74	75.30	80.12	85.25
C. Off. Exchange rate (1 US$= Tk.)	71.17	79.10	79.93	77.72	77.67	78.26	79.12	82.10	84.02	84.78
D. CIF price at port of entry (Tk./mt)	29789.65	41480.67	38768.44	31470.33	27082.03	28794.00	23062.06	23818.50	26098.54	28362.81
E. Domestic handling cost (from port to wholesale) (Tk./mt)	2441.06	2653.07	2832.96	3041.08	3235.94	3427.37	3613.81	3822.70	4032.06	4259.81
F. Border price at wholesale (Tk./mt) (D+E)	32230.71	44133.74	41601.41	34511.41	30317.96	32221.37	26675.87	27641.20	30130.60	32622.62
G. Domestic handling cost (Cost from farmgate to wholesale) (Tk./mt)	564.10	613.09	654.66	702.76	747.79	792.02	835.11	883.38	931.76	984.39
H. Border price at farmgate (Tk./mt) (F+G)	32794.81	44746.83	42256.07	35214.17	31065.75	33013.39	27510.98	28524.58	31062.36	33607.02
I. Border price at farmgate (Tk./kg)	32.79	44.75	42.26	35.21	31.07	33.01	27.51	28.52	31.06	33.61

Source: Authors' estimation based on data from FPMU database and Bangladesh Bank.

Sensitivity analysis

The economic profitability analysis discussed in the previous section is a measure of production efficiency. This sort of measure generates static information regarding the comparative advantages of one alternative over another. The static analysis fails to generate information regarding the disadvantaged group. In this case, the sensitivity analysis is essential since the results may differ due to change in resource endowments, production technologies, market forces, and government policies. It may be worthwhile to examine the degree to which the efficiency of DRC measures estimated under the set of baseline assumptions is likely to be affected by changes in key parameters' values.

Assumption 1

Effect of changes in paddy yield increase by 10, 15, and 20% and decrease by 10, 15, and 20%, respectively.

Assumption 2

Marketing spread between the wholesale and retail levels increases by 10 and 20% and decreases by 10 and 20%, respectively.

Assumption 3

Border rice prices at the farm gate level increase by 10, 20, and 30% and decrease by 10, 20, and 30%, respectively.

Assumption 4

Border prices of rice, Urea, TSP, and MoP at the farm gate level increase by 10, 20, and 30% and decrease by 10, 20, and 30%, respectively.

Assumption 5

Border prices of Urea, TSP, and MoP at the farm gate level increase by 10, 20, and 30% and decrease by 10, 20, and 30%, respectively.

Results and Discussion

Boro season

The results of estimated DRC values from 2010-11 to 2019-20 are presented in Table 6 for the *Boro* season in Bangladesh. DRC values are less than 1 in all the periods except 2018-19. The estimated DRC values reveal that Bangladesh has a comparative advantage at import substitution of HYV rice production in the *Boro* season. These results are in line 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 is the high prices of rice in the international market and the higher per unit yield of rice in Bangladesh.

Furthermore, the present results indicate that the value of domestic resources used in producing per ton of *Boro* season rice in Bangladesh is less than the import cost. It is said that the adoption of the available modern rice technologies (HYVs) in *Boro* season has already reached a plateau (Alam and Islam, 2013). Therefore, further advancement in the growth of yield and rice supply would require the adoption of newly devolved stress-tolerant varieties in unexploited large stress-prone areas in the country to achieve future food security (access) well as comparative advantage of producing MV rice in *Boro* season. However, the estimated DRC value for 2018-19 is higher than 1, indicating no comparative advantage in the dry season rice production. It might be due to the lower border price of rice and a bit high domestic resources and non-tradable inputs costs, and the unstable rice price in the domestic market.

Table 6. DRC on import parity basis for modern *Boro* season rice production in Bangladesh from 2010-11 to 2019-20

Items	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
A. Total tradable inputs (Tk./mt)	5453.94	6577.77	6679.89	5947.55	5939.09	5738.95	5674.34	6257.58	6857.77	7484.99
Urea	1080.99	1471.36	1457.74	1323.24	1258.02	1159.66	970.87	1064.07	1256.32	1189.18
TSP	599.89	851.78	764.55	645.01	655.30	664.68	554.45	544.42	677.93	639.65
MOP	510.14	666.44	629.35	522.24	456.85	485.49	404.57	407.83	452.99	560.12
Seed	1751.81	2162.65	1977.18	1444.34	1342.03	1202.23	1265.45	1749.44	1720.53	2054.38
Pesticide	400.00	319.15	319.15	317.80	336.13	336.13	378.15	449.35	458.33	750.00
Machinery charge	1111.11	1106.38	1531.91	1694.92	1890.76	1890.76	2100.84	2042.48	2291.67	2291.67
B. Total non-tradable inputs (Tk./mt)	10416.00	11615.32	12262.98	12689.83	14607.98	15123.95	15930.67	17484.07	17912.50	18252.92
Human labor	5333.33	6127.66	6382.98	6610.17	7563.03	8067.23	8571.43	9803.92	10000.00	9843.75
Manure	533.33	638.30	638.30	1016.95	1512.61	1512.61	1680.67	1633.99	1666.67	1666.67
Irrigation	1911.11	2012.77	2378.72	2186.44	2421.01	2421.01	2529.41	2634.80	2759.17	2866.67
Interest on operating capital (IOC)	193.78	283.40	309.79	333.90	380.25	392.02	418.07	551.88	570.00	542.50
Rental value	2444.44	2553.19	2553.19	2542.37	2731.09	2731.09	2731.09	2859.48	2916.67	3333.33
C. Output price (Tk./mt)	31305.99	40988.46	39677.67	29231.97	26089.03	23371.24	24600.24	25905.70	24488.23	29239.94
D. DRC = (B/(C-A)	0.40	0.34	0.37	0.54	0.72	0.86	0.84	0.89	1.02	0.84

Source: Authors' estimation based on data from FPMU database and Bangladesh Bank.

Sensitivity Analysis

The sensitivity analysis is essential since the results might differ due to the changes in resource endowments, the difference in production technologies, market forces, and application of, or variation in government policies. It may be worthwhile to examine the degree to which the estimated efficiency measures under the set of baseline assumptions are likely to be affected by changes in key parameters' values. This section highlights 1) how changes in the paddy yield level, 2) marketing spread between the wholesale market to the retail level, 3) border price of rice at the farm gate, 4) border prices of rice, urea, TSP, and MoP at the farm gate, and 5) border prices of urea, TSP, and MoP at the farm gate in the static situation, which is expected to prevail over the longer run. It will ultimately affect the comparative advantage of rice production in Bangladesh. Figure 1 shows how the comparative advantage of rice production in Bangladesh has been affected by different factors.

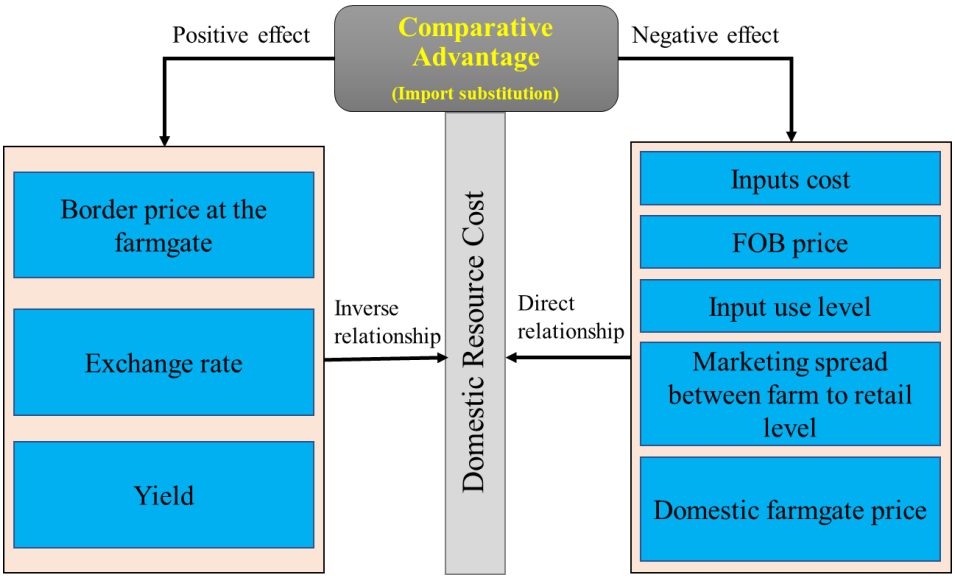

Figure 1. Diagram of different factors showing the positive and negative effects on DRC

Assumption 1: Effect of changes in paddy yield

The scenario of the changes in DRC values due to changes in paddy yield can be viewed in Table 7. We have simulated the changes in paddy yield by increasing 10, 15, and 20%. Similarly, we also tried to see the effect of paddy yield decreases by 10, 15, and 20%. The results show that DRC values are highly sensitive to the changes in paddy yield. When the paddy yield increased by 10, 15, and 20%, all the DRC values have decreased gradually. The level of comparative advantage for

Bangladesh improved in producing MV rice in the *Boro* season at import substitution. A decrease in paddy yield by 10, 15 and 20% would make the domestic rice production inefficient for import substitution for *Boro* season in Bangladesh. The DRC values have gradually increased from the base values, and the country gradually decreased comparative advantage at import substitution in *Boro* season.

Table 7. Effect of changes in *Boro* season paddy yield on DRC in Bangladesh during 2010-11 to 2019-20 (import parity basis)

Indicators	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
10% increased	0.36	0.30	0.33	0.48	0.64	0.75	0.74	0.78	0.89	0.73
15% increased	0.34	0.28	0.31	0.46	0.60	0.71	0.70	0.74	0.83	0.69
20% increased	0.32	0.27	0.30	0.43	0.57	0.67	0.66	0.70	0.79	0.65
10% decreased	0.46	0.39	0.43	0.63	0.84	1.00	0.98	1.04	1.19	0.98
15% decreased	0.50	0.42	0.46	0.68	0.91	1.09	1.06	1.13	1.31	1.07
20% decreased	0.54	0.45	0.50	0.74	1.00	1.19	1.16	1.25	1.46	1.19

Source: Authors' estimation based on data from FPMU database and Bangladesh Bank.

Assumption 2: Effect of changes in marketing spread between farm to the retail level

The impacts of changes in marketing spread of price between the wholesale to retail levels on DRC are presented in Table 8. We have simulated the changes (i.e., increase) in marketing spread of price between the wholesale to retail levels by 10, 15, and 20% and then 10, 15, and 20%decrease. The results show that DRC values are highly sensitive to the marketing spread of price changes between the wholesale and retail levels. An increase in marketing spread of price by 10, 15, and 20% would make the domestic rice production inefficient for import substitution for *Boro* season in Bangladesh. The DRC values increased gradually, previously at the base case in the *Boro* season at import substitution. A decrease in the marketing spread of price by 10, 15, and 20% would make the domestic rice production efficient for import substitution for the *Boro* season in all the years. The DRC values have decreased gradually for the *Boro* season from the base case.

Table 8. Effect of changes in *Boro* season price spread between the wholesale market to retail level on DRC in Bangladesh from 2010-11 to 2019-20 (import parity basis)

Indicators	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
10% increased	0.42	0.35	0.39	0.58	0.77	0.93	0.91	0.97	1.12	0.91
15% increased	0.43	0.36	0.39	0.59	0.80	0.97	0.95	1.02	1.19	0.95
20% increased	0.44	0.36	0.40	0.61	0.83	1.01	0.99	1.07	1.26	1.00
10% decreased	0.39	0.33	0.36	0.52	0.68	0.80	0.78	0.82	0.93	0.78
15% decreased	0.38	0.32	0.35	0.50	0.66	0.77	0.76	0.79	0.89	0.75
20% decreased	0.37	0.32	0.35	0.49	0.64	0.74	0.73	0.76	0.85	0.72

Source: Authors' estimation based on data from FPMU database and Bangladesh Bank.

Assumption 3: Effect of changes of border price of rice at the farm gate

The impact of changes in the border price of rice at the farm gate on DRC is presented in Table 9. We have simulated rice's border price changes at the farm gate by 10 and 20% increases and at 10 and 20%decreases. The results show that DRC values are highly sensitive to rice's border price changes at the farm gate. When the rice's border price at the farm gate increased by 10 and 20%, all DRC values show that the country has a comparative advantage to produce rice at import substitution in the *Boro* season. However, a decrease in rice's border price at the farm gate by 10 and 20% would make the domestic rice production inefficient for import substitution for the *Boro* season. The DRC values show an increasing trend from the base values.

Table 9. Effect of changes in Boro season border price of rice on DRC in Bangladesh from 2010-11 to 2019-20 (import parity basis)

Indicators	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
10% increased	0.36	0.30	0.33	0.49	0.65	0.76	0.75	0.79	0.90	0.75
20% increased	0.33	0.28	0.30	0.44	0.58	0.69	0.68	0.71	0.81	0.67
10% decreased	0.45	0.38	0.42	0.62	0.83	0.98	0.96	1.01	1.17	0.96
20% decreased	0.52	0.44	0.48	0.72	0.96	1.15	1.12	1.18	1.37	1.12

Source: Authors' estimation based on data from FPMU database and Bangladesh Bank.

Assumption 4. Effect of changes in border prices of rice, urea, TSP, and MoP at the farm gate

The impact of changes in border prices of rice, urea, TSP, and MoP at the farm gate on DRC are presented in

Table 10. We have simulated the changes in border prices of rice, urea, TSP, and MoP at the farm gate by 10, 20, and 30% increase and then also at 10, 20, and 30%decrease in the *Boro* season. The results show that DRC values are highly sensitive to the changes in the border price of rice, urea, TSP, and MoP at the farm gate. When the border prices of rice, urea, TSP, and MoP at the farm gate increased by 10, 20, and 30%, all the values of DRC improved gradually. The country has a comparative advantage to produce paddy at import substitution in the *Boro* season at import substitution from the base value. However, a decrease in border prices of rice, urea, TSP, and MoP at the farm gate in the *Boro* season by 10, 20, and 30% would make the domestic rice production inefficient for import substitution for the *Boro* season in Bangladesh. The DRC values show increasing values from the base values.

Table 10. Effect of changes in Boro season border prices of rice, urea, TSP, and MoP on DRC in Bangladesh from 2010-11 to 2019-20 (import parity basis)

Indicators	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
10% increased	0.36	0.31	0.34	0.49	0.65	0.77	0.76	0.80	0.91	0.75
20% increased	0.33	0.28	0.31	0.45	0.59	0.70	0.69	0.73	0.83	0.68
30% increased	0.31	0.26	0.28	0.41	0.54	0.64	0.63	0.67	0.75	0.63
10% decreased	0.45	0.38	0.42	0.61	0.82	0.97	0.95	1.00	1.15	0.95
20% decreased	0.51	0.43	0.47	0.70	0.93	1.11	1.09	1.15	1.32	1.09
30% decreased	0.59	0.49	0.54	0.81	1.09	1.30	1.27	1.34	1.56	1.28

Source: Authors' estimation based on data from FPMU database and Bangladesh Bank.

Assumption 5. Effect of changes in border prices of urea, TSP, and MoP at the farm gate

The impact of changes in the border prices of urea, TSP, and MoP at the farm gate on DRC was estimated, and the results are presented in Table 11. We have simulated the changes in border prices of urea, TSP, and MoP at the farm gate level by 10, 20, and 30% increase and then 10, 20, and 30%decrease in the *Boro* season.

Table 11. Effect of changes in Boro season border prices of urea, TSP, and Mop on DRC in Bangladesh from 2010-11 to 2019-20 (import parity basis)

Indicators	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
10% increased	0.41	0.34	0.37	0.55	0.73	0.87	0.85	0.90	1.03	0.85
20% increased	0.41	0.34	0.38	0.56	0.74	0.88	0.86	0.91	1.04	0.86
30% increased	0.41	0.35	0.38	0.56	0.75	0.89	0.87	0.92	1.06	0.87
10% decreased	0.40	0.33	0.37	0.54	0.72	0.85	0.83	0.88	1.00	0.83
20% decreased	0.40	0.33	0.37	0.53	0.71	0.84	0.82	0.87	0.99	0.82
30% decreased	0.39	0.33	0.36	0.53	0.70	0.83	0.82	0.86	0.98	0.81

Source: Authors' estimation based on data from FPMU database and Bangladesh Bank.

The results show that DRC values are highly sensitive to the changes in the border price of urea, TSP, and MoP at the farm gate level. An increase in the border prices of urea, TSP, and MoP at the farm gate by 10, 20, and 30% increase all the DRC values gradually. The country has decreased the level of comparative advantage in paddy production at import substitution in the *Boro* season. However, a decrease in border prices of urea, TSP, and MoP in the *Boro* season at the farm gate by 10, 20, and 30% would make the domestic rice production efficient for import substitution for the *Boro* seasons in Bangladesh. The DRC values show a decreasing trend from the base value.

Conclusions and Recommendations

The study findings indicate that Bangladesh has a comparative advantage in modern rice production in the *Boro* season at import substitution. The present results further suggest that the value of domestic resources used in producing per ton of MV *Boro* rice in Bangladesh is less than the import cost. It implies that policies focused on attaining self-sufficiency, especially for rice, are economically viable. However, in the year 2018-19, the DRC value is higher than 1, indicating that there was no comparative advantage in the *Boro* season rice production. It might be due to the lower border price of rice, a bit high price of domestic resources and non-tradable inputs, and instability of the domestic rice market.

The sensitivity analysis shows that all the indicators that have been used in this particular analysis strongly influence (both increased and decreased) DRC values. Government and policymakers can concentrate on the market spread between wholesale and retail markets, the border price of rice, urea, TSP, and MoP at the farm gate level to gain a long-run comparative advantage. Besides, rice breeders should emphasize increasing paddy yield in the *Boro* season with new variety. Moreover, a loss minimization strategy at the post-harvest level would effectively increase the national yield of paddy to help to gain a comparative advantage

in rice production.

In accelerating comparative advantage in rice production in the longrun in Bangladesh, the following policy implications can be drawn:

a) There is scope to reduce the per-unit cost of production through increasing the existing rice yield frontier by advanced research and evolving new rice genotypes and crop husbandry. Enhancing crop cultivation in coastal fallow lands in the country's southern belt and increasing cost efficiency in rice production would also be effective measures.

b) There are vast areas under abiotic stresses (e.g., salinity, flash flood, submergence, and drought) (see Rahman et al., 2013). These areas need to be brought under rice production to raise the level of overall productivity. Development and proper dissemination and adoption of stress-tolerant rice varieties (higher-yielding) would help sustain further rice production growth in the country.

c) The marketing spread of price between the wholesale to retail levels has strongly influenced DRC values. Comparative advantage can be achieved for producing rice at import substitution in the long run by reducing price spread between the wholesale to production levels. The government can take initiatives like price support for rice production, remove the illegal costs of transportation, reduce production costs by subsidizing the electricity costs in rice processing, reduce the rice industry's bank interest rate, etc. Moreover, the government can actively participate in the market to reduce the dominant millers' and traders' market power to refrain them from exercising price controlling power to earn excess profit. It will minimize the supply chain's price spread and increase the rice production comparative advantage at import substitution.

d) To increase rice production's competitive advantage and sustain food security in Bangladesh, the government and respective authorities should ensure up-to-date information on input availability and prices, availability of improved varieties, output market prices, and food grain policy.

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Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

Authors' contributions

MAI planned and conceptualized the research, collected data, analyzed data, and drafted the manuscript; MARS gave technical guidance, checked the research methods, and provided an in-depth manuscript review; MCR provides guidance and comprehensive manuscript review; MSR collected data and organized the field activities. All the Authors read and accepted the final manuscript.

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