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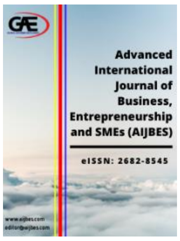

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ASSESSING ECONOMIC IMPACTS AND RETURNS TO INVESTMENT IN *BORO* RICE RESEARCH AND EXTENSION IN BANGLADESH

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Abstract:

This study quantifies the impact and returns on investment from Boro rice breeding research and extension in Bangladesh from 1971 to 2022 using the economic surplus model and project evaluation techniques. The purpose of the study is to assess the economic impact and effectiveness of public investments in rice breeding research and extension, providing insights for future policy and funding decisions. The novelty of this study lies in its comprehensive evaluation over 51 years, applying both closed and open economy perspectives to capture a broader range of benefits and potential savings. Results indicate that rice breeding research generated social benefits of Taka 1236.74 billion in a closed economy and Taka 1199.55 billion in an open economy, saving US$ 40.22 billion in foreign exchange. The investment yielded an estimated net present value (NPV) of Taka 1133.75 billion, an internal rate of return (IRR) of 75%, and a benefit-cost ratio (BCR) of 15. These findings underscore the need for increased public support for agricultural research in Bangladesh. However, benefits primarily accrued to consumers, with producers facing

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losses due to assumptions of a small, open economy and lower demand elasticity compared to supply. The study recommends increased investment in public rice research institutes for R&D and extension programs to achieve food self-sufficiency.

Keywords:

Boro Rice, Rice Research And Extension; Economic Surplus Model; Modern Rice Varieties; Monte-Carlo Simulation; Bangladesh

Introduction

Rice (Oryza sativa) is the principal and staple food of Bangladesh which is cultivated on around 78% (11.42 million hectares) of the country's total farm area (Al Mamun et al., 2021; Nadim et al., 2022) and over 80% of the total irrigated area (J. Shelley et al., 2016). The rice sector contributes 70% of the agricultural Gross Domestic Product (GDP) and one-sixth of the national income in Bangladesh. Almost 16.5 million farm families in the country grow rice (BBS (Bangladesh Bureau of Statistics), 2023). On average, the size of land holding for small, medium and large farmers is 0.13, 1.13 and 2.13 hectares (ha) respectively (BBS, 2023). As a staple food, rice supplies 67.5% of the total calories and 60% of the total protein requirements of the daily food intake (FAO (Food and Agriculture Organization), 2023). Compared to the global average of 57 kg, Bangladeshis consume more than 170 kg of rice per person annually (Shew et al., 2019).

Bangladesh ranks as the third-largest rice producer globally, reaching about 39.1 million tonnes in 2023 (Farhan & Intakhab Ali, 2023). Rice has been cultivated in three overlapping seasons, namely *Boro, Aman,* and *Aus* (Al Mamun et al., 2021). *Boro* is the leading rice production crop, heavily reliant on irrigation and fertilizers, followed by *Aman* and *Aus*. Nevertheless, the share of *Boro* rice in the value chains is relatively higher than that of other two rice (Kabir et al., 2021). Of the three rice types, *Boro* rice alone accounts for 60% of annual rice production and over 52% of Bangladesh's total food grain production (BBS, 2022), which also has a year-round effect on domestic market prices. About 99.2% of the land is planted with high yielding rice varieties during the *Boro* season, of which 67.04% is developed by the Bangladesh Rice Research Institute (BRRI) (Dikitanan et al., 2022). Therefore, it can be said that the *Boro* is a crucial economic food crop for attaining food security in Bangladesh. This crop helped Bangladesh to become a so-called "Bottomless Basket" nation to a "Full Food Basket" (Al Mamun et al., 2021). However, this situation is vulnerable due to the growing population, declining natural resources (cultivable land, labour, water, etc.), and escalating natural threats, such as flash floods, droughts, saline intrusion, cyclones, and storms, among others (Timsina et al., 2018).

The major achievement of the rice research system in Bangladesh, as in other Asian countries, has been the development of improved varieties. Most of the rice varieties released in Bangladesh are from the Bangladesh Rice Research Institute (BRRI) and the Bangladesh Institute of Nuclear Agriculture (BINA), where IRRI germplasm is mainly used in the breeding programs. Since 1971, 139 modern high-yielding rice varieties have been developed, with BRRI accounting for about 78% of these, BINA 17%, and public agricultural universities 5% (Rahman & Connor, 2022). The Department of Agricultural Extension (DAE) and Bangladesh Agricultural Research Council (BARC) support these research activities.

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The introduction of IRRI-bred varieties, such as IR8 and IR20, before Bangladesh's independence was pivotal. Collaborative research between BRRI and IRRI since 1973 has led to the development of new rice varieties, focusing on disease resistance and yield improvement. Notable varieties like BRRI dhan29, released in 1994, have significantly boosted yields. BRRI dhan28 and BRRI dhan29 have dominated *Boro* season production, while BR11 and BRRI dhan49 are prevalent in the *Aman* season. As a result, average rice yields in Bangladesh have increased from 1.75 t/ha in the 1970s to 4.57 t/ha in the past decade, transforming Bangladesh from a food-deficit country to one that is self-sufficient in food despite its growing population. However, recent years have seen a slowdown in yield growth rates, highlighting the need for continued investment in rice R&D (Dikitanan et al., 2022).

Public spending on agricultural R&D in developing countries, including Bangladesh, remains relatively low. In 2017 and 2016, Bangladesh invested only 0.4% of its agricultural GDP in research. Despite this, investments in rice R&D have been crucial in driving production growth. The introduction of improved rice varieties during the Green Revolution generated substantial economic gains, estimated at USD 10.8 billion annually by the late 1990s in South and Southeast Asia (Dikitanan et al., 2022). However, concerns have emerged regarding the slowing pace of varietal replacement and smaller increases in yield potential since the 1970s (Atlin et al., 2017; Dikitanan et al., 2022). This trend could threaten future food security if it is not addressed. Increased investments in rice breeding research are vital for food security and environmental sustainability. Understanding the impact of past investments is crucial for guiding future efforts.

Several studies have estimated that rice research and development (R&D) has consistently demonstrated high rates of return compared to other agricultural commodities (Akino & Hayami, 1975; Brennan, & Malabayabas, 2011; Deb & Mustafi, 1997; Dikitanan et al., 2022; Flores-Moya et al., 1978; Gill, 1983; Herruzo, 1985). For instance, Fan et al. (2000) found that rice research in China yielded a net present value (NPV) of USD 5.2 billion between 1991 and 2000. In India, similar efforts generated USD 3.6 billion in social benefits, while in the Philippines, Brennan and Malabayabas (2011) estimated an NPV of USD 4.3 billion from 1985 to 2009. Raitzer et al. (2015) concluded that publicly funded rice research produced more social benefits than other types of research funding.

In Bangladesh, several studies have assessed the economic returns of rice R&D. Notable works include those by Gill (1983), Siddiqui (1985), Dey and Evenson (1991), Nagy and Alam (2000), Dey and Mustafi (1997), and more recently, Dikitanan et al. (2022) and Islam et al. (2024). These studies highlight the significant economic impacts of rice research and extension in the country. The most recent study by Islam et al. (2024) who estimated the aggregate distributional social benefits and returns on investment of rice research and extension in Bangladesh during last 50 years. However, few have focused on the distributional impacts between producers and consumers in a specific rice seasons. It is also noted that most of these studies evaluated specific rice varieties developed before the 2000s, except for the work by Dikitanan et al. (2022) and Islam et al. (2024)

According to Alston et al. (1998), the distribution of benefits from agricultural research depends on the elasticities of supply and demand, the nature of supply shifts caused by research, and the functional forms of supply and demand. The price elasticity of demand is crucial in determining whether producers gain a surplus during technological transitions (Akino & Hayami, 1975; Herruzo, 1985; Deb & Mustafi, 1997; Flores-Moya et al., 1978). The

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distribution of surplus between producers and consumers is significantly influenced by whether the economy is open or closed and the presence of international trade (Flores-Moya et al., 1978; Miah et al., 2015).

Studies by Akino and Hayami (1975), Flores et al. (1978), Herruzo (1985), and Deb and Mustafi (1997) have shown that rice research and extension are most beneficial in a closed economy where consumers are the sole beneficiaries and producers are disadvantaged. In an open economy, producers also benefit while consumers continue to enjoy economic welfare and save foreign exchange.

However, to the best of the authors' knowledge no studies to date have estimated social benefits and rates of returns from *Boro* rice, considering all public research and extension costs comprehensively. Therefore, this study aims to quantify the economic impact and returns on investment from *Boro* rice varietal improvement research and extension in Bangladesh using the economic surplus approach from 1971 to 2022.This study seeks to provide information for policy makers, donors, researchers, extension workers, and the public on the contribution and the rate of return of investment in *Boro* rice research and extension in Bangladesh.

Material and Methods

Data

Adoption Data Of Modern High-Yielding Rice

The adoption data of modern Boro rice varieties were collected from the annual household survey of the Bangladesh Rice Research Institute (BRRI), Bangladesh Institute of Nuclear Agriculture (BINA) and the district survey of the Department of Agriculture Extension (DAE).

Rice Production, Prices And Yields Data

The study gathered data on *Boro* rice production, prices, and yields from published and unpublished studies, as well as informal interviews with scientists. The consumer price index (CPI), rice price, and the acreage, output, and yield of modern and local *Boro* rice varieties were all taken from the Bangladesh Bureau of Statistics (BBS) various Statistical Yearbooks (1971–2022). Prices for the middle-income group were adjusted to the 2020/21 constant prices using the Bangladesh CPI.

Demand And Supply Elasticities

The demand and supply elasticities were chosen after reviewing relevant previous studies conducted in Bangladesh between 1971 and 2022. The average value of demand elasticity was estimated at -0.45 from the studies of Alamgir and Berlage (1973), Ahmed and Shams (1994), Begum and Luc D'Haese (2010), Alam et al.(2011), Hossain and Younus (2016), and Siddique et al. (2020). On the other hand, the average supply elasticity of rice was estimated at 0.48 from the following studies by Alam (1992), Deb and Mustafi (1997) and Dorosh et al. (2001) in Bangladesh. This study estimated the demand elasticity of rice under an open economy at -1.00 based on studies such as Kumar et al. (2011), Siddique et al. (2020), and Yeong-Sheng et al. (2009).

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Economic Surplus Model (ESM): A Theoretical Concept

Akino and Hayami (1975) established a model that evaluated consumer and producer surplus by assuming a pivotal shift in the supply curve and regarded the supply function movement as a horizontal shift. The economic surplus concept was used to assess economic well-being and the effects of policies and other interventions on economic well-being (Alston et al., 1998). The concept is commonly employed to measure the benefits of adopting improved varieties. Consumer and producer gains make up the economic surplus. Figure 1 depicts consumer surplus as Area P_aP_nB under initial conditions (i.e., pre-research supply curve S_n and demand curve D). This is the surplus or benefit that a well-functioning market provides to consumers. A consumer surplus is the area beneath the demand curve, minus the consumption cost. The consumption cost is defined as the region below the pricing line, P_n.

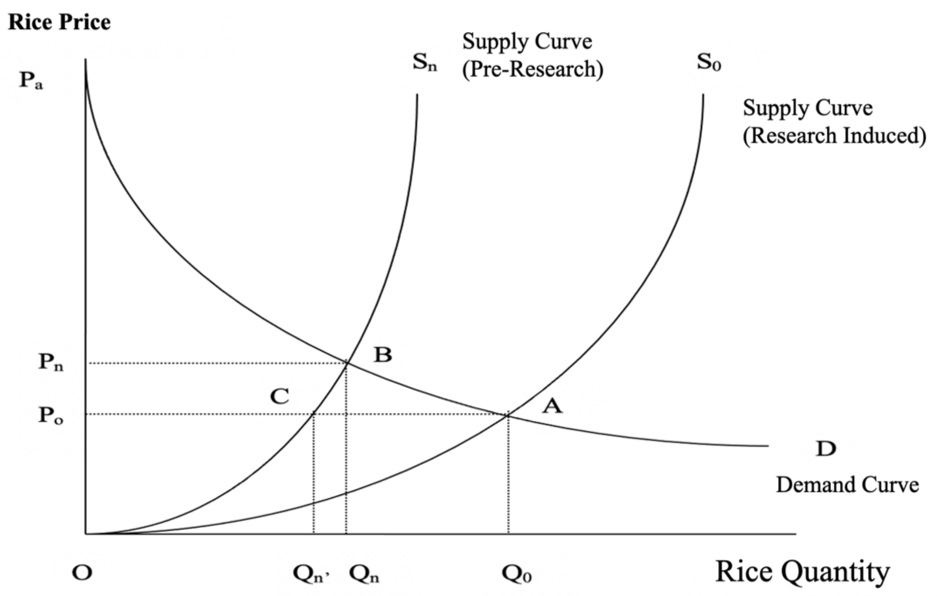

Figure 1 Model of Estimating Social Benefits to Rice Research and Extension (*Closed Economy*)

Source: Akino and Hayami (1975)

The producer surplus depicted by the area P_nBO in Figure 1 represents the excess after farmers have paid all of their production costs, whereas the area OBQ_n is the area left over after they have paid all of their production costs (Alston et al., 1998). Farmers who adopt an intervention, such as an improved variety, typically indicate one of two things: (i) they can produce more of the commodity with the same number of resources (i.e., land area and other inputs); or (ii) they can produce the same number of commodity output with fewer resources. In either instance, a shift to the right of the supply curve is indicated, as seen in Figure 1 (the shift from S_n to S_o). The shift in the supply curve caused by the adoption of an intervention also shifts the commodity's initial equilibrium price and quantity. The discrepancy in economic surplus between the pre-research and post-research periods is used to estimate the new price quantity equilibrium economic surplus (economic benefits).

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The change in consumer surplus as a consequence of a shift in the supply curve from S_n to S_o is depicted in Figure 1 as the Area ABC + Area P_nBCP_0. Changes in the supply curve reduce the price of the commodity that is now available to buy. Figure 1 also shows a change in producer surplus as Area OAC–Area P_nBCP_o when the supply curve moves from S_n to S_o. The reduced cost of production of the same unit product that farmers enjoy as a result of the intervention is known as Area OAC. This shows the monetary value of the benefits to the farmers as a result of implementing the intervention. The adoption of the intervention, on the other hand, increased the quantity produced, dropping the commodity's price (P_n to P_o) and decreasing farmers' revenue. Farmers recover some of their losses by selling larger amounts of the commodity (Q_n to Q_o). Nevertheless, the reduced price indicates that farmers have lost the same amount as the Area P_nBCP_o. If the area of OAC is greater than the Area P_nBCP_o, farmers collectively benefit from the adoption of an intervention, and the Area P_nBCP_o may be bigger under certain circumstances. The size of the two areas is measured by the elasticities of supply and demand curves, as well as the type of the supply curve shift.

The sum of the change in consumer surplus, in addition to the change in producer surplus i.e., (Area ABC + Area BP_nP_0C) + (Area OAC-Area BP_nP_0C) = Area ABC + Area OAC is the total social gains to society as a result of the new interventions (Alston et al., 1998). Thus, we may write the equation as:

Change in Consumers Surplus (ΔCS)	= Area P_nBCP_o + Area ABC
Change in Producers Surplus (ΔPS)	= Area OAC – Area P_nBCP_o.
Change in Total Social Surplus (ΔTS)	= Area P_nBCP_o + Area ABC + Area OAC – Area P_nBCP_o.
	= Area ABC + Area OAC
	= Area OAB

The estimated price elasticity of demand is employed in the preceding formulas for a closed economy model. A sufficiently large number of studies, such as Deb and Mustafi (1997), Flores-Moya et al. (1978), Herruzo (1985), and Miah et al. (2015) are utilized in a small open-economy model with entirely elastic demand. The number of exports or imports in a small open economy market is small in contrast to total global commodity trade. As a result, the commodity's global price has little or no effect (the small country assumption). In this case, the product's price does not change as the supply curve shifts. In the context of this study, the rice market in Bangladesh is modelled as a small open-economy market.

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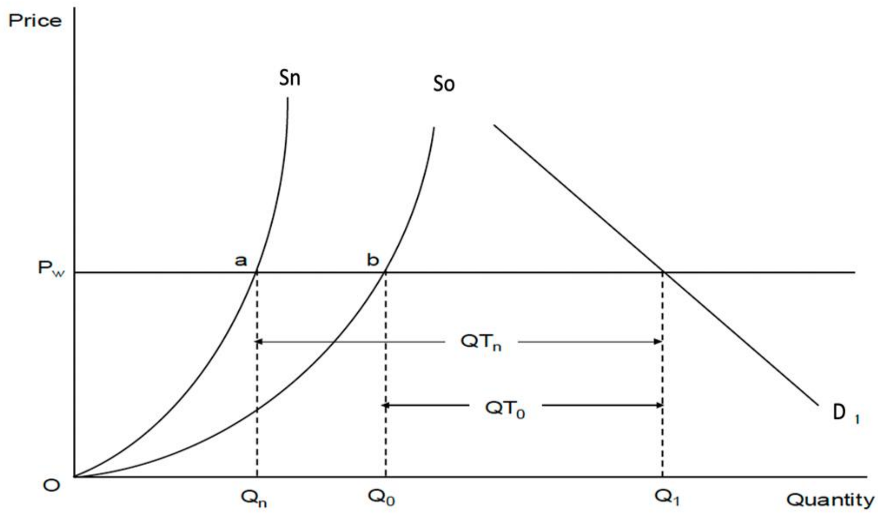

Figure 2 Model of Estimating Foreign Exchange Savings (*Small Open-economy*)

Source: Akino and Hayami (1975); Deb and Mustafi (1997); Flores-Moya et al. (1978)

Figure 2 depicts the change in economic surplus for a small open-economy market that is mostly dependent on local production but still allows imports to fill the deficit. The rice market in Bangladesh is an example of this kind of market. The initial equilibrium is characterized by the global price, P_W and the amount that is demanded by Bangladeshi consumers, Q_1. When confronted with the pre-research supply curve, S_n, producers supply Q_n amount of rice at a price of P_W. Imports of rice are equal to a QT_n. Rice producers raised their output to an amount Q_o and increased Q_nQ_0 when confronted with the research-induced supply curve (the supply curve that exists because farmers have adopted new high-yielding varieties).

Imports of rice decreased by the same amount as production, Q_nQ_0, bringing them to QT_0. Since P_w does not change (small economy assumption), so is consumer surplus. Neither situation is better nor worse off. As a result, the change in economic surplus brought on by the adoption of new rice varieties is the only change in producer surplus, shown in Figure 2 by area OAB (which corresponds to area OAC in Figure 1). P_w Q_nQ_0 is the amount of money that was saved because of better rice varieties.

Empirical Approach

The approximation formulae for determining the changes in producer and consumer economic surplus developed by Akino and Hayami (1975) are described below. For a closed economy study (Figure 1), the following equation is used to determine the change in economic surplus:

$$\text{Area ABC} \approx 0.5\, P_oQ_o\{k(1+\gamma)\}^2/(\gamma+\eta) \quad (1)$$

$$\text{Area OAC} \approx k\, P_oQ_o. \quad (2)$$

$$\text{Area BP}_n\text{P}_o\text{C} \approx \{P_oQ_ok(1+\gamma)/(\gamma+\eta)\} \times [1-\{(0.5\, k(1+\gamma)\,\eta\}/(\gamma+\eta) - 0.5(1+\gamma)] \quad (3)$$

where,

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P_o = Price of paddy rice in BDT/ton (existing market price)

Q_o = Quantity production of paddy rice in tons (existing production)

P_n = Price that would exist in the absence of research

Q_n = Quantity of the production that would exist in the absence of research,

k = Horizontal supply shifter

γ = Price elasticity of rice supply

η = Absolute price elasticity of rice demand.

Estimation of Yield Advantage

The yield advantage is one of the most important determinants of the growth of economic surplus. The higher the growth in surplus, the higher the yield of modern rice varieties compared with traditional varieties. The major HYV of rice in terms of adoption rate in various seasons was considered in this study, and the variety was checked over time. In this study, the average yield of local varieties was assumed once at the beginning of 1971, and then the average yield of modern rice varieties in farmers' fields was replaced as a check variety in the following years. The formula shown below was used to calculate the yield advantage (increase) of new varieties over an older or more traditional variety:

Yield advantage = 1 – the average yield of traditional varieties / the average yield of new varieties. (4)

The data on local and HYV rice yield at the farmers' level were collected from various issues of Statistical Year Books of Bangladesh published by the Bangladesh Bureau of Statistics (BBS).

Estimation of Supply Shifter (k)

The total yield advantage of improved rice varieties over the local variety, measured by the area sown to the improved rice variety, is known as the supply shifter k. The horizontal shift from the equilibrium price P_n given S_n to the equilibrium price P_o given S_0, which corresponds to a distance equal to Q_nQ_o in Figure 1, is known as k in the Akino and Hayami (1975) approximation formula. Several studies such as Dikitanan et al. (2022), and Miah et al. (2015) used this method. The following formula is used to calculate the supply shifter k:

$$k_t = \sum_{i=1}^{n} \left(1 - \frac{Y_t}{Y_{it}}\right) A_{it} \quad (5)$$

Where:

Y_{it} = yield of the improved rice variety in year t
Y_t = The base yield (or average yield of old rice varieties) previously grown, and would continue to be produced in the absence of new varieties
A_{it} = The proportion of the total area sown to a variety of rice in year t

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n = The number of improved rice varieties

Estimation of Rates of Return

The study, which requires data on annual social returns and their corresponding annual social costs, employed the following efficiency measurement criteria to evaluate the efficiency of investment in rice research and extension: Ex-ante analysis often employs the discounting approach. Because this study is an ex-post analysis, we employed the consumer price index (CPI) instead of the discounting factor to render money commensurable across time. Besides, utilizing CPI is ideal because it is based on actual data.

Estimation of Net Present Value (NPV)

Net present value (NPV) is the sum of all funds recovered from the investment in research. The following formula was used to calculate the NPV of the benefits:

$$NPV_n = \sum_{t=0}^{n} \frac{B_t \bullet CPI_n}{CPI_t} - \sum_{t=0}^{n} \frac{C_t \bullet CPI_n}{CPI_t} \tag{6}$$

where,

CPI = The consumer price index
B_t = The gross benefit in year t
C_t = The cost in year t
t = time duration, from 0 to n year. Here, 0 is the initial investment cost.

Estimation of Benefit-cost ratio (BCR)

Likewise, the formula of the converted or inflated Benefit Cost Ratio (BCR) is as follows:

$$BCR_n = \sum_{t=0}^{n} \frac{B_t \bullet CPI_n}{CPI_t} \div \sum_{t=0}^{n} \frac{C_t \bullet CPI_n}{CPI_t} \tag{7}$$

where,

CPI = The consumer price index
B_t = The gross benefit in year t
C_t = The cost in year t
t = time duration, from 0 to n year. Here, 0 is the initial investment cost.

Estimation of Internal Rate of Return (IRR)

The internal rate of return (IRR) is the discount rate that equates the NPV of an investment opportunity to zero (Bosri, R., 2016). The IRR was calculated in the same way as the net present value (NPV), except that the NPV equals zero. The IRR is always expressed as a percentage. The following formula and calculation were used to arrive at the figure:

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$$0 = NPV = \sum_{t=1}^{T} \frac{C_t}{(1+IRR)^t} - C_0 \quad (8)$$

where,

C_t = Net Cash inflow during the period t
C_0 = Total initial investment costs
IRR = The internal rate of return
t = The number of periods

Results and Discussion

Estimation Of Boro Rice Research And Extension Expenditure

Rice research and extension in Bangladesh are conducted by three major organizations such as the Bangladesh Rice Research Institute (BRRI), the Bangladesh Institute of Nuclear Agriculture (BINA), and the International Rice Research Institute (IRRI). The Department of Agriculture Extension (DAE) and Bangladesh Agricultural Research Council (BARC) are performed extension and administrative services with the prime rice research organizations. The Boro rice research and extension expenditure comprised the yearly expenditure of the above organizations for varietal development and disseminations of the new high yielding variety to the farmers (Table 1).

Infrastructure, benefits and salaries, vehicles, maintenance and repairs, research and development, training, higher education, and other expenses were included in these institutional costs. In the absence of detailed information about the costs of rice research by other institutions like IRRI, BINA, BARC, and other agricultural universities, we assumed the BRRI cost as a benchmark for technology generation. BARC is mainly provided at administrative costs. The expenditures of BRRI and IRRI were estimated from 1970/71 to 2021/22. On the other hand, the expenditure of BINA were started after 1975/76 due the innovation of new rice varieties and extension expenditures of DAE, administration costs incurred by BARC which were started after 5 years later of the development of the improved variety.

To estimate research and extension costs of *Boro* rice varietal research in Bangladesh we incorporate national agricultural research expenditure data from the *Agricultural* Science and Technology Indicators (ASTI) (ASTI, 2022). For the analysis, the current total expenditures were converted to 2020–21 constant prices (inflated prices) using the national CPI Index. A similar method was used by Dikitanan et al. (2022), Islam et al. (2024) and Dey and Mustafi (2001) in Bangladesh.

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Table 1. Estimated Boro Rice Research and Extension Expenditure, 1970/71 to 2021/22

Figure in billion Taka

Year	Aggregate Rice Research and Extension Costs (Deflated)	*Boro* Rice Research and Extension Costs (Deflated)	BRRI Costs	IRRI Costs	BINA Costs	BARC Cost	DEA Costs	Others Costs (public universities)
1970-71	2.51	1.00	0.30	0.12	-	-	-	-
1973-74	2.50	1.18	0.35	0.14	-	-	-	-
1976-77	5.01	2.75	0.83	0.33	0.50	0.19	0.83	0.08
1979-80	5.61	3.02	0.91	0.36	0.54	0.21	0.91	0.09
1982-83	2.80	1.20	0.36	0.14	0.22	0.08	0.36	0.04
1985-86	1.71	0.66	0.20	0.08	0.12	0.05	0.20	0.02
1986-87	1.12	0.42	0.13	0.05	0.08	0.03	0.13	0.01
1989-90	1.21	0.43	0.13	0.05	0.08	0.03	0.13	0.01
1992-93	2.61	0.81	0.24	0.10	0.15	0.06	0.24	0.02
1995-96	4.02	1.76	0.53	0.21	0.32	0.12	0.53	0.05
1998-99	5.01	2.20	0.66	0.26	0.40	0.15	0.66	0.07
2001-02	5.91	2.77	0.83	0.33	0.50	0.19	0.83	0.08
2004-05	6.22	2.98	0.89	0.36	0.54	0.21	0.89	0.09
2007-08	6.51	3.25	0.98	0.39	0.59	0.23	0.98	0.10
2010-11	5.11	2.50	0.75	0.30	0.45	0.17	0.75	0.07
2013-14	6.50	2.60	0.78	0.31	0.47	0.18	0.78	0.08
2016-17	9.81	3.72	1.12	0.45	0.67	0.26	1.12	0.11
2019-20	10.82	3.89	1.17	0.47	0.70	0.27	1.17	0.12
2021-22	11.21	4.03	1.21	0.48	0.73	0.28	1.21	0.12
Total cost	**258.72**	**111.95**	**33.58**	**13.43**	**19.33**	**7.51**	**32.17**	**3.22**

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Share of Total costs (%)	100	30	12	18	7	30	3

Note: Rice research and extension costs are deflated in the constant prices of the year 2020-21

Table 1 presents a comprehensive overview of the deflated expenditures associated with rice research and extension activities in Bangladesh from 1970/71 to 2021/22, measured in billion Taka at constant prices of 2020/21. Over this period, the aggregate rice research and extension spending reached 258.72 billion Taka, highlighting a substantial investment in enhancing rice production. Of this, *Boro* rice research accounted for 111.95 billion Taka, which is about 43% of the total costs, emphasizing its importance in Bangladesh's agricultural output. The yearly data shows a notable increase in expenditure, rising from 2.51 billion Taka in 1970/71 to 11.21 billion Taka in 2021/22, reflecting the growing emphasis on improving rice yields and production efficiency. Institutional contributions vary significantly, with the Bangladesh Rice Research Institute (BRRI) spending 33.58 billion Taka, representing 30% of the total *Boro* research and Extension costs, while the Department of Agricultural Extension (DEA) spending of 32.17 billion Taka 30% of the total *Boro* costs. The International Rice Research Institute (IRRI) contributed 13.43 billion Taka, equating to 12%, and the Bangladesh Institute of Nuclear Agriculture (BINA) accounted for 19.33 billion Taka, or 18%, indicating their active roles in agricultural innovation. The Bangladesh Agricultural Research Council (BARC) and public universities also participated, with expenditures of 7.51 billion Taka (7%) and 3.22 billion Taka (3%) respectively, underlining their supportive roles in research and education. The data reveals a consistent increase in funding over the decades, with significant leaps in certain periods aligning with national agricultural policies and technological advancements.

Social Benefits And Its Distribution From Boro Rice Research And Extension

The study revealed that *Boro* rice research and extension investments yielded substantial amount of social benefits in both closed and open economies. Table 2 presents a comparative analysis of social benefits and their distribution from *Boro* rice research and extension under both closed and open economy scenarios over the period from 1970/71 to 2021/22. Table 2 delineates consumers' surplus, producers' surplus, and social benefits measured in billion Taka for selected years, with price elasticity of rice parameters $\eta = 0.45$ and $\gamma = 0.48$ for the closed economy, and $\eta = -1.00$ and $\gamma = 0.48$ for the open economy.

Under closed economy, the total social surplus was estimated at Taka 1236.74 billion, while the total changes in consumers' and producers' surpluses were estimated at Taka 1760.01 and Tk -523.23 billion, respectively, from *Boro* rice research and extension. The results showed that consumers were the sole beneficiaries of the research and that producers were made worse off (Table 2 and Figure 3). This result is due to the low price elasticity of demand. The rightward shift of the supply function against an inelastic demand led to reduced revenue for rice growers. However, society gained gains amounted to Taka 1236.74 billion in social welfare from *Boro* rice research and extension from 1971 to 2022.

Conversely, under an open economy, consumer surplus and producer surplus are generally higher and less volatile. The consumer surplus peaks at 39.05 billion Taka in 1994-95, and the producer surplus remains positive except in 1999-00 (Figure 4). Consequently, the social benefits under an open economy exhibit greater stability and higher values, peaking at 45.28 billion Taka in 1994-95.

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Table 2 Social Benefits And Its Distributions From Boro Rice Research And Extension

	Closed Economy (η =0.45 ; γ=0.48)			Open Economy (η =1; γ=0.48)		
Year	Consumers' surplus	Producers' surplus	Total Surplus	Consumers' surplus	Producers' surplus	Total Surplus
	(billion Tk)	(billion Tk)	(billion Tk)	(billion Tk)	(billion Tk)	(billion Tk)
1970-71						
1974-75						
1976-77	22.2	-6.3	15.9	13.8	1.6	15.3
1978-79	27.4	-7.8	19.6	17.0	1.9	18.9
1980-81	24.7	-7.2	17.4	15.3	1.6	16.9
1982-83	29.0	-8.4	20.6	18.0	1.9	19.9
1984-85	27.8	-8.1	19.6	17.3	1.8	19.0
1986-87	30.1	-8.8	21.3	18.7	1.9	20.6
1988-89	43.0	-11.4	31.6	26.6	3.7	30.3
1990-91	60.6	-15.9	44.7	37.4	5.3	42.8
1992-93	43.0	-10.8	32.3	26.5	4.2	30.8
1994-95	63.3	-15.8	47.5	39.1	6.2	45.3
1996-97	43.5	-12.2	31.3	27.0	3.2	30.2
1998-99	35.7	-11.6	24.1	22.3	1.3	23.6
2000-01	7.2	-2.6	4.6	4.5	0.1	4.6
2002-03	5.8	-2.1	3.7	3.7	0.0	3.7
2004-05	44.2	-14.1	30.1	27.6	1.9	29.4
2006-07	38.0	-12.9	25.1	23.8	1.0	24.8
2008-09	37.7	-12.8	24.8	23.6	0.9	24.5
2010-11	60.8	-20.0	40.8	38.0	2.1	40.1
2012-13	29.4	-10.1	19.3	18.4	0.7	19.1
2014-15	53.0	-17.3	35.7	33.1	2.0	35.0
2016-17	37.6	-12.8	24.9	23.5	1.0	24.5
2018-19	35.1	-12.1	23.0	22.0	0.8	22.7
2020-21	28.1	-9.9	18.2	17.6	0.5	18.1
2021-22	35.6	-12.2	23.4	22.3	0.8	23.1
Total	**1760.01**	**-523.23**	**1236.74**	**1093.87**	**105.60**	**1199.51**

Note: η *stands* for demand elasticity and γ stands for supply elasticity

Table 2 and Figure 4, demonstrated that in an open-economy scenario, both consumers and producers benefit significantly, enhancing economic welfare and saving foreign exchange. The consumers' surplus amounts to Taka 1093.87 billion, which is substantially higher than the producers' surplus of Taka 105.60 billion, largely due to the high price elasticity of demand. Overall, the country achieves a total societal surplus of Taka 1199.55 billion.

These findings are consistent with previous studies using similar models conducted in Bangladesh (Deb & Mustafi, 1997; Dey & Mustafi, 2001; Islam et al., 2024; Miah et al., 2015; Nagy & Alam, 2000; Shiblee, 2011; Siddiqui, 1985), the Philippines (Flores-Moya et al., 1978), Spain (Herruzo, 1985), and Japan (Akino & Hayami, 1975).

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The results suggesting that an open economy framework potentially yields more significant and stable social benefits from *Boro* rice research and extension. This stability suggests that an open economy framework yields greater overall social benefits, providing a more favourable and balanced environment for both consumers and producers compared to a closed economy.

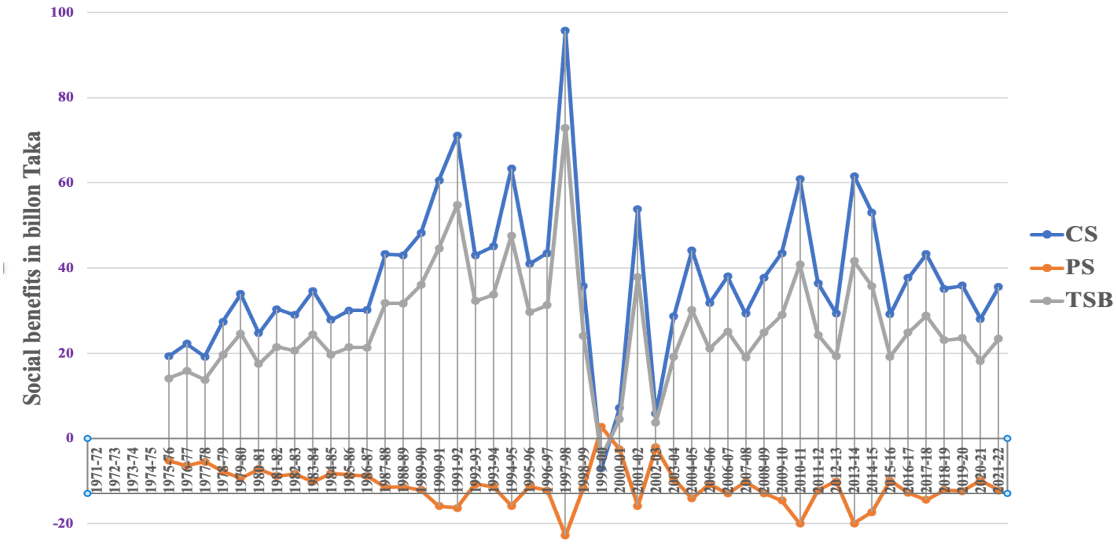

Figure 3 Distribution Of Social Benefits (*Closed Economy*)

Note: CS stands for consumer surplus, PS stands for producer surplus and TSB stands for total social benefits

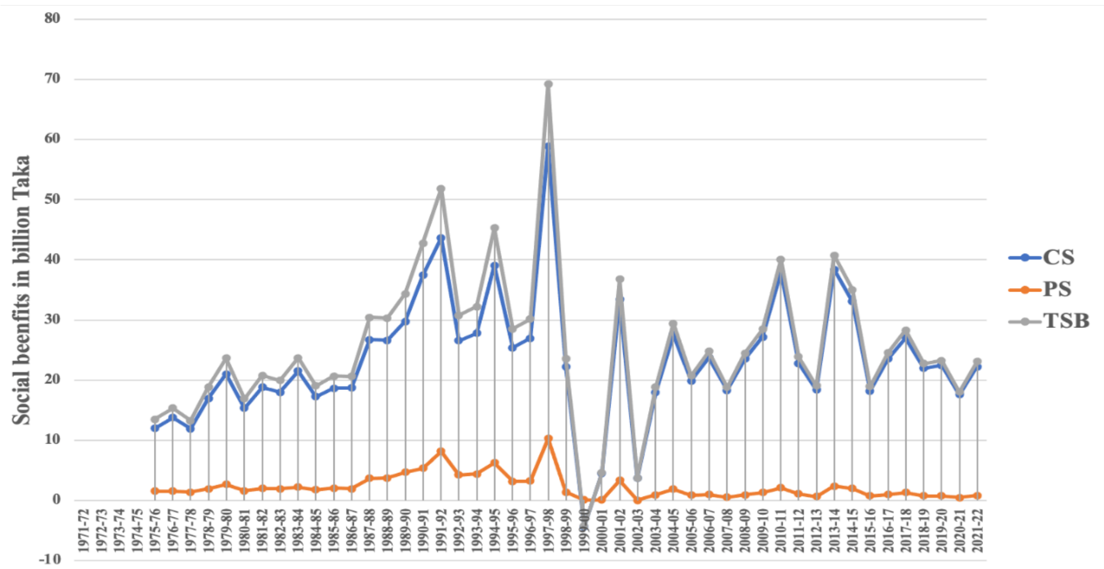

Figure 4 Distribution Of Social Benefits (*Open Economy*)

Note: CS stands for consumer surplus, PS stands for producer surplus and TSB stands for total social benefits

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Foreign Exchange Savings From Boro Rice Research And Extension

The yearly increase in production due to research save the country's foreign exchange to a remarkable extent. First, the research-induced increase in *Boro* rice production for each year was calculated by multiplying the country's total *Boro* rice by its respective production function shifter *k*.

Foreign exchange savings was calculated by multiplying the results by the world rice price. Considerable amounts of rice are imported in Bangladesh every year to meet the demand of the growing population. The imported value of rice was US$373 million in 2022 (OEC, 2024).

Table 3. Foreign Exchange Savings From Investment In *Boro* Rice Research And Extension

Year	Inflated Import Rice Price (Constant Price in 2020-21)	Supply Shifter	*Boro* Rice Production (Cleaned)	Additional *Boro* Production due to research	Foreign Exchange Savings (FES)
	US$/Tonne	K_t	Million tonnes	Million tonnes	Billion US$
1970-71	9016.39	0.01	1.64	0.02	0.15
1972-73	8241.76	0.05	2.22	0.11	0.91
1974-75	15415.02	0.07	2.29	0.16	2.47
1976-77	5405.41	0.09	2.24	0.20	1.09
1978-79	4195.80	0.09	2.43	0.22	0.92
1980-81	5133.33	0.08	3.15	0.25	1.29
1982-83	2777.78	0.08	3.35	0.27	0.74
1984-85	2049.18	0.08	3.67	0.29	0.60
1986-87	1554.40	0.08	4.73	0.38	0.59
1988-89	1722.09	0.11	6.03	0.66	1.14
1990-91	1475.24	0.11	6.81	0.75	1.11
1992-93	986.12	0.12	6.77	0.81	0.80
1994-94	1218.01	0.12	7.22	0.87	1.06
1996-97	1356.00	0.09	8.14	0.73	0.99
1998-99	1027.05	0.05	11.03	0.55	0.57
2000-01	552.40	0.01	11.77	0.12	0.07
2002-03	590.00	0.01	12.84	0.13	0.08
2004-05	769.23	0.05	13.98	0.70	0.54
2006-07	755.93	0.03	17.76	0.53	0.40
2008-09	1064.99	0.03	18.06	0.54	0.58
2010-11	891.61	0.04	15.77	0.63	0.56
2012-13	803.97	0.03	16.00	0.48	0.39
2014-15	490.00	0.05	19.00	0.95	0.47
2016-17	409.46	0.03	19.58	0.59	0.24
2018-19	421.00	0.03	19.35	0.58	0.24
2020-21	443.81	0.02	19.80	0.40	0.18
2021-22	446.93	0.03	19.82	0.59	0.27
Total Foreign Exchange Savings (billion US$)					**40.22**
Note: 1USD=BDT 85.39 in 2020					

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Table 3 provides an analysis of foreign exchange savings from *Boro* rice research and extension in Bangladesh between 1970/71 and 2021/22. It includes inflated import rice prices (adjusted to 2020-21 constant prices), supply shifters, *Boro* rice production, additional production, and foreign exchange savings in billions US dollars. The period from 1970 to 1975 saw the highest import prices, peaking at 15,415.02 US$/Tonne in 1974-75, resulting in significant foreign exchange savings of up to 2.47 billion USD due to increased *Boro* production.

Over time, import prices declined, dropping below 500 US$/Tonne by 2014-15, while *Boro* rice production increased, with additional production peaking at 0.95 million tonnes in 2014-15. Despite lower savings per tonne in later years due to decreased import prices, total foreign exchange savings amounted to 40.22 billion USD over the 50-year period. This highlights the impact of agricultural research in reducing import dependency and enhancing food security, emphasizing the importance of continued investment in agricultural development.

Social Rates of Return

To evaluate the efficiency of allocating public resources to *Boro* rice research, it's essential to compare the annual gross social benefits with the annual cost of the research program. By examining the ratio of benefits to costs annually, policymakers can gauge the effectiveness of their investment in rice research. This analysis helps ensure that resources are allocated optimally, maximizing the societal return on investment in agricultural research. Equations (1) through (3) were used to estimate the total social benefits to rice research and extension expenditures once the supply shifter k had been calculated. The equations were embedded into a computer spreadsheet for ease of computation. Costs for rice research are estimated to have begun in 1970/71 and finished in 2021/22; extension expenses are estimated to have begun in 1975/76; and benefits are estimated to have begun in 1975/76. To estimate rates of return on investments, a 5-year research and development lag was utilized.

Internal rates of return (IRR), benefit-cost ratio (BCR), and net present value (NPV) rates of return in closed and open economies are displayed in Table 4. In both closed and open economies, it has been discovered that the rates of return for investments made in rice research and extension are nearly the same in terms of BCR and IRR.

Table 4. Estimated Rates of Return on *Boro* Rice Research and Extension

Parameter	Closed Economy	Open Economy
Net Present Value (NPV) (Billion Taka)	1133.75	1096.78
Benefit Cost Ratio (BCR)	15	15
Internal Rate of Return (IRR) (%)	75	73

Table 4 presents the estimated net present value (NPV) of Taka 1133.75 billion and Taka 1096.78 billion in the closed and open economies, respectively. The findings of the aggregate NPV indicate that rice research and extension have generated an amount of Taka 1133.75 billion as a net gain for society under the closed economy. The benefit-cost ratio (BCR) of the research was estimated at 15, which is constant for both economies.

The estimates of the benefit-cost ratio showed that 1 Taka invested in rice research and extension has generated an average social benefit of Taka 15 to Bangladesh. Using the consumer price index (CPI), the IRR was estimated at 75% and 73% for the closed and open economies, respectively. The internal rate of return (IRR) from rice research was 75%,

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implying that each Taka 100 invested in rice research and extension has produced an average annual profit of Taka 75.

The estimates of the rate of return of this study are supported by several recent global impact studies on rice research, for example (Alston et al., 2022; Dikitanan et al., 2022; Hurley et al., 2016; Pardey et al., 2016). In addition, the study's returns rates are also supported by rice research and development studies (Deb & Mustafi, 1997; Dikitanan et al., 2022; Islam MS et al., 2024; Nagy & Alam, 2000; Siddiqui, M.R, 1985).

Sensitivity Analysis

In this study, the Monte Carlo simulation technique was utilized in the sensitivity analysis.

Table 5. Statistical Characteristics Of The Output Variable

Statistics	**Expected Value NPV (eNPV)**	**Expected Value of IRR (eIRR)**
	(Billion Taka)	
Base	1133.75	75%
Trails	1000	1000
Mean	1205.65	78%
Median	1195.32	78%
Mode	-	-
Standard Deviation	1110.93	30%
Minimum	1228.75	73%
Maximum	1546.21	78%
Probability of project loss	11.23%	9.7%
Skewness	0.35	0.06
Kurtosis	0.14	-0.03
Coeff. of Variability	0.93	0.43

Monte Carlo simulation is an analytical method that addresses uncertainty-related problems by employing random numbers and probability distributions. It finds applications across various business and scientific domains. The Monte Carlo approach estimates the expected value or outcome of the problem under investigation.

In this study, Monte Carlo simulation was conducted with 1000 trials and a confidence level of 95%. Table 5 shows that the base parameters, including a net present value (NPV) of Taka 3,538.76 billion and an internal rate of return (IRR) of 68%, were used for rice research and extension in Bangladesh from 1971 to 2022.

The Monte-Carlo simulation technique was employed to estimate the expected net present value (NPV) of a project, revealing a standard deviation of Taka 1110.93 billion and a mean value of Taka 1205.65 billion. This analysis indicates that the project's uncertainty is relatively low, as the gap between the mean NPV and standard deviation is not substantial. Results suggest that the project generated larger benefits than initially anticipated, with a projected NPV exceeding the base NPV. With a coefficient of variability less than 1, indicating minimal chances of project failure, there's an 89.77% likelihood of project success compared to an 11.23% probability of loss. Additionally, the Monte-Carlo simulation estimated the mean value of the expected internal rate of return (IRR) at 78%, with a standard deviation of 30%. The IRR

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ranged from 73% to 78%, with a coefficient of variability of 0.43, suggesting a low risk of project failure. Based on the IRR criterion, there's a 90.3% chance of project acceptance, while the NPV rule indicates a 75.77% chance of success.

Conclusions and Policy Recommendation

The findings of this study demonstrate and prove the considerably high social returns of research and extension and that *Boro* rice breeding research has benefited Bangladeshi society. This study's documented high rate of returns (IRR of 75%, BCR of 15 and NPV of Taka 1133.75 billion) suggests an underinvestment in Bangladeshi rice research and extension. Therefore, the government should invest more resources in *Boro* rice research and extension in the future. The findings from this study have shown that under closed economy, consumers were the sole beneficiaries, while producers were the losers. However, this situation may not be conducive to economic prosperity. The government and relevant authorities should provide price support for the survival of rice producers. One of the potential areas to tackle is the annual adoption rate of modern *Boro* rice cultivars, which requires a major boost given that the seeds are not readily available. The government and non-governmental organizations should initiate a seed production program so that farmers can get quality seeds at a reasonable price. Therefore, the Bangladesh government and donors should allocate adequate resources to rice research and extension programs in Bangladesh to attain sustainable food security in the future.

The academic contribution of this work lies in its comprehensive evaluation of the economic impact and returns on investment in rice breeding research in Bangladesh over 51 years. This study is innovative as it applies both closed and open economy perspectives, providing a nuanced understanding of the social and economic benefits. The original approach combines the economic surplus model with project evaluation techniques, offering robust insights that can inform future agricultural policies and funding decisions. This work fills a gap in the existing literature by demonstrating the significant foreign exchange savings and high benefit-cost ratio, underscoring the importance of sustained investment in agricultural research.

Limitations Of The Study

This study employed the economic surplus model to assess the economic impact. It remains one of the most preferable methods for economic valuation studies on research and technology, despite the various criticisms of this technique. This study evaluated constant supply and demand curves with a pivotal shift in the supply curve. Future studies could be done using a parallel shift of the supply curve with point elasticity of the supply and demand functions and a parallel shift of the supply curve with constant elasticity of the supply and demand functions. Methods other than the economic surplus model can also be applied in future research. The fundamental limitation of this study is data availability; specifically, the national rice research expenditure data are not available. The estimations have to rely on a manual calculation using the BRRI rice research expenditures as a benchmark, and the expenditures from other institutions were calculated under certain assumptions. The use of national rice research expenditure would improve the estimation of the rate of return (IRR).

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References

Ahmed, A. U., & Shams, Y. (1994). Demand elasticities in rural Bangladesh: An application of the AIDS model. *The Bangladesh Development Studies*, 1–25.

Akino, M., & Hayami, Y. (1975). Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development: Reply. *American Journal of Agricultural Economics*, *57*(4), 734–735. https://doi.org/10.2307/1238901

Al Mamun, Md. A., Nihad, S. A. I., Sarkar, Md. A. R., Aziz, Md. A., Qayum, Md. A., Ahmed, R., Rahman, N. M. F., Hossain, Md. I., & Kabir, Md. S. (2021). Growth and trend analysis of area, production and yield of rice: A scenario of rice security in Bangladesh. *PLOS ONE*, *16*(12), e0261128. https://doi.org/10.1371/journal.pone.0261128

Alam, M. J., Buysse, J., Begum, I. A., Wailes, E. J., & Van Huylenbroeck, G. (2011). The welfare impact of policy interventions in the foodgrain markets in Bangladesh. *Journal of Economic Policy Reform*, *14*(3), 215–225.

Alam, S. (1992). Rice Yield Growth Scenerio and Factors Contributing to Output Changes of Different Rice Varieties and Types in Bangladesh. *Bangladesh Journal of Agricultural Economics*, *15*(2), 19–33.

Alamgir, M., & Berlage, L. J. (1973). Estimation of income elasticity of demand for foodgrain in Bangladesh from cross section data: A skeptical view. *The Bangladesh Economic Review*, *1*(4), 387–408.

Alston, G. Pardey, P., & Rao, X. (2022). Payoffs to a half century of CGIAR research. *American Journal of Agricultural Economics*, *104*(2), 502–529. https://doi.org/10.1111/ajae.12255

Alston, George W. Norton, & Philip G. Pardey. (1998). *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*. International Service for National Agricultural Research (ISNAR). https://ebrary.ifpri.org/digital/collection/p15738coll11/id/6/

ASTI. (2022). *Agricultural Science and Technology Indicators, National Agricultural Research Expenditure Database, Bangladesh*. https://www.asti.cgiar.org/.

Atlin, G. N., Cairns, J. E., & Das, B. (2017). Rapid breeding and varietal replacement are critical to adaptation of cropping systems in the developing world to climate change. *Global Food Security*, *12*, 31–37. https://doi.org/10.1016/j.gfs.2017.01.008

BBS (Bangladesh Bureau of Statistics). (2022). *Yearbook of Agricultural Statistics-2021*. Bangladesh Bureau of Statistics, Statistical and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh. www.bbs.gov.bd

BBS (Bangladesh Bureau of Statistics). (2023). *Yearbook of Agricultural Statistics of Bangladesh*. Ministry of Planning. Government of the People's Republic of Bangladesh. www.bbs.gov.bd

Begum, M. E. A., & D'Haese, L. (2010). Supply and demand situations for major crops and food items in Bangladesh. *Journal of the Bangladesh Agricultural University*, *8*(1). https://ageconsearch.umn.edu/record/208471/

Bosri, R. (2016). Evaluation of Managerial Techniques: NPV and IRR. *UITS Journal*, *5*, 48–57.

Brennan, J. P. & Malabayabas, A. (2011). *International Rice Research Institute's contribution to rice varietal yield improvement in South-East Asia*. International Rice Research Institute.

Deb, U. K., & Mustafi, B. A. A. (1997). *Social Returns to Rice Research in Bangladesh*. https://doi.org/10.22004/AG.ECON.202336

Dey, M. M & Evenson, R. E. (1991). *The economic impact of rice research in Bangladesh.*

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Volume 6 Issue 21 (September 2024) PP. 108-128
DOI 10.35631/AIJBES.621009
Dey, P. K., & Mustafi, B. A. A. (2001). Economic Returns To Investment on Br11 Variety Of Rice in T. Aman Season. *Bangladesh Journal of Agricultural Economics*, *24*, 57–74.

Dikitanan, R. C., Pede, V. O., Rejesus, R. M., Bhandari, H., Alam, G. M. M., & Andrade, R. S. (2022). Assessing returns to research investments in rice varietal development: Evidence from the Philippines and Bangladesh. *Global Food Security*, *33*, 100646. https://doi.org/10.1016/j.gfs.2022.100646

Dorosh, P.A. (2001). Trade liberalization and national food security: Rice trade between Bangladesh and India. *World Development.*, *29*(1), 673–689.

Fan, S., Hazell, P., & Thorat, S. (2000). Government Spending, Growth and Poverty in Rural India. *American Journal of Agricultural Economics*, *82*(4), 1038–1051. https://doi.org/10.1111/0002-9092.00101

Farhan, S., & Intakhab Ali, S. (2023). *Assessing the Potential Impacts of the Russia-Ukraine War on Food Security in South Asian Countries: Current Status and Implications on Bangladesh's Dependence on Wheat Imports (November 1, 2023)*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4831059

Flores-Moya, P., Evenson, R. E., & Hayami, Y. (1978). Social Returns to Rice Research in the Philippines: Domestic Benefits and Foreign Spillover. *Economic Development and Cultural Change*, *26*(3), 591–607. https://doi.org/10.1086/451041

FAO (Food and Agriculture Organization) (2023). *Food Outlook—Biannual Report on Global Food Markets* (pp. 1–174). https://reliefweb.int/report/world/food-outlook-biannual-report-global-food-markets-november-2023-enarruzh

Gill, G.J. (1983). *Agricultural research in Bangladesh: Costs and returns. Dhaka*.

Herruzo, A. C. (1985). Returns to agricultural research: The case of rice breeding in Spain. *European Review of Agricultural Economics*, *12*(3), 265–282. https://doi.org/10.1093/erae/12.3.265

Hossain, M., & Yunus, M. (2016). Estimates of per capita consumption of food grains in Bangladesh. *The Bangladesh Development Studies*, *39*(1–2), 103–116.

Hurley, T., Pardey, P. G., Rao, X., & Andrade, R. S. (2016). *Returns to food and agricultural R&D; Investments worldwide, 1958-2015*. https://hdl.handle.net/10568/119583

Islam MS, Kamarulzaman, NH, Shamsudin, MN, Nawi, NM, Alam, MJ, & Bhandari, M. (2024). Economic Impact and Returns on Investment of Rice Research and Extension in Bangladesh: An Economic Surplus Approach. *Journal of Hunan University Natural Sciences*, *51*(6), Article 6. http://www.jonuns.com/index.php/journal/article/view/1587

Shelley et al. (2016). *Rice Cultivation in Bangladesh: Present Scenario, Problems, and Prospects* (0). International Center for Research and Education in Agriculture, Nagoya University. https://doi.org/10.50907/jicad.14.0_20

Kabir et al. (2021). Doubling Rice Productivity in Bangladesh: A Way to Achieving SDG 2 and Moving Forward. *Bangladesh Rice Journal*, *24*(2), 1–47. https://doi.org/10.3329/brj.v24i2.53447

Miah, M, Shiblee, S, & Rashid, M. (2015). Economic Impacts of Oilseed Research and Development in Bangladesh. *Bangladesh Development Studies*, *38*(1), 1–31.

Nadim, M. K. A., Hoque, M. M., Islam, M. M., Alim, S. M. A., Ahmed, B., & Reza, M. S. (2022). Morphological characterization and adaptive trail of two prominent T. Aman Rice (Oryza sativa L.) lines under different locations of Bangladesh. *Asian Journal of Environment & Ecology*, *19*(4), 1–8.

Nagy, J. G., & Alam, M. F. (2000). The impact of agricultural research in Bangladesh: Estimating returns to agricultural research. *Project Report, BARC, Dhaka and International Fertilizer Development Centre, Muscle Shoals, Alabama*.

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OEC. (2024). *Rice in Bangladesh | The Observatory of Economic Complexity*. https://oec.world/en/profile/bilateral-product/rice/reporter/bgd

Pardey, P. G., Andrade, R. S., Hurley, T. M., Rao, X., & Liebenberg, F. G. (2016). Returns to food and agricultural R&D investments in Sub-Saharan Africa, 1975–2014. *Food Policy*, *65*, 1–8. https://doi.org/10.1016/j.foodpol.2016.09.009

Praduman Kumar, P. K., Anjani Kumar, A. K., Shinoj Parappurathu, S. P., & Raju, S. S. (2011). *Estimation of demand elasticity for food commodities in India*. https://www.cabidigitallibrary.org/doi/full/10.5555/20113229878

Rahman, M. M., & Connor, J. D. (2022). The effect of high-yielding variety on rice yield, farm income and household nutrition: Evidence from rural Bangladesh. *Agriculture & Food Security*, *11*(1), 35. https://doi.org/10.1186/s40066-022-00365-6

Raitzer et al. (2015). *Is Rice Improvement Still Making a Difference? Assessing the Economic, Poverty, and Food Security Impacts of Rice Varieties Released from 1989 to 2009 in Bangladesh, Indonesia and the Philippines*. https://hdl.handle.net/10568/128929

Shew, A. M., Durand-Morat, A., Putman, B., Nalley, L. L., & Ghosh, A. (2019). Rice intensification in Bangladesh improves economic and environmental welfare. *Environmental Science & Policy*, *95*, 46–57. https://doi.org/10.1016/j.envsci.2019.02.004

Shiblee, S. (2011). *Ex-post economic impact assessment of investment in vegetable research and extension in Bangladesh. Doctoral dissertation.* [Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh, Bangladesh.]. Retrieved from http://www. saulibrary. edu. bd/daatj/public/index.

Siddique, M. A. B., Salam, M. A., & Rahman, M. C. (2020). Estimating the demand elasticity of rice in bangladesh: An application of the AIDS model. *Asian Journal of Agriculture and Rural Development*, *10*(3), 721–728.

Siddiqui, M.R. (1985). *Social Returns to Rice Research in Bangladeh.* [Upublished M.Econ.]. University of New England, Armidale.

Timsina, J., Wolf, J., Guilpart, N., van Bussel, L. G. J., Grassini, P., van Wart, J., Hossain, A., Rashid, H., Islam, S., & van Ittersum, M. K. (2018). Can Bangladesh produce enough cereals to meet future demand? *Agricultural Systems*, *163*, 36–44. https://doi.org/10.1016/j.agsy.2016.11.003

Yeong-Sheng, T. E. Y., Shamsudin, M. N., Mohamed, Z., & Mahir Abdullah, A. (2009). Demand analyses of rice in Malaysia. *MPRA Paper*, *15062*.

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