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COVID-19 and Policy Impacts on the Bangladesh Rice Market and Food Security

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Abstract: This research employs a partial equilibrium model to estimate the short- and long-run effects of COVID-19 and rice policies on Bangladesh's rice market and food security. We also analyze the impact of relevant policies in terms of their effectiveness in mitigating stresses stemming from a hypothetical pandemic with a COVID-19-like impact. The results indicate that the effect of COVID-19 on Bangladeshi food security during FY 2019/20 was mixed, as the indicators of food availability improved by 5%, and decreased by 17% for food stability, relative to what they would have been otherwise. Policy simulation results indicate that a higher import tariff improves self-sufficiency status, but undermines rice availability and accessibility by bending the market toward a restrictive trade regime. Results also indicate that unlike stock enhancement policy, closing the existing yield gap improves rice availability, accessibility, and moderates the depressing effect of a future event with repercussions similar to COVID-19, although the yield policy appears more speculative and could be too costly. The insights generated contribute to the understanding of policies that aim to achieve sustainable development goals related to aggregate food security, and build resilience against future shocks akin to COVID-19.

Keywords: Bangladesh; COVID-19; food security; partial equilibrium; rice

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1. Introduction

There have been numerous studies on the concept of food security. Food security is relevant to the global policy agenda because of concern over issues such as growing population, rising production costs, declining agricultural production, and climate change [1,2]. Improved food security is also viewed as the key to achieving the sustainable development goal (SDG) [3]. Attention on food security was heightened after the global food price crisis of 2006-08, which pushed an additional 130 to 155 million people into poverty in 2008, and triggered riots in more than two dozen countries, including Bangladesh [4,5]. Similarly to the food price crisis of 2006-08, the COVID-19 pandemic could have a detrimental effect on food security. Containment measures such as lockdowns and social distancing imposed by governments around the globe to slow down the pandemic have amplified the risks of food insecurity directly through supply chain disruptions, and indirectly through decreases in purchasing power due to negative income shocks [6–8]. According to WFP [9], by the end of 2021 an additional 121 million people will be pushed into acute food insecurity due to the economic fallout of the pandemic. Bangladesh implemented a series of mitigation strategies to contain the pandemic, and the economic slump and supply chain disruptions triggered by such measures could have detrimental effects on agricultural production, trade, and price volatility. Rice availability, accessibility, and stability in Bangladesh could be affected, at least in the short run. Moreover, the current crisis seems unlikely to help Bangladeshi policymakers meet their stated objectives to increase food security and to achieve a transition toward sustainable development targets under the SDG agenda.

Our objective in this paper is to inform policy decisions relating to the Bangladesh rice market and food security indicators, and to conduct a COVID-19 impact analysis by

comparing the baseline projections generated using pre-and post-COVID-19 exogenous macroeconomic, policy, and trade data. We also test the impact of different policy scenarios on the Bangladesh rice market, as well as the state of Bangladesh's food security during a hypothetical future pandemic after these policy options have been put in place. We do so by developing a partial equilibrium, structural-based model that incorporates Bangladesh's food and trade policies.

Despite the evidence of adverse effects from the food price increase, spikes, and income shocks on poverty and food security, little has been done to provide a long-term outlook on the food security status of Bangladesh [10–14]. To date, there have been insufficient efforts to examine the effects of food or trade policy changes or exogenous shocks on the Bangladeshi food market's fundamentals. The need for such analysis is even more compelling as the effects of the COVID-19 pandemic are likely to spill over into longer-run food security via income and food price impacts. In Bangladesh, food accounts for about 70% of total expenditures for the poor, defined as the bottom quintile of the income distribution, and the poor spend at least 35% of their income on staple foods [15]. Rice is the staple food of Bangladesh, which provides two-thirds of the calorie needs and half the protein consumption of the nation [16]. The rice sector is one of the key targets of the Government of Bangladesh's (GoB) food policy to ensure food security for all people at all times [17]. COVID-19 has potential jeopardize food security as it has already caused disruptions in food production, value chain, and access [18–20]. Therefore, estimates of the impact of COVID-19, future events with a COVID-19-like effect, and food and trade policies on Bangladesh food security seem likely to be of relevance to the policymakers. If so, then there is a need for estimates of such effects to help policymakers formulate better policy responses toward the current and potential impact of COVID-19 on Bangladeshi food security and to maintain rice market stability in the face of any future disruptions.

1.1. Literature Review

Previous studies provided limited retrospective and prospective insights into the rice market and related food security concerns of Bangladesh. For example, Del Ninno et al. [21] analyzed the impact of the 1998 flood on Bangladesh's food security at national and household levels, and provided policy implications for managing future natural disasters in developing countries. Chen and Lu [22] measured the food security index (FSI) level changes in Bangladesh, and analyzed the contributions of factors such as total population, total cropping area, mean crop yield, and per capita consumption of rice and rice equivalents on FSI change during 1990–2013. Some studies provided projections for the Bangladesh rice market, and simulated supply and demand balance for rice under alternative scenarios [23–26]. There are studies that analyzed public stock requirement for stabilizing prices and mitigating future supply disruptions [27,28]. One common limitation of these studies is the omission of certain macroeconomic variables and trade policies (e.g., GDP, exchange rate, import tariff) in analyzing the rice market and food security. However, they do not explicitly employ any analytical tools that can capture the effect of shocks related to future events and policy changes on aggregate food security dimensions. Moreover, older studies might not relate well to the impacts of the COVID-19 pandemic, despite its potentially large impacts including at the intersection of food consumption and online shopping [29,30], business innovation [31], working environments [32], agricultural and food markets, and trade more generally [33,34].

The partial equilibrium model developed in this study for the Bangladeshi rice market can fill this gap, as it quantifies the impact of a pandemic and certain policy options on key food security indicators. Although we found no studies of current Bangladeshi rice policy and food security that use the method employed here, several studies used a partial equilibrium framework to analyze and quantify agricultural and trade policies, examining their impact on different agricultural commodities in other parts of the world. Fathelrahman et al. [35] used a partial equilibrium framework to measure the welfare effect of food trade liberalization in India, Egypt, Pakistan, Saudi Arabia, and the United

Arab Emirates (UAE). Others examined the effects of trade and agricultural policies on the rice sector in Madagascar [36], Japan [37], and Thailand [38]. Partial equilibrium models have also been used to estimate the effect of water subsidy policy on Banana farming in Jordan [39] and to analyze the effect of trade liberalization in the world wheat market on US wheat export demand elasticity [40]. Moreover, there are studies that simultaneously examined the impact of alternative policy responses on the Japanese and Indian rice and wheat markets [41,42].

1.2. Contribution

To the best of our knowledge, this research makes several unique contributions to the existing literature. First, this is a pioneering study in estimating the ex-post and ex-ante effects of COVID-19 on Bangladesh's rice market and food security using the partial equilibrium technique. Second, this is the first study to address the possibility of a trade regime switch in analyzing Bangladesh's rice market and related policies within a partial equilibrium framework. There is evidence that the Bangladeshi rice market sporadically shifts between autarky and import parity regime [16,28]. Hence, the trade regime-switching mechanism employed in this research is more accurate in that it addresses the possibility of changing price formation under different market and policy conditions. Finally, we also evaluate the effectiveness of existing policies to cope with shocks that may stem from future events like COVID-19. The findings from this study will provide policymakers quantified insights regarding the current pandemic and help them to understand the potential effect of future pandemics on Bangladesh's rice market and the sustainability of food security.

2. Food and Trade Policies of Bangladesh

The current food policy framework in Bangladesh includes producer-oriented (e.g., public food stocks), consumer-oriented (e.g., public food grain distribution system), and trade and market-oriented (e.g., import tariff) policies whose stated purposes include ensuring an adequate and stable supply of food [43]. The current policy environment interlaces rice and food security policy, as discussed in this section, previewing our use of three policy instruments: import tariff, public stock, and yield gap closure. These are used to assess the impact of external shocks and variations on the dimensions of food security of Bangladesh.

The initial trade liberalization process in Bangladesh was started in the early 1980s with a new industrial policy in 1982. Major trade reforms were started in 1991, with the elimination of non-tariff import restrictions on most of the agricultural products and with the legalization of rice import by the private sector in 1994. Since then, governments have used import tariffs as a crucial policy instrument to develop the domestic rice market, stabilize prices, and provide price incentives to producers and consumers. For example, to cover the production losses caused by the 1998 flood, the government removed import tariffs to encourage private sector import to avoid a food supply shortage. Such short-term policy action, along with the prompt port clearance, prevented domestic market price from rising above import parity level price. Del Ninno et al. [44] stated that such initiatives allowed the private sector to import a substantial amount of rice and proved to be less costly compared to the production shortfall following the 1988 flood, which was mainly handled through government commercial imports. We had observed similar policy actions following the 2004 monsoon flood and the 2007/08 world food crisis when the government quickly reduced rice import tariffs from 23% and 5% to 8% and 0%, respectively. At the end of the financial year (FY) 2018/19, the government nearly doubled (from 28% to 55%) import tariff to boost producer price after rice production hit an all-time high of 36 million metric tons (mmt) in FY 2017/18. Such flexibility in trade policies is also perceived as useful from a food security perspective, and there are certainly important implications. For example, studies indicate that Madagascar's 2004 rice crisis was aggravated by the government's reluctance to lower import tariff rates [45,46].

Public food grain stock policy is another instrument that is intended to help maintain food security. Due to the inelasticity of food grain demand in the short run, even a small disruption in food grain output can cause massive fluctuation in the market price without the ready availability of government buffer stocks for price stabilization [47,48], at least in the absence of private stocks and fully liberalized trade. Under the current public stock policy, GoB seeks to stabilize food grain prices by responding to both positive and negative supply disturbances through food grain purchases and sales [49]. Goletti [50] stated that such interventions by the government influence market expectations about price. Del Ninno et al. [44] stated that despite smaller production shortfalls, the rise in nominal rice price was much bigger after the 1974 flood compared to the 1988 and 1998 floods as the government's ability to intervene in the domestic market was hampered by low public stock. Currently, GoB mandates maintaining a minimum public stock of 1 mmt of food grain to smooth out price volatility associated with supply disturbance and handle emergency offtake requirements [49].

Godfray et al. [51] stated that low yield results from a lack of technical knowledge, skills, or from constraints that limit investment in productivity-enhancing measures. Achieving yield improvements that close the gap between realized yield and the best possible yield is proposed by some as a factor that would contribute to improved food security [52]. The feasibility of such yield improvements and the cost of significant steps in this direction is unknown. For example, since the scope for production growth through area expansion is very limited, GoB has focused on improving current yield status through the adoption of the System of Rice Intensification (SRI), which involves better management of plants, soil, water, and nutrients [53]. Although important, we are not aware of any study that relates exact yield increase estimates and costs for this program.

3. Model Design, Elasticities, and Historical Data

3.1. Model Background

Since the trade liberalization in 1994, Bangladesh has consistently imported rice from the world market, as represented by the Thai export price. Such persistent trade indicates that changes in the world price might be transmitted to the domestic rice price through spatial arbitrage. Dorosh and Rashid [28] found evidence of long-run transmission from the subsidized below-poverty-line price of India to the domestic price during 2002–2007. Following Dorosh and Rashid [28], we employ the co-integration method to examine the spatial price linkage between Bangladesh domestic price and external price. We update the model with additional monthly data ranging from January 2000 to October 2020 and world reference price (Thailand free on board 5% broken rice). Our findings indicate that there exist at least two co-integrating relationships between Bangladesh and world price, implying a long-run equilibrium relationship (see online Supplement Tables S1–S3). However, the increase in the import tariff from 28% to 55% in FY 2019/20 proved to be high enough to eliminate import almost entirely. This indicates that such a tariff level can influence the correlation between domestic and world price and cause the Bangladesh rice market to be autarkic. Since the Bangladeshi rice market can switch between imports with tariff and autarky, it is important to utilize a partial equilibrium approach that can capture the equilibrium pricing conditions under different trade regimes. Therefore, we employ a partial equilibrium model that solves for market equilibrium price under import and autarky regimes.

3.2. Modeling Framework

The model developed here is a multi-equation partial equilibrium model and is divided into three blocks, namely: supply, demand, and price linkage. The blocks contain behavioral equations that are estimated based on the economic and production dynamics of the Bangladesh rice market, although key elasticities are drawn from the relevant literature (see online Supplement S1). Total domestic rice supply consists of production and beginning stocks. Production is estimated by multiplying total area planted and yield.

Total rice demand of Bangladesh is determined by domestic demand, seed, feed, and wastage, ending stock, and export supply. In this study, we divided net domestic demand (domestic demand minus seed, feed, and wastage) by the total population to obtain the per capita net domestic demand for rice. In the price linkage block, separate trade and price equations for different market regimes are estimated to formalize the relationship between world market prices, trade, and domestic prices.

Figures 1 and 2 depict the flow of the Bangladeshi rice market model's essential components with and without trade, respectively.

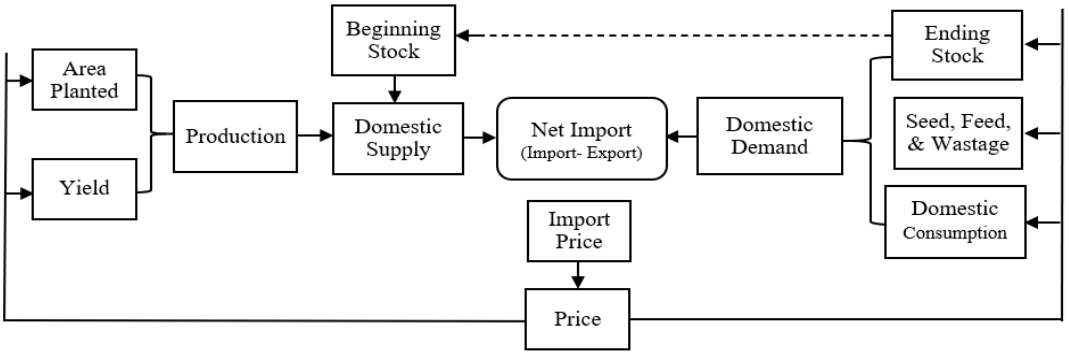

Figure 1. Model framework: import parity.

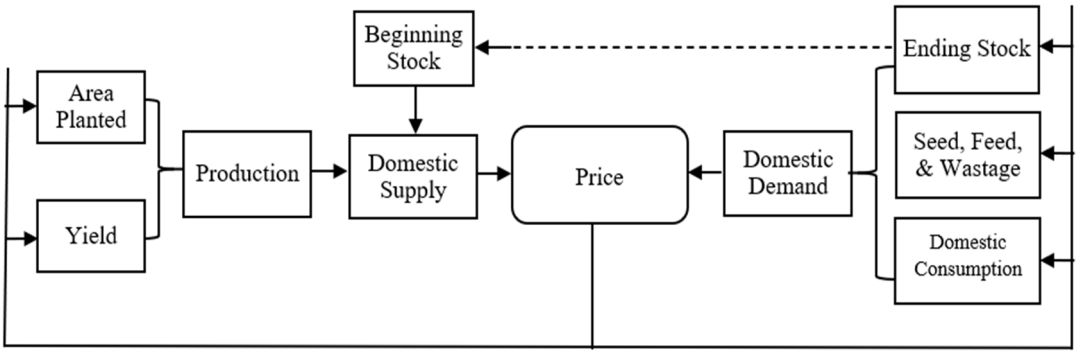

Figure 2. Model framework: autarky.

Under autarky, the model uses a price equilibrator framework to simulate equilibrium price through setting demand equal to supply. Unlike autarky, domestic price in import parity regime is determined by the world market price with the tariff and imports clear the market. The switching mechanism used in this model is triggered by the price levels and allows the model closure to switch between autarky and import parity. For example, the model switches to autarky when the import parity price stays above the autarky price. Similarly, the model closes on net trade when the import parity price is less than the autarky price.

3.3. Elasticity

The price and income elasticities of rice have not been estimated here; instead, they are borrowed from the existing literature. Table 1 reports elasticity estimates available in the relevant literature. As a rule, rice demand and supply are found to be inelastic with respect to rice price and income. Demand elasticities range fairly narrowly from –0.30 to –0.89, and supply elasticities run from 0.20 to 0.50. Income elasticities of rice demand are all positive in this literature, with values no lower than 0.30 and as high as 0.68, suggesting a fairly uniform view that this is normal, but a necessity with decreasing budget share as income rises.

Table 1. Elasticity estimates.

Author	Data Type	Demand Elasticity	Supply Elasticity	Income Elasticity
Hasan [54]	Survey		0.30	0.40 to 0.60
Hossain and Yunus [26]	Survey	–0.59 to –0.68		0.36 to 0.43
Dorosh and Rashid [28]	Literature survey	–0.30 to –0.50	0.20 to 0.30	0.30 to 0.50
World Bank [55]	Literature survey	–0.55 to –0.89	0.30 to 0.50	0.51 to 0.64
Del Ninno et al. [44]	Market	–0.45		0.35
Brennan [56]	Market	–0.50	0.40	
Ahmed and Shams [57]	Survey	–0.45		0.68

Source: Authors.

For this study, we use a value of –0.50 for demand own-price elasticity, 0.30 for supply elasticity with respect to rice returns per acre, and 0.40 for income elasticity of demand. Real price, returns, and income are used. These values correspond to the elasticities found in the literature, with greater weight given to studies that are more recent.

3.4. Data

To study the Bangladeshi rice market, we use national level and yearly data from various sources. The historical period used in this research is FY 1995/96 to FY 2019/20. This period is considered to provide an adequate number of observations that are representative of current market conditions, because the liberalization of agricultural imports in Bangladesh started in 1990, and import procedures were deregulated in 1994. Table 2 presents descriptive statistics for key supply and demand variables.

Table 2. Descriptive statistics.

Variable	Unit	Mean	Std. Dev	Min	Max
Area planted	thousand acres	27,041	1349	24,567	29,388
Yield	ton/acre	1.06	0.18	0.72	1.32
Imports	thousand metric ton	903	968	4	3889
Seed, feed and wastage	thousand metric ton	3237	953	1769	4647
Ending stocks	thousand metric ton	627	266	123	1256
Price	BDT */metric ton	20,953	8435	9820	37,570
Thailand 5% parboiled price	USD/metric ton	375	134	187	616

Note: * Bangladeshi Taka. Source: Authors.

Imports appear the most volatile component of supply if assessed by comparing the standard deviation to the mean, or comparing maximum and minimum values. However, domestic production is many times higher than imports, as implied by the product of mean area and mean yield. Although area and yield both vary, if assessed by the standard deviations, the ranges seem small as compared to the mean values. Most production and imports go to food use, but a share is assumed in the government statistics to go to seed and feed uses or waste. Demand-side variability is a mirror of domestic production because, although ending stocks could in principle moderate the impact of supply shocks on domestic use, the mean stock level represents a small share of the market quantities in historical data. The ranges of prices, both domestic and border, have been substantial in this period.

Market data, including production, area planted, yield, imports, feed and residual, ending stock, world market price (Thailand 5% parboiled rice price), and exports, were collected from the Food Planning and Monitoring Unit (FPMU) of the Ministry of Food of Bangladesh Government. Historical GDP, exchange rate, consumer price index, and population data were collected from the World Bank. Policy data, certainly including the import tariff rate, were collected from the Bangladesh Ministry of Agriculture, the International Fertilizer Development Center [58], and the World Trade Organization's Tariff Analysis Online database, respectively.

4. Food Security Indicators, Exogenous Assumptions, and Scenarios

4.1. Food Security Indicators

Food security is a broad term that includes both macro dimensions, such as price stability that ensures availability and access to food, and micro dimensions that allow individuals to produce or purchase food according to their dietary preferences. Our approach is focused on the macro dimensions of Bangladesh's food security, and thereby relevant to policymakers who consider the implications of their strategies for aggregate rice demand, supply, and price in terms of their food security implications. Thompson et al. [59] analyzed food security characteristics of developing countries using the macro food security dimensions, namely availability, stability, and accessibility. One concern is that the macro approach does not necessarily capture the underlying dynamics of food security between and within households. Nonetheless, macro analysis of food security is still crucial in that insufficient per capita food availability would affect the market price and, thereby, food access at the individual level [60]. Therefore, we measure the implications of market shocks for availability, stability, and accessibility dimensions of Bangladesh food security. GoB's national food policy plan of action also articulated food availability, supply stability, and access as core food security objectives [49].

Quantitative measures of the availability, accessibility, and stability dimension of food security that respond to markets, and more specifically to policy impacts on markets, require indicators. Ideally, each indicator reflects the characteristics of a specific dimension, and together a set of such indicators can provide an unbiased assessment of the impacts of policy options on food security. There are no definitive measures of food security dimensions. Thus, our proposed measures (Table 3) are developed based on the definition of these dimensions, variables widely used to represent market conditions, and previous studies that developed the framework for indicators of food security dimensions.

Table 3. Food security indicators.

Dimension	Indicators
Availability	Per capita consumption ratio
Accessibility	Real price ratio
Stability	Self-sufficiency ratio, stocks-to-consumption ratio

Source: Authors.

We use the per capita consumption ratio, a comparative indicator which measures the deviation of projection year per capita rice consumption from the base periods (FY 2017/18 to FY 2019/20) mean per capita consumption, for an indicator of availability [59]. Per capita income is a useful measure for the accessibility or economic affordability of food. Since GDP is exogenous to the model and no shocks are planned on this variable, we have not used per capita GDP as an indicator of accessibility despite its appropriateness. As an alternative, we use the ratio of projection year average real price relative to the average real price in the base period (FY 2018/19 to FY 2019/20) as a measure of accessibility as price relates to consumer's food accessibility. We use the self-sufficiency ratio and stocks-to-consumption ratio as measures of stability [59]. The self-sufficiency ratio is the ratio of domestic production relative to the available supply. The stocks-to-consumption ratio is an indicator of supply buffer by expressing what part of needs at going prices could be met through stock release in the event of a production or import shock.

4.2. Model Assumptions

Variables and assumptions used in the model include GDP growth to back-calculate nominal GDP level, yearly population growth, consumer price index (CPI) inflation (Bangladesh and the U.S.), and Thailand free on board (FOB) 5% broken rice (Table 4).

Table 4. Variables and assumptions.

Variable	With-COVID Simulation	Without-COVID Simulation
Real GDP growth	1.6% FY 2020/21 and 1% in FY 2021/22	7.8% in FY 2019/20 and 7.4% from FY 2020/21 onward
Population projections	UN's medium variant projections	Same as with-COVID model
CPI Bangladesh	5.7% in FY 2020/21 and 5.6% from FY 2021/22 onwards	5.5% from FY 2019/20 onwards
CPI U.S.	0.6% in FY 2020/21 and 2.2% from FY 2021/22 onwards	2.2% in FY 2019/20 and 2.3% from FY 2020/21 onwards
Exchange rate	Constructed based on the difference between Bangladesh and the U.S. consumer price	Same as with-COVID model
World price	Thailand 5% FOB Bangkok; forecasts are taken from World Bank's commodity markets outlook, April 2020	Thailand 5% FOB Bangkok; forecasts are taken from World Bank's commodity markets outlook, October 2019
Import tariff	55% from FY 2021/22 onward	Same as with-COVID model
Fertilizer subsidy	Moving average of past three years subsidy per ton	Same as with-COVID model

Source: International Monetary Fund [61,62], United Nations [63], and World Bank [64–67].

4.3. COVID-19 and Policy Scenario Analysis

In this section, we explain the assumptions and mechanisms used to analyze the impact of COVID-19 and the current policy environment on the Bangladesh rice market and food security.

COVID-19: To estimate the effect of COVID-19, we compare with- and without-COVID-19 results. Holding all else constant, we generate different baseline values by changing macroeconomic projections and world price to reflect the changing conditions caused by the pandemic. We do this by replacing projections (estimated by the World Bank and IMF as of October 2020) with forecasts made in January 2020 and October 2019.

Scenario 1—Import tariff: This scenario explores one mechanism that might be suggested by the self-sufficiency goal of the Seventh Five Year Plan (2016–2020) of the Bangladesh government [68], namely, increasing the import tariff to a level that eliminates arbitrage between domestic and world prices. At this tariff, import becomes nonexistent. In our policy experiment, we raise the current 55% import tariff to 90%; a rate that is not beyond the realm of possibility given past values, yet high enough to make import unfeasible.

Scenario 2—Public stocks: As of FY 2019/20, the public food grain storage capacity of Bangladesh stands at 2.3 mmt, and the GoB has a target of expanding public storage capacity to 3 mmt [69]. Moreover, IFPRI recommended a 2.4 mmt rice stock level to avoid shortfall as seen in 2007–2008 [28]. Under this scenario, we assume that over the next ten years, the GoB will gradually increase its rice stock to 3 mmt.

Scenario 3—Import tariff and public stocks: This scenario tests the combined effect of protectionist trade policy and greater rice stocks on Bangladesh rice market and food security.

Scenario 4—Yield gap closure: In this scenario, we explore the idea of ensuring food security by closing the gap between realized yield and attainable rice yield. Timsina et al. (2018) stated that Bangladesh's current rice yield is not enough to meet future demand [70]. They estimated that the average yield potential of three major rice crops of Bangladesh could be 3.51 tons/acre. Alam et al. [71] stated that the adoption of best management practices, along with appropriate nitrogen management options, could reduce the yield gap by 45%. Since we find no stated government policy goals for future rice production levels or estimates of yield increase as a result of current production enhancement programs, we use the estimate from Alam et al. [71]. We set the actual yield estimate to grow annually by 4.5% to simulate a 45% yield gap closure over the projection period.

We represent the above policy scenarios as though they are costless. Our primary objective is to quantify the shifts in the Bangladesh food security dimensions using these policy tools, not to evaluate these policies' costs or to provide a complete benefit-to-cost assessment.

5. Results

5.1. COVID-19 and Bangladesh's Rice Market

The results of the effect of COVID-19 on Bangladesh's rice market are reported in Table 5. To conserve space, we only report ex-post and ex-ante short and long-run effects.

Table 5. COVID-19 impact (% change relative to without-COVID-19 baseline).

	2019/20	2020/21	2021/22	2029/30	2030/31
Area	0%	–1%	–1%	3%	3%
Yield	0%	0%	0%	0%	0%
Production	0%	–1%	–1%	3%	4%
Net import	0%	0%	0%	–67%	–52%
Total domestic demand	0%	–1%	–1%	–2%	–2%
Ending stocks	–17%	0%	1%	–1%	–1%
Price/KG	–5%	–1%	–6%	10%	11%
Food security indicators (absolute change)					
Per capita consumption ratio	0.00	–0.01	–0.01	–0.03	–0.03
Real price ratio	–0.05	–0.01	–0.07	0.09	0.09
Self-sufficiency ratio	0.00	0.00	0.00	0.05	0.05
Stocks-to-consumption ratio	–0.01	0.00	0.00	0.00	0.00

Source: Authors' calculation.

We did not assume any shocks in FY 2019/20's rice area and yield, as monsoon season rainfed and dry season irrigated rice varieties are usually planted by early February. Therefore, no production effect is reported. The net import status of the country is also unaffected, mostly due to the prohibitive import tariff imposed at the onset of FY 2019/20, which pushed the world price above the autarkic price. Except for ending stock and price, COVID-19 appeared to have little to no impact (mostly zero or less than 1%) on the Bangladeshi rice market during FY 2019/20. Results (Table 4) show that domestic rice price in FY 2019/20 would have been 5% higher had there been no pandemic. Such a depressed rice price could be due to the dampened rice demand or the slow pace of the public rice procurement program due to lockdown, which contributed little to raise producers' price. Total domestic demand in FY 2019/20 increased slightly by 0.4%. This is mainly due to the low-income growth caused by COVID-19 related lockdown and mobility restrictions that imposed additional constraints on income-generating activities. The largest immediate impact is on ending stocks, at least in relative terms, which is 17% lower than in the case of without-COVID-19 levels. The modeled price response reflects how public stocks tend to be used. FAO (2020) reports that GoB's special open market operations sell rice at a subsidized price to vulnerable groups, which lends credence to this outcome [72]. As regards food security in FY 2019/20, COVID-19 had a much smaller impact on rice market food stability than on accessibility. The real price ratio dropped by 5%, indicating consumers improved access to rice. The stocks-to-consumption ratio declined marginally and could be explained by GoB's effort to stabilize the market by expanding targeted food grain distribution and relief programs that required the additional release of rice from public reserves.

The ex-ante short-run (FY 2020/21–FY 2021/22) effect of COVID-19 on rice production is negative, but in the long run (FY 2029/30–FY 2030/31), production increases by an average of 3%. The supply response occurring mostly through acreage change can be explained by the changes in domestic price. In the short run, price is determined endogenously in the domestic market, and no net import changes are reported. In the long run, domestic price trades at import parity level triggering demand for import. However, with-COVID-19, net imports are, on average, 60% smaller than that of the without-COVID-19 model. This is due to the relatively improved self-sufficiency caused by the fall in domestic demand

compared to without-COVID-19 levels during the projection periods. The dampening effect of eroding purchasing power due to income loss coupled with price hikes in later baseline years explains such a fall in domestic demand. On the other hand, the pandemic's effect on ending stock is relatively negligible and attributable to the domestic price change. With regard to food security indicators in the future, COVID-19 negatively affects rice availability, as per capita consumption of rice is projected to fall by an average of 2% during the projection period. The effect on rice accessibility is mixed, as the real price ratio improves in the short-run but reverses in the end by an average of 9%. The long-run self-sufficiency ratio increases by an average of 5%, indicating an improvement in rice market stability, whereas the stocks-to-consumption ratio remains unchanged.

5.2. Baseline Projections

A 10-year rice supply and demand outlook is developed for FY 2020/21 to 2030/31 with-COVID-19 macroeconomic and world price assumptions. We also assume normal weather and continuation of macro and trade policies in place in Autumn 2020.

The results (Table 6) indicate that rice production in Bangladesh is projected to reach 48 mmt in FY 2030/31, reflecting a gradual increase in acreage and yield during the projection period. A steady rise in nominal rice price from BDT (Bangladeshi Taka) 34/Kilogram (KG) in 2021/22 to BDT 57/KG in FY 2030/31 induces farmers to increase their land allocation, on average, by 0.6% annually. Influenced by higher domestic price and positive long-run trends, rice yield is also projected to increase from 1.4 ton/acre in FY 2021/22 to 1.6 ton/acre in FY 2030/31. Despite production improvements, a gradual increase in domestic demand fueled by positive income growth outpaces the increase in production. Although a continuation of the 55% import tariff appears to be sufficiently large to drive net import to zero until FY 2027/28, the evolving market conditions eventually cause the price to rise to the import parity level allowing trade to pass over the current tariff in the later baseline years. Net import and domestic demand reach 2.4 mmt and 50 mmt by FY 2030/31, respectively. Ending stock, on the other hand, remains steady around one mmt during the projection period.

Table 6. Baseline projections.

	2021/22	**2022/23**	**2023/24**	**2024/25**	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**
Area	28,427	28,516	28,572	28,929	29,234	29,432	29,647	29,912	30,110	30,099
Yield	1.36	1.39	1.41	1.44	1.46	1.49	1.52	1.54	1.56	1.59
Production	38,633	39,527	40,383	41,621	42,797	43,852	44,945	46,083	47,073	47,766
Net import	0	0	0	0	0	0	0	335	1292	2393
Total domestic demand	38,624	39,532	40,388	41,621	42,798	43,854	44,946	46,416	48,360	50,155
Ending stocks	1051	1046	1041	1041	1041	1039	1038	1039	1044	1047
Price/KG	34	37	40	43	45	48	52	54	55	57
	Food security indicators (absolute change)									
Per capita consumption ratio	0.98	0.99	1.00	1.02	1.04	1.06	1.08	1.11	1.15	1.19
Real price ratio	0.97	1.00	1.03	1.03	1.03	1.04	1.06	1.05	1.02	0.99
Self-sufficiency ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.97	0.95
Stocks-to-consumption ratio	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02

Source: Authors' calculation.

With regards to food security, rice availability appears to improve as the per capita consumption ratio increases from 0.98 in FY 2021/22 to 1.19 in FY 2030/31. Results for rice accessibility, proxied by the real price ratio, are mixed. The real price ratio increases during autarky years and reverses with the start of imports, implying net rice consumers' terms of access to rice will be positively affected by the change of trade regime. The effect of regime change is opposite for the stability dimension as the self-sufficiency ratio is projected to fall during the later baseline years. The stocks-to-consumption ratio, another proxy for Bangladesh's rice market stability, does not change significantly, only marginally decreasing from 0.03 in 2021/22 to 0.02 in 2030/31. It should be noted that such a trend in ending

stock is determined exclusively by the modeling approach, where we assumed domestic price is the key driver of the GoB's stock behavior. We considered alternative approaches, but the historical estimates of the impact of price on public stocks appeared to support this representation. We subject this assumption, as well as other policy assumptions, to additional analysis in the next section.

5.3. Scenario Analysis

5.3.1. Scenario 1: Import Tariff

Under this scenario, we increase the current 55% import tariff to 90%. The estimated effects of a high import tariff on the Bangladeshi rice market are reported in Table 7.

Table 7. Changes from baseline projections- higher import tariff.

	2021/22	2022/23	2029/30	2030/31
Area	0%	0%	0%	1%
Yield	0%	0%	0%	0%
Production	0%	0%	1%	2%
Net import	0%	0%	–100%	–100%
Total domestic demand	0%	0%	–2%	–3%
Ending stocks	0%	0%	–1%	–1%
Price/KG	0%	0%	6%	10%
Food security indicators (absolute change)				
Per capita consumption ratio	0.00	0.00	–0.03	–0.04
Real price ratio	0.00	0.00	0.06	0.10
Self-sufficiency ratio	0.00	0.00	0.03	0.05
Stocks-to-consumption ratio	0.00	0.00	0.00	0.00

Source: Authors' calculation.

No effects are reported in the early baseline years due to the absence of imports at that time since the tariff is already prohibitive. However, in the later years, a 90% import tariff eliminates net import, resulting in higher domestic production, lower domestic consumption, and lower ending stocks. Although tariff escalation improves the stability dimension, if judged based on the food security indicators presented here, the effects are negative for rice availability and accessibility. The findings are consistent with that of Minten et al. [45]. Compared to baseline values, the per capita consumption ratio is reduced by an average of 4%, and the real price ratio increases by an average of 8%, indicating the waning food security status of Bangladesh by these measures due to the higher import tariff.

5.3.2. Scenario 2: Public Stocks

In this scenario, we gradually increase the ending stock level to achieve the rice stock holding target of 3 mmt by FY 2030/31. Simulation results are reported in Table 8. It is important to note that some of the reported changes are big such as 170% increase in ending stock in FY 2029/30; this is due to the small baseline values and large relative changes.

The results show that shocks in public stocks increase the price by an average of 1%. In the long run, the domestic price is driven by the world price and arbitrage, independent of domestic supply and demand. Therefore, except for net import, no other changes are reported. However, looking at the food security indicators, we observe some improvements in the stability dimension, mainly due to the improvement in the stock level.

Table 8. Changes from baseline projections- public stocks.

	2021/22	2022/23	2029/30	2030/31
Area	0%	0%	0%	0%
Yield	0%	0%	0%	0%
Production	0%	0%	0%	0%
Net import	0%	0%	10%	7%
Total domestic demand	0%	0%	0%	0%
Ending stocks	33%	51%	170%	186%
Price/KG	1%	1%	0%	0%
Food security indicators (absolute change)				
Per capita consumption ratio	0.00	0.00	0.00	0.00
Real price ratio	0.01	0.01	0.00	0.00
Self-sufficiency ratio	0.00	0.00	0.00	0.00
Stocks-to-consumption ratio	0.01	0.01	0.04	0.04

Source: Authors' calculation.

5.3.3. Scenario 3: Import Tariff and Public Stocks

This scenario simulates the impact of the simultaneous implementation of a protectionist policy and stock build-up on the Bangladeshi rice market and food security. Results (Table 9) indicate that in the long run, Bangladesh's rice market switches from import parity to autarky in response to the dual shocks in tariff and stocks. Such shocks effectively eliminate trade and put downward pressure on domestic demand by raising the price.

Table 9. Changes from baseline projections- higher import tariff and public stocks.

	2021/22	2022/23	2029/30	2030/31
Area	0%	0%	0%	1%
Yield	0%	0%	0%	0%
Production	0%	0%	1%	2%
Net import	0%	0%	–100%	–100%
Total domestic demand	0%	0%	–2%	–3%
Ending stocks	17%	33%	170%	186%
Price/KG	1%	1%	7%	11%
Food security indicators (absolute change)				
Per capita consumption ratio	0.00	0.00	–0.03	–0.05
Real price ratio	0.01	0.01	0.07	0.11
Self-sufficiency ratio	0.00	0.00	0.03	0.05
Stocks-to-consumption ratio	0.01	0.02	0.04	0.05

Source: Authors' calculation.

With regard to food security indicators, rice availability and accessibility deteriorate as a consequence of protectionist measures and larger rice stockpiles. The per capita consumption ratio declines by an average of 4%; this is mainly due to the adjustment in rice consumption in order to buffer price shocks. The real price ratio increases by an average of 9%, leading to a fall in longer-run access to rice. The stability of Bangladesh food security is enhanced as both the self-sufficiency and stocks-to-consumption ratio improve relative to the baseline levels. The self-sufficiency ratio increases in the long run, indicating greater domestic supply and reduced dependency on trade for meeting demand. Gradual improvement in the stocks-to-consumption ratio indicates an enhancement in the GoB's capacity to cope with market demand and supply shocks.

5.3.4. Scenario 4: Yield Gap Closure

In this scenario, we implicitly assume that ongoing government initiatives (e.g., input subsidy, soil management, land improvement, extension services) to boost productivity affect rice yield positively. This hypothetical case assumes that such policies successfully increase rice yield and yet ignores the costs of these policies. Nevertheless, because

improved productivity is a stated goal, the implications for the rice market and food security are relevant.

Results (Table 10) indicate that domestic price decreases by an average of 6% in the first few years but remains unaffected in the later baseline years. This indicates that the effect of yield shocks on price is more pronounced when the market operates under autarky and has no price effect when arbitrage through trade links domestic and world price. The resultant decline in price triggers market adjustments, such as less acreage planted. Production, consumption, and ending stocks are greater in these early years. Domestic price in later baseline years is predetermined by the world price, so no response in price is possible since downward pressure caused by greater production affects the amount traded rather than global rice prices. In the absence of price shocks, changes in domestic supply or demand relative to the baseline are not expected. Nonetheless, the long-run negative acreage response found here is not contrary to the theoretical expectations. There are delays between price changes and eventual crop production due to evolving expectations and lags inherent in crop production. As such, the lower crop returns in the early years cause sustained area reduction relative to the baseline. However, the area effects are dissipating by the end of the projection period and would likely reverse in time if producers were motivated by the combination of higher yield and unchanged price to plant more rice area than in the baseline.

Table 10. Changes from baseline projections- yield gap closure.

	2021/22	**2022/23**	**2029/30**	**2030/31**
Area	–1%	–2%	–2%	–1%
Yield	4%	4%	5%	5%
Production	3%	2%	3%	4%
Net import	0%	0%	–94%	–67%
Total domestic demand	3%	2%	0%	0%
Ending stocks	1%	1%	0%	0%
Price/KG	–7%	–5%	0%	0%
Food security indicators (absolute change)				
Per capita consumption ratio	0.03	0.02	0.00	0.00
Real price ratio	–0.07	–0.05	0.00	0.00
Self-sufficiency ratio	0.00	0.00	0.03	0.03
Stocks-to-consumption ratio	0.00	0.00	0.00	0.00

Source: Authors' calculation.

In the short run, the positive yield shock improves rice availability and accessibility. The per capita consumption ratio increases by an average of 3%, and the real price ratio drops by 6%, indicating an expansion in rice consumption and improved market access. Regarding long-run food security, the rise in the self-sufficiency ratio indicates an improvement in the rice market stability.

5.4. Pandemic, Policies, and Bangladesh Food Security

This section evaluates the impact of a hypothetical pandemic on Bangladeshi food security in the event that the policies mentioned above are put in place. We do this by replicating shocks, similar to COVID-19 in FY 2027/28 and FY 2028/29 in terms of macroeconomic variables and world price effects. In other words, we estimate the impacts of another, similar pandemic on the Bangladesh rice market with each of these policies in place as well as without any of them implemented. The hypothetical future pandemic is represented by repeating the percent changes in macroeconomic variables and world rice prices that our data sources estimate in FY 2019/20 and FY 2020/20 in the future period. Table 11 reports changes in food security indicators caused by a hypothetical pandemic starting in FY 2027/28 with and without the above listed policies in place. Detailed results are outlined in Supplement Tables S4–S6. Results indicate that the hypothetical pandemic without policy changes shifts the trade regime from import parity to autarky,

puts downward pressure on domestic production, consumption, and price, and increases ending stocks. The last year effects are, however, different because the lower prices lead to less area as compared to the baseline, which after being priced out of world markets, combines to raise the domestic price as compared to baseline levels. Since the Bangladeshi rice market becomes autarkic due to the hypothetical pandemic, we only considered policy options (public stockholding and yield gap closure) that can influence price when determined by domestic supply and demand.

Table 11. Food security, hypothetical future pandemic, and policies–% change relative to baseline.

Hypothetical future pandemic—no pre-existing policy				
	2027/28	2028/29	2029/30	2030/31
Per capita consumption ratio	0%	–2%	–5%	–7%
Real price ratio	–5%	–9%	–2%	3%
Self-sufficiency ratio	0%	1%	3%	5%
Stocks-to-consumption ratio	1%	3%	6%	7%
Hypothetical future pandemic—pre-existing stock policy				
Per capita consumption ratio	0%	–2%	–5%	–7%
Real price ratio	–4%	–8%	–1%	4%
Self-sufficiency ratio	0%	1%	3%	5%
Stocks-to-consumption ratio	139%	160%	186%	209%
Hypothetical future pandemic—pre-existing yield gap closure policy				
Per capita consumption ratio	2%	0%	–3%	–5%
Real price ratio	–10%	–14%	–7%	–2%
Self-sufficiency ratio	0%	1%	3%	5%
Stocks-to-consumption ratio	0%	2%	4%	6%

Source: Authors' calculation.

Table 11 (hypothetical future pandemic: no pre-existing policy) indicates that during the period FY 2027/28 to FY 2030/31, the per capita consumption ratio and real price ratio decrease by an average of 4% and 3%, respectively. The self-sufficiency ratio and stocks-to-consumption ratio, on the other hand, increase by an average of 2% and 4%. The table (hypothetical future pandemic- pre-existing stock policy scenario) also shows a pre-existing stock policy improves only rice stability, not rice availability or accessibility when compared to estimates obtained under no policy or production enhancement policy scenario. A pre-existing production enhancement policy, on the other hand, better smooths the effect of the pandemic on rice availability and accessibility as the per capita consumption ratio and real price ratio decrease by an average of 1% and 9%, respectively. Furthermore, with the exception of the stocks-to-consumption ratio under the stock policy scenario, such a policy yields estimates of the stability indicators, which is quite similar to that of estimated under other scenarios.

6. Conclusions

This paper analyzed the impacts of COVID-19 on the Bangladeshi rice market within the framework of a partial equilibrium regime-switching model, and is the first such exercise of which we are aware. We provided an initial estimate of the short- and long-run effects of COVID-19 on the Bangladeshi rice market and food security sustainability by comparing baseline projections. We analyzed the effect of shocks in policies related to trade, public stock, and productivity on rice supply, demand, and food security dimensions. Finally, we assessed the effectiveness of these policies to smooth out shocks that may arise from a future pandemic similar to COVID-19.

The analysis showed that COVID-19 causes a shift in the rice trade regime, supply, and demand in the coming years. We found that the pandemic has had a mixed impact on the Bangladeshi rice market and food security. The short-run domestic prices are lower than they would be otherwise. Long-term prospects for post-COVID-19 rice supply, demand,

and trade indicate a weakened Bangladeshi food security. Income shocks reduce per capita domestic demand during the projection period. The lower short-run prices cause sluggish production growth in later years, which, when combined with slower but continued growth in domestic demand, result in a higher price in later baseline years. COVID-19 improves self-sufficiency in rice by causing a reduction in imports. With regards to aggregate food security, the findings appear mixed. Rice availability improves due to the rise in per capita consumption. The real rice price remains relatively constant, indicating access to rice is not jeopardized during the projection period given the assumptions. However, the rice market stability indicators deteriorate largely due to the rise in imports in the later baseline years and slow public stock growth.

With regard to policy experiments, a higher import tariff helps to improve self-sufficiency status but undermines rice availability and accessibility by bending the market toward a restrictive trade regime. The experiment with public stock policy reveals that increasing the ending stock incrementally, even up to the targeted level of 3 mmt, has limited implications for rice market fundamentals and food security indicators, particularly as long as stocks can be increased through greater imports. The results also indicate that having such a policy does not necessarily provide a large buffer against future market disruptions stemming from an event with repercussions similar to COVID-19. Conversely, combining public stock and import tariff policy was shown to improve rice market stability, however doing so also curbs the consumer demand by raising the domestic price. The results of the yield gap closure scenario indicate that closing the yield positively affects rice availability, accessibility, and stability and hence improves the short- and long-run food security of Bangladesh. The analysis also shows that such a policy better insulates the Bangladesh rice market from the depressing effect of a COVID-19 like pandemic compared to other scenarios considered. However, as noted earlier, policies that successfully increase yields could be costly and have apparently been elusive.

Bangladesh's food security has already been challenged by growing population, reduced acreage supply, and climate change [73,74]. COVID-19, however, posed policy challenges that policymakers have not experienced before, namely responding simultaneously to demand-side shocks triggered by declining income levels and to supply-side shocks caused by disruption in trade. Apart from relying on short-run policies such as expanding social safety net programs to deal with transitory food insecurity, policymakers may also focus on long-run food and trade policies to sustain food security and build resilience against future shocks. Policy recommendations aligned with the findings of this study are to recognize the scope for an open trade regime that permits rice imports to offset domestic production shortages and price volatility, to bear in mind the potential for productivity improvement to bridge the supply gap between demand and domestic production, and to balance the benefits from strategic grain reserves in terms of stabilizing prices and consumption with the cost of rice procurement, storage, and administration. Our modeling approach provides an objective assessment of rice market's fundamentals and the current policy environment. Nonetheless, there are limitations to our study and certain improvements can be made for a more nuanced assessment. For example, future research efforts could focus on capturing the impact of relevant economy-wide distortions on the Bangladeshi rice market and the dynamics between this market and other agricultural and non-agricultural sectors. Future research that aims to contribute to evidence-based policy decision-making could also consider distortionary and fiscal costs of policy interventions. To summarize, while there are limits to our assessment, this research can help concerned stakeholders, especially policymakers, to better understand the dynamics of the Bangladeshi rice market as well as improve the debate over policy choices to achieve goals relating to the food security of Bangladesh. More importantly, the insights generated can help devise policy options that aim to build resilience against shocks akin to COVID-19. Results for this case might be relevant for other developing countries whose staple foods are provided through a combination of domestic production and imports.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su13115981/s1, S1: Rice supply; S1: Rice demand; S1: Model closure; Table S1: Augmented Dickey–Fuller test for unit root; Table S2: Lag length selection; Table S3: Co-integration test: Bangladesh price & Thai 5% parboiled price; Table S4: Hypothetical future pandemic, no policy changes (% change relative to baseline); Table S5: Hypothetical future pandemic with pre-existing public stock policy (% change relative to baseline); Table S6: Impacts of a hypothetical future pandemic with pre-existing yield gap closure policy (% change relative to baseline).

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