

Fifty Years of Agricultural Development in Bangladesh: A Comparison with India and Pakistan

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The final publication is available at Springer via

<http://dx.doi.org/10.1007/s43546-022-00240-3>

Permanent link to this version <https://hdl.handle.net/20.500.14078/2740>

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Abstract

Since its independence in 1971, Bangladesh has made remarkable economic progress, evolving from a low-income to a lower-middle-income country. Its agricultural sector remains essential for the economy and food and nutrition requirements despite having a gradually declining share of GDP and employment. This paper examined various aspects of the agricultural growth of Bangladesh using different forms of analysis, including the use of a log-linear Cobb-Douglas production function. Empirical models include the ordinary least squares (OLS) method for investigating the agricultural growth in Bangladesh since independence and the generalized least square (GLS) method for the cross-country comparison with India and Pakistan. We observe that Bangladesh underwent a typical sectoral transformation in employment and GDP growth, transferring labor from the low-productive agriculture sector to the high-productive manufacturing and service sectors. Such a transformation was due to the increasing surplus labor in the agriculture sector because of growing mechanization as well as the increased labor demand from rural off-farm activities and manufacturing and service sectors, resulting in enhanced rural wages and standard of living. The agriculture sector of Bangladesh, despite its continuously declining contribution to GDP, remains vital for sustained food and nutrition security and economic growth. The low values of calculated output elasticities from our regression results imply a limited growth possibility with the existing technology. Despite this and several other constraints, the agriculture sector has potential for growth by developing and adopting appropriate technology and realizing efficiency gains from proper input and output mixes. These need to be supported by appropriate policies and institutions. As land is a major constraint, less land-intensive subsectors like livestock and poultry should also be explored among the possible policy recommendations.

Key Words: Agricultural development, Bangladesh, Production function, Productivity growth

JEL Classification : Q10, Q11, Q16, Q18

1. Introduction

Bangladesh gained independence 50 years ago in 1971 from Pakistan. The new nation, Bangladesh, ravaged by the war of independence, natural disasters, and famines, was predicted to fail economically by many western policymakers. Indeed, it was famously called a “bottomless basket” by Henry Kissinger, the then US Secretary of State (Sen 2013). From that perspective, Bangladesh has made notable economic progress since its inception (Ahluwalia and Hussain 2004; ADB-ILO 2016) and surged forward from a low-income country to a lower-middle-income country. The GDP growth rate of Bangladesh increased from 2 – 3 percent in the 1970s to 7 – 8 percent in the 2010s (Raihan and Khan 2020). Along with its economic progress, Bangladesh has been able to reduce poverty (Gautam and Faruquee 2016; Hill and Cevallos 2019; Raihan and Khan 2020) and improve food security (Bose and Dey 2007; Mainuddin and Kirby 2015; Osmani et al. 2016; Begum et al. 2013; GOB 2020).

Agriculture is regarded as the backbone of Bangladesh’s economy, although its share of contribution to gross domestic product (GDP) continues to decline, reaching as low as 12.68 percent in 2019 (World Bank 2021a). Many empirical studies suggest that agricultural development is a prerequisite for economic progress. An increase in agricultural productivity is essential for the successful development of industrial and service sectors (Rostow 1959). In most developed Western countries [England, for example], the early stage of industrial development relied on increasing domestic agricultural production (Islam 2017; Ansari and Khan 2018). At an early stage of development, growth in the agriculture sector allows for an increase in production with a declining labor force. The excess labor from agriculture moves to more productive sectors helping the latter expand (Lewis 1954), a structural transformation.

The development of Bangladesh seems to follow a typical structural transformation, moving surplus labor away from agriculture to manufacturing and service sectors (Lewis 1954). Such a change is considered essential for the economic development of a nation (Ansari and Khan 2018). The basic tenet of structural transformation is the transfer of labor from the low-productive sector (agriculture) to the high-productive sector (manufacturing and service). Increased productivity through mechanization in the agriculture sector (Hossain et al., 2012; Rahman et al., 2021) creates surplus labor and dampens the real wages of agricultural workers (Taslim and Taslim 2018). However, Zhang et al. (2014) observe rising real wages in rural Bangladesh, seemingly contradicting the surplus labor hypothesis. One reason for the rising wage rate could be the booming manufacturing sector (Kabeer and Mahmud, 2004), especially readymade garments, which employs four million people (BBS 2021), causing surplus labor in the agriculture sector to decrease

and the wage rate to increase. Such rising rural real wage is not due to the increase in the marginal productivity of labor (Zhang et al. 2014). Rather, it is due to the growing employment demand in the non-farm sector, a model originally formulated by Arthur Lewis in 1954. Alternative job opportunities for low-skilled workers in the non-farm sector offer them higher bargaining power. Another reason behind the rising rural wage is increasing public spending on social safety net programs, where the poor receive transfer payments from the government [i.e., 100-day employment program¹]. The expansion of microfinance institutions², where rural poor have access to financial resources, also entices them to non-farm sectors (Zhang et al. 2014), also helped increase the rural wage.

Rapid urbanization and industrialization lead many rural households to engage in non-farm activities (Sen et al. 2021). Part of the rural labor force moves out of the country for a better life, reducing the pressure on the domestic labor market (ADB-ILO 2016). In the agriculture sector, though, the increasing adoption of modern varieties and mechanization technologies continues to replace labor. The net impact is an increase in the wage rate. Two hypotheses – subsistence and efficiency wages – as Ahmed (1981) advanced, are not sufficient to explain such a wage premium. Instead, some structural factors are needed. Based on data from 1973 to 1995, Raihana (2013) observes that labor input has been increasingly substituted by fertilizer and irrigation, contributing to surplus labor. In addition, agriculture is a land-dependent sector that exhibits diminishing returns to investment (Islam 2017), indicating that economic growth through the agriculture sector has a limit. The demand-side theory behind such a structural shift is that an increase in income intensifies the demand for agricultural products less proportionately than manufacturing and service products (Fisher 1939; Clark 1957). However, the structural transformation varies from economy to economy, and the economic development primarily comes from non-agricultural sectors, i.e., manufacturing and service sectors. All researchers do not universally share this view of emphasizing the non-agricultural sector for economic growth.

¹ Bangladesh has been implementing many safety-net programs which include both cash and in-kind contributions to the poor. The 100-day Employment Generation Program (100-DEGP) is one such program initiated in 2008. Food for Work was another well-known program introduced in 1975 (Osmani and Chowdhury 1983; Zhang et al. 2014; Mannan et al. 2018). In 2015, the Government of Bangladesh announced a comprehensive National Social Security Strategy (NSSS) to ensure a comprehensive social protection system for all (Khatun and Saadat 2020) and an important theme of the 8th Five Year Plan is “A broad-based strategy of inclusiveness with a view to empowering every citizen to participate fully and benefit from the development process and helping the poor and vulnerable with social protection-based income transfer;” (GED 2020).

² Microfinance has been prevalent in Bangladesh. Since the establishment of Grameen Bank in 1983, both the number of subscribers and the number of disbursements increased exponentially (Khandker et al. 2016; Khan and Malik 2020). Khandker and Koolwal (2016) show that microcredit benefits low-income households by increasing agricultural income through livestock and off-farm income, but not crop income indicating an outward push of rural labor from agriculture.

Tiffin and Irz (2006), analyzing the contribution of agriculture to economic growth in 85 countries, conclude that agriculture is the causal variable of economic growth in developing countries but not necessarily in developed countries. Gardner (2005), on the other hand, states that the development of agriculture is independent of per capita GDP growth and neither necessary nor sufficient for the growth of different sectors. Tsakok and Gardner (2007), examining the development of the UK, USA, Korea, and China, determine that agriculture's contribution is not universal. Instead, it depends on a case-by-case basis. For Bangladesh, Islam et al. (2020) conclude that both the agriculture and manufacturing sectors contribute to economic growth.

Agriculture plays a vital role in reducing rural poverty and in maintaining employment, but not uniformly in all nations or at all times. In general, increases in agricultural productivity affect both employment and wage rate. For example, in India, agricultural yield growth is credited for poverty reduction (Datt and Ravallion 1998) but discredited for worsening income inequality among rural farmers (Foster and Rosenzweig 2004). In Bangladesh, Emran and Shilpi (2018), examining the Upazila (subdistrict) level data from three household expenditure surveys (2000, 2005, and 2010), postulate that a decline in employment in agriculture worsened poverty and inequality as the poor people in rural areas disproportionately depend on agriculture. The percentage of employment in agriculture declined from 69.1 in 1991 to 38.30 in 2019 (World Bank 2021a). This decline in employment share does not indicate that agriculture is becoming less important. Instead, it implies a reduction in surplus labor in agriculture, allowing other sectors, i.e., manufacturing and service industries, to grow. Sen et al. (2021) find the structural shift of household employment from agriculture to other sectors, and the migration is more prominent in rural areas than in urban centers. Earlier, Abdullah (1998) attributed the microcredit program as the pioneer of employment generation and poverty reduction.

In Bangladesh, the agriculture sector remains the vital source for providing food and nutrition security despite the declining trend of available land for cultivation, increasing population, and progressively adverse production environments due to climate change and salinity problems. The growth of the agriculture sector has turned Bangladesh from a chronic food-deficit country to a nearly food-sufficient one despite the rapid growth of population (GOB 2020). Net total food grain production continues to increase, and at the turn of the century, it surpasses the food grain requirement (Ara and Ostendorf 2017). Per capita availability of food and nutrition also increases which leads to a continuous decline in child malnutrition as indicated by stunting and underweight children (Osmani et al. 2016). The progress of the agriculture sector is driven by intensive crop, livestock, and fish farming. Some contributing factors to

this intensification are improved varieties and breeds, modern production and management technologies, diversified production systems, and better government policies and institutions. This increase in agricultural productivity helps toward the goal of achieving food and nutrition security. Availability of per capita nutrition has increased, and the percentage of the population undernourished has decreased. Similarly, the proportion of the population under poverty has also shown an overall declining trend (World Bank 2021).

Bangladesh's agriculture policy has been directed toward increasing food security and reducing poverty. Very little attention has been placed on examining the agriculture sector's role in improving economic growth. There was no national agriculture policy during the first several years after independence. Although many specific policies focusing on narrow areas of agriculture and rural development were present, nationally coordinated policies for comprehensive development were absent (MOA 2006). The first national agriculture policy was formulated in 1999, focusing primarily on crop production. The stated objective was “*to make the nation self-sufficient in food through increasing production of all crops including cereals and ensure a dependable food security system for all*” (MOA1999). Even the latest national agriculture policy of 2018 focuses on the crop sector only with the primary goal “*to achieve safe, profitable agriculture and sustainable food and nutrition security*” (MOA 2018). The agriculture sector must diversify with the aim being not just achieving food security but also expanding employment and contributing to economic growth. Islam et al. (2018), analyzing data from integrated household surveys, observe that farm diversification is directly related to diet diversity and nutrition security.

Despite improving many aspects of food and nutrition security, Bangladesh still experiences substantial poverty and a lack of food and dietary diversity. In addition, what policies are appropriate to allow the agriculture sector to contribute more to the economic growth of Bangladesh have not been explored fully. In this context, the following questions are pertinent. Can the agriculture sector maintain its productivity in the future to improve food and nutrition security and economic growth? Will the trend of food and nutrition security and economic development be sustained? What are the policy options that can help solve these questions? To the best of our knowledge, there is no comprehensive study in answering such questions concentrating on the entire history of the agriculture sector in Bangladesh (since 1971), although there are studies that cover specific periods (i.e., Ahmed 1988; Hossain 1984; Miah et al. 2020).

A comparison of the agriculture sector of Bangladesh with that of its neighboring countries may be worth examining. India surrounds Bangladesh geographically, and both countries have similar cultures, environments, and institutions. Bangladesh also has a historical tie with Pakistan as it was a province of Pakistan during 1947 – 1971. In fact, before 1947, the entire region [what we call Indian Subcontinent today] was part of British India. Therefore, it makes sense to compare the performance of the agriculture sector in Bangladesh with that of India and Pakistan. To our knowledge, there is little documentation on the development of the agriculture sector in Bangladesh in comparison with that of India and Pakistan, especially looking at the entire 50-year period. This study is expected to fill that gap as well.

The specific objectives of this study are to examine: how different agricultural production components have evolved during the last half a century, how successful the agricultural production components have been in providing food and nutrition security and economic growth of the nation, which inputs were more effective than others in the development of crop production, what is the performance of the agriculture sector in Bangladesh relative to India and Pakistan, and what strategies the Government of Bangladesh should follow for sustained agricultural development. This paper offers an overview of the agricultural development in Bangladesh, compares it with that in India and Pakistan, and recommends policies that Bangladesh should follow to ensure sustained agricultural growth to satisfy the basic food and nutrition needs of its people and diversify and improve economic growth.

The rest of the paper is organized as follows. Section 2 briefly describes the methods, data sources, and empirical models employed in this research. Section 3 lays out the evolutionary development of different components of the agriculture sector [crop, livestock, and fish] and identifies potential areas for improvement. Section 4 compares the performance of the agriculture sector of Bangladesh with that of India and Pakistan, focusing on the crop sector only. Section 5 concludes and makes recommendations for further improvement for sustainable agricultural development in Bangladesh.

2. Methodology

We begin with a sketch of the existing literature on the trend of agricultural development of Bangladesh over the past 50 years. Studying the available data, we present overall progress on the three key subsectors – crop, livestock, and fisheries.

Since Bangladesh suffered from a terrible famine during the early years of independence, the crop sector, especially rice, the main food crop for the people of Bangladesh, was important. We have examined the contribution of different inputs in the production of crop, in general, and that of rice. More specifically, we have considered a log-linear production function with the Ordinary Least Squares (OLS) regression model to examine the effect of different inputs on crop and rice production. To make cross-country comparisons of the performance of the crop sectors among Bangladesh, India, and Pakistan, we used a Generalized Least Squares (GLS) model. We offered a brief exposition of the role of agriculture in nutrition security, environment, economic growth, and trade and policies. We also compared the development of the agricultural sector and economic growth in Bangladesh with that of India and Pakistan.

2.1. Data

We have used secondary data from various sources, including FAOSTAT, World Development Indicators of the World Bank database, Our World in Data, and the International Labour Organization. We have also considered some government agency reports of Bangladesh like multiple issues of the Statistical Yearbook of Bangladesh, Fisheries Statistical Yearbook of Bangladesh, Statistical Reports from Bangladesh Bureau of Statistics, and other published and non-published sources. Information from other government documents, i.e., Five-Year Plans, departmental reports, etc. were also consulted. Much of the annual data series used in this study begins in 1961. However, in some cases, electronic data were not available before 1991, and we obtained data from some hard copy records. Although we tried our best to create a comprehensive database covering the entire period of 50 years, we could not find data for the entire period for some variables and for all three countries. As one can imagine, 1971 was the year of Bangladesh's War of Independence, not much statistical data were collected in that year, and we have used the figures reported in FAOSTAT. Data on agriculture, crop, cereal crops, and livestock production in index forms (2014-16 = 100) are all obtained from FAOSTAT. Data on other variables are in actual quantities³.

2.2. Model Specification

³ Data on pesticide in Pakistan are obtained from several published sources including Tariq et al. (2007), Khooharo et al. (2008) and Khan et al. (2020). Data unavailable for few years were interpolated from the existing ones.

We used an OLS regression model to estimate the production function representing the impact of different inputs on the aggregate crop and rice output. We made use of the Cobb-Douglas (C-D) production function to model the relationship between the output (dependent variable) and the inputs (independent variables) as follows:

$$Y_t = AX_{1t}^{\beta_1} \cdot X_{2t}^{\beta_2} \cdot X_{3t}^{\beta_3} \dots X_{nt}^{\beta_n} \varepsilon_t; \quad (1)$$

where, Y_t is total output in period t , A is the technology parameter, X_{it} is the amount of input i used in period t , β_i is the partial elasticity of input i , and ε_t is a multiplicative error term. We transform the C-D production function (Equation 1) to a log-linear OLS regression model, as is common in the literature (e.g., Hayami and Ruttan 1970). In general, OLS method provides the most efficient estimates for measuring the growth rates of variables and the elasticity of output with respect to a particular input (e.g., labor, land, capital, etc.) (Greene 2012; Ramírez et al. 2002). Following our log-linear transformation, the empirical model representing the C-D production function is

$$\ln Y_t = \ln A + \beta_1 \ln X_{1t} + \beta_2 \ln X_{2t} + \dots + \beta_n \ln X_{nt} + u_t. \quad (2)$$

where $u_t (= \ln \varepsilon_t)$ is the error term with mean 0 and variance σ_u^2 .

We used land, labor, irrigation, three types of fertilizers, namely nitrogen (N), phosphorus (P) and potassium (K), as well as pesticides as inputs to identify their impact on output – crop and rice. Therefore, the log-linear model of the production function can be re-written as follows:

$$\begin{aligned} \ln Y_t = \ln A + \beta_1 \ln X_{t(\text{Land})} + \beta_2 \ln X_{t(\text{Labour})} + \beta_3 \ln X_{t(\text{irrigation})} + \beta_4 \ln X_{t(\text{Fertilizer}_N)} \\ + \beta_5 \ln X_{t(\text{Fertilizer}_P)} + \beta_6 \ln X_{t(\text{Fertilizer}_K)} + \beta_7 \ln X_{t(\text{pesticides})} + u_t; \end{aligned} \quad (3)$$

Assuming normally, independently, and identically distributed errors, we estimated the β 's for the production functions for both crop and rice using the OLS method with a robust variance estimator (Greene 2012). Two models were estimated, one with a time trend as an explanatory variable to address the presence of possible autocorrelation in data and one without time trend. Durbin's alternative test was also conducted to check the presence of serial correlation in each model (Durbin 2012).

As is commonly done, we tested for multicollinearity among the independent variables. As expected, multicollinearity was present among some of the independent variables (e.g., three fertilizers: Nitrogen, Potassium, and Phosphorus). We ran a similar OLS regression by combining the three fertilizers as a single input while keeping the other

explanatory variables the same in the respective models. The estimated coefficients (using the combined fertilizers) showed similar signs (not reported in the paper).

We compare the impact of some of the inputs on cereal cop production by extending our empirical model to include India and Pakistan. A generalized least squares (GLS) regression model (Equation 4) provides a cross-country comparison of the cereal crop production functions using Bangladesh as the base case. We use cereal crops instead of rice as we did in the case of Bangladesh since rice is not the prevalent crop in some parts of India and Pakistan. We used the generalized least square (GLS) regression models incorporating panel data structure (Greene 2018) for cross-country comparisons between Bangladesh, India, and Pakistan. The underlying empirical model we followed is:

$$\ln Y_{jt} = \ln A + \beta_1 \ln X_{jt(\text{Land})} + \beta_2 \ln X_{jt(\text{Labour})} + \beta_3 \ln X_{jt(\text{irrigation})} + \beta_4 \ln X_{jt(\text{Fertilizer}_N)} + \beta_5 \ln X_{jt(\text{Fertilizer}_P)} + \beta_6 \ln X_{jt(\text{Fertilizer}_K)} + \beta_7 \ln X_{jt(\text{pesticides})} + \alpha_j \text{Country}_j + u_{jt}; \quad (4)$$

where $j=1, 2, \dots, m$ is the number of panels ($m=3$ countries) and $t=1, 2, \dots, T$ is the number of observations in panel j (28 years from 1991 to 2018). Due to issues related to data availability for the two-stage GLS models, our selected period is 1991-2018 for this cross-country regression analysis.

We assumed two different scenarios for the variance-covariance estimation of u_{jt} as expressed in two models – Models 3 and 4. The former provides the estimates of β 's and α 's (in equation 4), using a two-stage GLS model with heteroskedastic but uncorrelated errors across panels. Since there was evidence of first-order autocorrelation in the regression estimation of crops, we used a three-stage GLS with heteroskedastic and panel-specific AR (1) autocorrelation structure to deal with that (Greene 2018).

3. Agriculture in Bangladesh

Historically, the agriculture sector has been the lifeblood of the people of Bangladesh. It has been the principal provider of fuel, food, nutrition, shelter, recreation, and many other amenities (Ahmed 1988; Hossain et al. 1990; Islam 1998). At one time, most of the population was involved in agricultural production, primarily with subsistence farming. The farm household had at their disposal certain physical [land, machinery, water, seed, etc.], biological [farm animal and human labor], and institutional [legal, procedural, and social systems] resources. Typically, the activities of a rural farm in Bangladesh include using these resources and producing crops, raising livestock and

poultry, culturing and capturing fish, collecting fuelwood, growing fast-growing plants for fuel, etc. (Hossain 1989; Hossain et al. 1990). There were few marketing and international trade activities. The profit and entrepreneurial motives were absent, and consequently, private innovation in farming was lacking. Over time, the situation has evolved. Slowly, mixed farming has shifted toward mono-farming and more intensive agriculture and commercial farming with profit and entrepreneurial motives. This section provides an overview of the agriculture sector for the last 50 years. Specifically, we would like to address the following: growth of agricultural productivity, technological innovation and adoption in agriculture, the relationship of agriculture with food and nutrition security, the interaction of agriculture with the environment responding to global climate change, and the contribution of agriculture to economic development.

3.1. Agricultural productivity

During the past 50 years, total agricultural productivity has increased by 265 percent and per capita productivity by 50 percent since 1971. The production of the crop subsector continues to grow; especially rice production has increased by 266 percent with a per capita increase of 47 percent, and wheat production has increased by 800 percent with a per capita increase of 265 percent). The cereal crop yield has increased by 202 percent during this period [Fig. 1]. However, the production of some minor crops has decreased contributing to lowering crop diversity.

Bangladesh is one of the most densely populated countries in the world [an average of 1239.58 people per square kilometer in 2018 compared to the world average of only 58.42]. It has experienced little opportunity to expand its area of production (World Bank 2021a). The net cropped area of Bangladesh has decreased by 5.42 percent, with a per capita land area reduction of 62 percent since independence due to urbanization, industrialization, and infrastructure development (FAO 2021). Accordingly, Bangladesh has concentrated on the vertical increase of agricultural production by boosting individual crop yields and incorporating multiple sequential cropping in a year, taking advantage of its year-round growing season. Analyzing 34 years of data, Anik et al. (2017) observe that Bangladesh experiences the highest productivity growth (1.05 percent) among South Asian countries, followed by India (0.52 percent). Bagchi et al. (2019), evaluating regional productivity for 19 regions of Bangladesh for 23 years, see a modest productivity growth of Bangladesh (only 0.03 percent) and noted regional disparities.

[Fig.1 around here]

The crop subsector heavily dominates the agriculture sector in Bangladesh. In Figure 1, the blue line representing the index of the agriculture sector is almost entirely covered by the pink line representing the crop subsector. The crop subsector contributes more than 61 percent of agriculture's share to GDP, followed by fisheries (20 percent), livestock (12 percent), and forestry (7 percent) (Karim et al. 2010). Within the crop subsector, the area under rice production occupies a substantial share. In 2015-16, rice occupied 74.85 percent of the total cropped area, with all other crops individually occupying less than three percent (BBS 2018). The increase in production came from several different sources – intensive production system, increased use of inputs [fertilizers, pesticides, irrigation, machinery, etc.], improved technologies, and institutional advancements.

[Table 1 around here]

Table 1 shows the historical production level of different crops, meat, and fish in Bangladesh for selected years. Over the last half a century, the growth rate of cereal crops has always been positive – over three percent until the turn of the century, after which it expresses a slowdown. The only other set of crops that has grown continuously and at a higher rate is the set of vegetable crops. Fruits, oilseeds, and pulses exhibit negative growth in the 1990s. Pulse crops continue to show negative growth even after the turn of the century, primarily due to their low productivity and prices, resulting in a lower profit or sometimes even loss. Rahman (2009) notes that the proportion of pulse-cropped areas decreased by 25 percent between 1960 and 1996. A similar result was also reported earlier by Ahmed (1988). The principal reasons for such a decrease are intense competition with cereals, especially rice, for obtaining food self-sufficiency and inadequate research and development on pulses for improved production technology. With the recent increase in prices due to shortage, some farmers switched back to pulses, which explains over five percent growth during the last decade. The expansion of one crop often comes at the expense of another as the agricultural land resource in Bangladesh is scarce. For example, the recent increase in oilseeds and pulse crops comes at the cost of cereal crops. The production of vegetable crops continues to grow to provide ample and diverse food choices resulting in improved food and nutrition security (Table 1). Future trends will depend on developing high-yielding crop varieties, production technologies, and relative prices. As the land resource in Bangladesh is at its capacity, the only way to increase production is through vertical increase – an increase in output per unit of land – which already shows diminishing marginal productivity (Table 1). In addition to modern inputs in major crop production, appropriate

technology and management practices must be used in all agricultural products. In Bangladesh, farm size is small, and many farmers still produce for subsistence purposes paying little attention to economic efficiency. If these subsistence farmers can be inspired to adopt modern farming techniques discussed above, the total output can be increased.

Meat production from buffalo, cattle, goat, and poultry has increased substantially at the turn of this century, but the rate has slowed down (Table 1). The increase in meat production has been relatively stable. The egg production growth has been the highest among the three livestock products. The growth of all three components increased up to the first decade of the 21st century and then slowed down afterward. It started turning toward an increasing trend upon developing and implementing the National Livestock Development policy in 2007. The recent slow-down of growth rate for some product may be an indication that the existing technology perhaps reached its capacity. And only further intensive and efficient production techniques and adoption of more high-yielding breeds may contribute to the sustained growth in this subsector.

Bangladesh is a leading fish-producing country globally, producing 4.28 million tons of fish in 2017-18 (DOF 2018; FAO 2021). It is the third-largest inland water capture producer in the world (producing 1.22 million tons) after China and India and the fifth aquaculture producer (producing 2.41 million tons) (FAO 2020). Fish production in Bangladesh increased substantially over the years, offering an essential protein and fat source (Fig.1). Before the independence of Bangladesh, capture fishery was the primary source of the fish harvest. In recent years, culture fishery in inland water made colossal progress and surpassed the capture fishery. Ahmed and Waibel (2019) observe that the aquaculture from homestead ponds contributes to increased food consumption and dietary diversity, offering better nutrition and health. Though geographically a small country, Bangladesh produces and consumes diverse fish species in various production and processing technologies (Belton et al. 2011, 2017; DOF 2020; Chakraborty 2021). Large and small fish, fresh, frozen, and dry [processed], fresh-water, and brackish-water fish are all commonly produced and consumed in Bangladesh. However, in recent years, total fish production slowed down as aquaculture reached its near capacity (World Bank 2021b). The adoption of high-yielding species and improved technology for intensive fish culture is necessary for the future healthy growth of fish production in Bangladesh.

In terms of total production and resource use within the agriculture sector, the crop is the predominant subsector, and rice is the prevalent crop within the crop subsector. We analyzed the production function of crops and rice for 48 years using all variables, except time, in logarithmic form (Table 2). For total crops, we found that the presence of

autocorrelation was minor, and the estimated coefficients did not differ significantly. For rice, no evidence of autocorrelation could be detected, and as such, there was little or no difference between coefficient estimates of with or without time.

Estimated elasticity coefficients for land are negative in both models for the crop and rice (Table 2). As explained later in this section, agricultural land in Bangladesh continued to decline for the last half a century, and a negative sign of the elasticity estimates of land is expected. However, in contrast to Talukder and Chile (2018), we find positive labor productivity coefficients for rice and crops. The coefficients are higher for crops than rice, indicating that rice has become relatively more mechanized than other crops. In fact, much of the technological developments in Bangladesh have been for the rice crop are for labor-saving.

Intensive cropping and increased amounts of other inputs cause an increase in the marginal productivity of labor (Selim 2009). Although Talukdar and Chile (2018) postulate the presence of surplus labor in agriculture, our study does not find sufficient evidence of its existence, indicating that the surplus labor has perhaps been absorbed in other sectors like manufacturing, construction, and off-farm activities. A similar argument was made earlier by Guha (2006) that a technical change in agriculture may be a factor of intersectoral migration of labor – from agriculture to industry. Khan (2015) perceives a labor force shifting from low-productive agriculture to high-productive manufacturing – a structural change. Whether this shift is due to a push from the agriculture sector or a pull from the manufacturing sector is debatable. Most possibly, it is a combination of both. An increase in rural non-farm activities is also a possible way for such a transformation. Muqtada (2020) identifies the expansion of rural infrastructure, development of markets, increase in education and skill development, initiation of financial services, etc. as principal areas of generating rural non-farm activities and employment. Bangladesh has also successfully exported its labor force to other countries worldwide (ADB-ILO 2016). With over five million of its productive workers abroad, it has become the fourth largest human resources exporter in the world after the Russian Federation, India, and Ukraine (UN 2017). These migrant workers contribute substantially to the generation of off-farm income of rural households adding to the transfer of labor from the agriculture sector (Mishra et al. 2015; Kikkawa and Otsuka 2020).

One might find it interesting that nitrogen fertilizer negatively contributes to rice and total crop production. The negative partial regression coefficient (Table 2) is because of other nutrients becoming limiting factors as phosphorus and potassium show positive contributions over time. Although nitrogen fertilizer is used for many crops, most of it

is still used in rice and under intensive cropping, where nutrient balance may be highly negative (BARC 2005). Talukder and Chile (2018) also report a negative coefficient for fertilizer in Bangladesh. Farmers in Bangladesh often over-use nitrogen fertilizers, although appropriate doses of the nitrogen fertilizer have been advocated all along (Hossain and Islam 2006; Emran et al. 2019). Aryal et al. (2021) note that over one-third of rice fields in the Indo-Gangetic region [14 villages from Bangladesh, 25 from India, and 12 from Nepal] over-used nitrogen fertilizer. Similarly, 15.5 percent of the wheat fields receive more nitrogen fertilizer than typically recommended. Farmers should be provided with appropriate education and training through extension and outreach services to be aware of the negative consequences of the overuse of chemical fertilizers.

Negative coefficients for irrigation in rice crops can be explained by the introduction of many drought-tolerant rice varieties by the Bangladesh Institute of Nuclear Agriculture, Bangladesh Rice Research Institute, and Bangladesh Agricultural University (Ahmed et al. 2016; Kader et al. 2020), as well as the increased irrigation expenses. The cost of irrigation varies widely but remains the largest among all inputs (Mainuddin et al. 2021). Another reason could be the enhanced efficiency of irrigation water through decentralized and small-scale entrepreneurs operating independent pump sets providing surface water from small reservoirs or shallow tube-wells from groundwater (Palmer-Jones 2001; Chowdhury 2010; Qureshi et al. 2015; Mottaleb et al. 2019).

[Table 2 around here]

Results of regression analysis [Table 2] have significant policy implications. Estimated coefficients reveal that Bangladesh has limited potential for increasing crop production by expanding inputs as cropped lands are shrinking and the output elasticity of most inputs became low. One way to increase productivity is by developing and adopting new technology and management practices. The other way to increase productivity is by increasing the efficiency of input use and appropriate input mix. Previous studies also observe a declining productivity due to falling efficiency and recommend several areas of improving efficiency – effective seed distribution, balanced and optimal fertilizer use, appropriate trade policies, and promoting new technologies (Rahman 2005). As the availability of irrigation water is shrinking, new technologies, cropping patterns, and management procedures should be developed that require minimum water (Qureshi et al. 2015).

3.2. Technology, Innovation, and Agriculture

Adopting innovative technologies in the agriculture sector comprised of high-yielding varieties, pesticides, irrigation, fertilizer, and agronomic practices in Bangladesh started in the 1960s along with the introduction of the Green Revolution in the world. However, the process went through several ups and downs, and Bangladesh did not see visible fruit until after the independence. It started emphasizing the development of the agriculture sector since its inception as most of its population depended on agriculture. Such a development requires appropriate education, training, and research. The establishment of formal agricultural educational institutions goes back to 1938 with the establishment of the Bengal Agricultural Institute [the predecessor of the current Sher-E-Bangla Agricultural University] in Dhaka with its first enrolment in 1941-42. The number of students was few, and the curriculum taught was not comprehensive (Rahman and Mirza 2013). However, with the curricular reform in the institute and the establishment of East Pakistan Agricultural University (now, Bangladesh Agricultural University) in 1961, agricultural education made its foot. After the independence of Bangladesh, the agricultural education system grew exponentially. Currently, there are four public agricultural universities and one veterinary and animal husbandry university in Bangladesh focused entirely on higher agricultural education. Two science and technology universities and two general universities also have agriculture departments (Bhuiyan 2013). Besides, another half a dozen private universities offer agricultural education and research opportunities in Bangladesh. These educational institutions and several agricultural research institutes⁴ have been developing appropriate technologies for increasing production. However, the dissemination of such technologies to the marginalized farmers, especially to the small and illiterate farmers of geographically isolated regions, remains behind due to insufficient extension services. The agricultural extension system in Bangladesh has a long history and is now a well-organized department. Despite this, the organization has not achieved the targeted outcome, and sufficient room for improvement remains (Karim and Noman 2018). In addition, appropriate technologies for those marginalized farmers need to be developed and transferred to them through suitable means. Despite several research institutes devoted to specific agricultural products, much of the focus has been on the rice crop due to its primary importance as the staple food. Many minor crops remain behind

⁴ Bangladesh has several agricultural research institutes. These are Bangladesh Agricultural Research Institute (BARI), Bangladesh Rice Research Institute (BRRI), Bangladesh Institute of Nuclear Agriculture (BINA), Bangladesh Jute Research Institute (BJRI), Bangladesh Fisheries Research Institute (FRI), Bangladesh Forest Research Institute (BFRI), Bangladesh Sugar Research Institute (BSRI), Bangladesh Livestock Research Institute (BLRI), Bangladesh Tea Research Institute (BTRI).

with little contribution to the variety of food and nutrition choices, and as such, contributing to nutritional security to the marginalized population.

Since agricultural land in Bangladesh is declining, the only way to increase production is to use appropriate input mix and technologies. Over time, the use of chemical fertilizers and pesticides has increased substantially (Fig. 3). In recent years, the use of chemical fertilizers increased markedly, especially phosphorus and potassium. The area equipped for irrigation, however, increased modestly. This indicates that the potential for an increase in irrigation is relatively low. The increased fertilizer use is not always an overuse, rather a necessity to compensate declining soil productivity over time. However, given the agroecological and climatic conditions, balanced fertilizer use is critical for achieving maximum productivity.

[Fig. 2 around here]

Agricultural mechanization has accelerated since the 1980s, primarily due to agrarian reforms in different areas, including tillage, irrigation, and threshing, contributing to the reduction of crop loss and increase in surplus agricultural labor (Shahabuddin 2020; Rahman et al. 2021). However, sufficient opportunities remain to expand mechanization further to boost yield. This can cause an increase in agricultural productivity, incentivize the innovators for farm machinery and strengthen the market system (IDE 2012). Previous studies also conclude that rapid mechanization in agriculture can improve crop yield and reduce production costs at the expense of employment, causing a labor surplus for which accompanying non-farm activities should be promoted (Shahabuddin 2020). In Bangladesh, though, sufficient non-farm activities seem to exist in absorbing surplus labor.

Bangladesh has made remarkable advancements in agricultural research. Bangladesh Agricultural Research Institute (BARI) researches a wide range of crops in its main, regional, and sub-stations all over the country. Besides, there are specific research institutes for rice, jute, sugarcane, tea, forest, livestock, fisheries, etc. These research institutes and universities have developed many high-yielding stress-tolerant crop varieties, livestock breeds, and fish species, contributing substantially to agricultural productivity. In recent years, these institutes developed over a thousand crop varieties, agronomic practices, new breeds, aquaculture techniques, and the like. Despite the past successes, Bangladesh needs to increase research and development efforts to improve land productivity, the only way to expand output. It also needs to emphasize minor crops, diversified cropping patterns, and shift from subsistence to commercial production. Collaboration among research institutes is essential to generate farming systems technologies appropriate

to the agroecological zones and for poor and marginalized farmers. Improvement in productive efficiency must ensure everyone's benefits, including the poor and marginalized farmers.

3.3. Agriculture and Nutrition Security

Agriculture remains the principal source of providing nutrition to the people of Bangladesh. Through increased agricultural production, Bangladesh achieved food self-sufficiency in terms of calorie needs as in 2010, an average Bangladeshi consumed 2,318 kcal per day, exceeding the requirement of 2,122 kcal per day (Osmani et al. 2016). However, people remain deficient in many other nutrients, and food insecurity prevails among 25 percent of the population (Osmani et al. 2016). Stunting, underweight, and malnutrition - which substantially reduce labor productivity - have not disappeared despite the enlarged food production through different agricultural products.

[Table 3 around here]

Food security in Bangladesh has been traditionally thought of as the availability of cereal grains, particularly rice, and as such, the production of paddy rice has received the most attention. Many studies synonymously use the accessibility to rice and wheat as the symbol of food security (Hossain and de Silva 2013; Mainuddin and Kirby 2015; Majumder et al. 2016). However, despite increased rice production and availability of calories, people in Bangladesh, especially marginalized low-income people, women, and children remain far from being nutritionally sufficient. Therefore, food security needs to be addressed by providing balanced nutrients based on biological needs rather than the availability of a particular food commodity. Recent studies have identified nutritional discrepancies among members of households (women, children) and income groups (Rabbani 2014) and emphasized diversified diet coming from varied agricultural production among different crops, livestock, and fish (Bose and Dey 2007; Belton et al. 2014; Islam et al. 2018; Ahmed and Waibel 2019; Roy et al. 2019).

Originating from the subsistence agricultural system, food and nutrition security in Bangladesh remains primarily driven by domestic agricultural production, which may worsen due to the reduction of agricultural land through increased urbanization (Bishwajit et al. 2014). Farmers of Bangladesh must grow more food using less land and water while facing further adverse conditions due to climate change. One possible option is to focus on diversifying farm production, as emphasized by Rehan et al. (2021). On the domestic front, along with systematic crop production,

intensive livestock and fish production may contribute to food and nutrition security in Bangladesh (Bishwajit et al. 2014; de Roos et al. 2018). However, food security may also worsen due to external factors, i.e., world food prices, especially for low-income people. Hossain (2014) suggests that if the price of rice goes beyond a certain point, lower-income people will become vulnerable to food security. Despite the need for fish and rice as staples, rural people with low income are more sensitive to price changes and exhibit higher elasticity of substitutions (Toufique et al. 2017).

The relationship between agricultural diversification, dietary divergence, and nutrition is not straightforward (Ahmed and Ghostlaw 2019), but a degree of relationship is expected. Previous studies identify five links through which agricultural production can affect nutrition: increased food availability, improved income, reduced prices, change in preferences, and intra-household resource control (Arimond et al. 2011). As expected, Headey and Hoddinott (2016) find a clear-cut contribution of rice yield on weight-for-height for children in Bangladesh, but no dietary diversity and height-for-age improvement. Given limited land, ponds, or small water bodies in Bangladesh, intensive fresh-water fish culture (aquaculture) can play an indispensable role in maintaining and improving nutrition security by providing high-quality animal protein through fish and poultry cultivation – either independently or through an integrated rice-fish, duck-fish or chicken-fish cultivation. However, appropriate technologies adoptable to Bangladesh’s agro-climatic and socio-economic conditions, and congenial risk-reducing policies need to be developed and implemented (Ahmed and Garnett 2010; Islam, 2016).

3.4. Agriculture and the Environment

The agriculture sector in Bangladesh cyclically interacts with environments – it gets affected by the environment and, at the same time, it affects the environment – the intensity of the former is much larger than the latter. The farming sector must adapt to the changing climate as depicted by variable rainfall, salinity, drought, floods, etc. Evidence suggests that climate change negatively affects several subsectors of agriculture in Bangladesh – crops, forestry, fisheries, and arable land (Roy and Haider 2018). The coastal zone of Bangladesh is relatively more vulnerable to climate change. However, variations in rainfall and temperature significantly affect long-run agricultural production in all areas (Salim et al. 2020). Recently, an adaptation of agriculture to climate change has become essential for both farmers and researchers (Akter and Ahmed 2021). In general, adaptation to the environment is a natural phenomenon, as explained in the theory of evolution. Research efforts need to be dedicated to developing varieties that can

acclimatize to the existing agroecological and socio-economic situations and the changing environment. As the first line of defense, despite plenty of limitations, farmers often substitute crop varieties and livestock breeds that can adapt to the situation (Delaporte and Maurel 2018). However, such an adaptation for maximizing output requires an appropriate input mix and production technology.

Aside from research and development, governments institute policies to mitigate the vulnerability of climate change. Bangladesh implemented National Adaptation Program Action (NAPA) and Bangladesh Climate Change Strategy and Action Plan (BCCSAP). The objective of these plans was to deal with several challenges like climate adversity and to ensure food security, social protection, infrastructure development, carbon reduction, institutional capacity building, etc. (Islam and Nursey-Bray 2017). Different models predicted different scenarios of the impact of climate change on Bangladesh. However, nearly all expected negative impacts (Agrawala et al. 2003; Chowdhury et al. 2021; Hijioka et al. 2014; Hoque et al. 2019; World Bank 2013). Islam et al. (2021) observe that rice farmers in the coastal region of Bangladesh have been reducing rice crops due to yield loss. The susceptibility of agricultural production to climate change indicates that separate comprehensive government actions are needed to address problems in different vulnerable areas. The strategy for a drought-prone area may not be the same as that of a salinity-affected site. Although Bangladesh is geographically small, its agroecological differences should be given prime consideration for exploiting maximum production potential.

3.5. Agriculture and the Economy

The agriculture sector of Bangladesh was the principal contributor to GDP [over 50 percent in the 1970s], although its share continues to decline to reach a level of only 12.7 percent in 2019 (Table 4). The agriculture sector's employment percentage also declined from 63.5 percent in 1970 to 38.3 percent in 2019, which is not nearly as much as we see in the share of GDP, indicating the possibility of existence of surplus labor in the agriculture sector. However, this does not necessarily imply an underperformance of the sector. Rather, it provides a clear indication that aside from fueling exports [mostly animal and vegetable products and by-products including fish] and employment, the sector has been successfully contributing to the transformation of the economy to move toward manufacturing and services. In addition to providing food and nutrition, agriculture provides rural jobs and fuels the economy toward development. This is particularly relevant for Bangladesh's economy as it had little opportunity to develop its

industrial and service sectors without sufficient support from the agriculture sector. The rapid growth of Bangladesh's economy and the declining share of employment in the agriculture sector indicates a structural change in labor productivity and a shift of labor from agriculture to manufacturing and service sectors.

[Table 4 around here]

Agricultural land as a percent of total land [LAND] increased slightly in the early years of Bangladesh, reaching 80 percent in the late 1980s but continues to decline since then, reaching just over 70 percent (Fig. 3). The recent decline is primarily due to substituting agricultural land with other industries – largely manufacturing and service. Despite a slight increase in agricultural land until the late 1980s, per capita agricultural production [APDN] continued to decline until the early 1990s, when it turned around due to faster growth in crop production [CPDN]. Such growth came from several areas, including intensive cultivation, modern technologies [irrigation, mechanization, fertilizer, pesticide, etc.], and improved management. Nonetheless, the share to GDP from agriculture [AgForFish] from the combined production of the crop, livestock, fisheries, and forestry exhibited a declining trend in the entire period (Fig. 3).

[Fig. 3 around here]

The economic growth of Bangladesh comes from all three sectors - agriculture, industry, and services. As agriculture is currently a relatively minor contributor to GDP growth, development strategies focusing only on agriculture will not lead to significant economic progress. However, the potential exists in improving agricultural productivity to contribute to GDP. The labor productivity in agriculture is still low despite a noticeable increase in farm wages during the last decades (GED 2015; Muqtada 2020). As usual, the focus should be to increase efficiency through the appropriate use of technology and input combinations (Bryan et al. 2018).

Growth in the agricultural sector is a precondition for economic development. For a poor agro-based economy, agricultural production growth offers the opportunity to reduce poverty and hunger. Johnston and Mellor (1961) state that growth in agriculture can contribute to economic development by providing food, industrial raw materials, domestic market, foreign exchange, and labor to other sectors. As an economy grows, its consumption demand for the food and service sector increases. However, lower-income elasticity of agricultural products relative to industrial products and services causes an increased demand for the latter forcing structural changes (Kuznets 1973; Atyas et al. 2015). So, the agricultural sector is the initial engine of economic growth of an economy, where it develops first and

then pulls the other sectors (manufacturing and service sectors) up by contributing labor and capital resources (Yao 2010). Agriculture, through its development, releases labor, raw materials, capital, and foreign exchange and creates demand for industrial goods and services (Tiffin and Irz 2006). Agricultural development is associated with mechanization, where machine power replaces labor but requires capital to produce and maintain machines. The application of modern technologies – high-yielding variety seeds, irrigation, fertilizer, pesticide – needs capital but generates higher income and improves the standard of living. The resulting structural transformation lowers GDP share and employment in agriculture and increases the share of manufacturing and service sectors. Bangladesh has followed the same pattern of economic development and is currently experiencing a higher growth rate in the latter sectors than agriculture.

3.6. Trade and policies in agriculture

Bangladesh is a net importer of food and agricultural products and overall goods and services, and the trade deficit has been widening despite increasing export (Fig. 4). Although Bangladesh produces enough rice for its population, it remains deficient in other cereal crops, pulses, oilseed crops, and many other minor but essential crops. Such a gap has increased over time and would likely continue to grow in the future. Although Bangladesh may remain self-sufficient in rice production (Timsina et al. 2018), it still imports eight percent of cereals (Udmale et al. 2021). Even with the reduction of yield gap, overall production will not be sufficient to meet future food grain demand, and Bangladesh will remain reliant on import for foods.

[Fig. 4 around here]

Bangladesh pursued an inward trade policy with a strong government control following its independence. Agricultural input and product markets were controlled by the Bangladesh Agricultural Development Corporation, resulting in limited production growth. A highly regulated policy environment, strict government control, nationalization of industries and service sectors made the economy less conducive to economic growth. Recognizing that, such a strategy was eased in the 1980s by introducing a liberal input market (reducing subsidies on agricultural inputs), liberalizing output markets, and gradually eliminating the public food distribution system. With differences in prices, farmers substitute low-value crops for high-value ones resulting in excessive growth among different groups of crops.

Although such a microeconomic argument is valid, the production choices of Bangladesh's farmers are also heavily driven by land-ownership status, risk exposure of the system, and farmers' education, training, access to credits, high-quality seeds, other modern technologies, etc. Existing agricultural policies also influence production choices. From the 1990s, more open agricultural policies became institutionalized, and production started to rise. Still, the agriculture sector continues to face hurdles from many areas, including declining agricultural land, availability of high-quality seeds, access to credit, inadequate investment in agriculture, and vulnerability to climate change (GED, 2020). The volatility of commodity prices due to a weak market system, insufficient storage facilities for certain products, and insufficient agricultural machinery and irrigation systems are also significant constraints. The opportunity cost of working in agriculture, even for rural laborers, became high. A movement of the labor force from agriculture to other sectors, especially manufacturing and service sectors, continued resulting in a sustained decline in the share of employment in agriculture. Increased non-farm employment opportunities for the rural population are a significant cause of such a structural transformation (Muqtada 2020; Mujeri and Mujeri 2021).

More open trade policies attracted investments in the manufacturing and service sectors, which contributed to a higher share of GDP and foreign exchange earnings. Bangladesh follows two tracks of industrialization policies – import substitution and export orientation. Immediately after independence, Bangladesh followed an import substitution production and industrialization policy, which did not bear much fruit. Since the 1980s, it moved away from such policies and turned toward export orientation. In recent years, the most important export-oriented industrial development has been the expanding garments sector, growing rapidly since 1985 (Hossain and Uddin 2021). In 2018, it grew at a rate of 8.76 percent. It is one of the principal driving forces of economic growth in terms of employment, foreign exchange earnings, and GDP. In 2018-19, this sector contributed over 10 percent of GDP and 84 percent of foreign exchange earnings (BBS 2021; World Bank 2021) and attracted female and unemployed labor from the agriculture sector. The export earnings from the garments sector significantly improve economic growth both in the short and in the long run, and the industry's development directly contributes to GDP growth (Islam 2021). Therefore, it is essential to educate and train unemployed and underemployed individuals, especially women, to be employed in the manufacturing and service sectors to increase productivity and economic growth.

Another area attracting labor force and investment from agriculture is human labor export and remittance earning. In 2019-20, the remittance earning for Bangladesh was 18.21 billion US dollars (BBS 2021). The growth of Bangladesh

economy and the lifestyle of people of Bangladesh, at present, rely heavily on income generated from the garments sector and the remittance earnings from abroad, which, in part, cause a movement of the labor force from agriculture to those areas. Remittance earnings do not contribute directly to the production process, and as such GDP, and their contributions to economic development have been far from conclusive⁵. Nonetheless, this manpower export directly impacts the domestic labor market and indirectly economic growth. In addition, although remittances boost economic growth, they can also cause an appreciation of the domestic currency and a reduction of export, an unintended consequence, often termed as the Dutch Disease (Daway-Ducanes 2019; Urama et al. 2019; Ratha and Moghaddam 2020). The economic development strategy of Bangladesh must follow an integrated approach of labor utilization and GDP growth, rather than simply focusing on one particular sector.

4. Comparison with India and Pakistan

In this section, we would like to compare the performance of Bangladesh agriculture with India and Pakistan over the same time period. To get a bird's eye of the overall development of Bangladesh, we also compare the GDP growth and some broad human development indicators of the three countries.

4.1. Comparison in the Economic Growth

Economic growth is commonly measured by the annual increase of real GDP, either total or per capita. Since the size of the Indian economy is much larger than Bangladesh and Pakistan, it is more pertinent to use per capita GDP for meaningful comparison. Pakistan's per capita GDP was significantly higher (almost 70 percent) than Bangladesh in the early seventies when the latter got its independence (Fig. 5). However, Bangladesh has overtaken Pakistan and is closing in on to India (World Bank 2021a). This illustrates how far Bangladesh has reached in its economic growth relative to India and Pakistan. Yusuf (2021), following the GDP growth rate, expects that Bangladesh may surpass

⁵ Empirical results are all over the map – negative, positive (Jawaid and Raza 2014; Salahuddin and Gow 2016; Amjad 2017; Mannan 2017; Zaman et al. 2021), u-shaped contribution (Hassan et al. 2016; Hassan and Shakur 2017; Kumar et al. 2018), causing Dutch disease (Roy and Dixon 2016), etc. Jawaid and Raza (2014) and Kumar et al. (2018) provided lists of previous studies with contradictory results.

India soon but questions the sustainability of this rapid growth as it depends on the single export commodity, garments. Bangladesh no doubt needs to diversify sources of its economic growth.

4.2. Comparison in the Agriculture Sector

All three countries are based on similar agricultural history, though not the same, nor they have analogous resources. We first compare the performance of the three countries examining the trend of some relevant variables. Then, we extend our empirical model described in section 2 to examine the relative productivity of the agriculture sector of these three countries with appropriate econometric techniques.

[Fig. 5 around here]

All three countries show a declining trend in the percentage of total employment in agriculture since 1991 (Fig. 5). In the early 1990s, the percentage of employment in agriculture was the highest in Bangladesh among the three countries (close to 70 percent in Bangladesh, compared to approximately 63 and 45 percent in India and Pakistan, respectively). However, that share decreased more sharply to 40.38 percent for Bangladesh and is now below India (44.60 percent) and very close to Pakistan (36.91 percent). Although the shares of employment in agriculture decreased for all three countries during the last three decades, Bangladesh experiences the highest rate of decline (Fig. 6). There could be two possible reasons - either Bangladesh had more surplus labor in the agriculture sector, or it has been more successful in pulling out labor from the sector, or a combination of both. Whatever the case maybe, a shift of labor from the low productive agriculture to the high productive manufacturing or service sectors is a positive direction toward economic growth. It seems that Bangladesh has been more successful in that relative to its two neighbors.

[Fig. 6 around here]

Similarly, the shares of value added by agriculture, forestry, and fishing as a percentage of GDP have declined for all three countries, but in Bangladesh at a much faster rate reaching the lowest (Fig. 7). Bangladesh had the highest share of GDP coming from the agriculture sector (nearly 60 percent in the 60s and early 70s) but dropped considerably in the early 80 and then continued to decline faster than India and Pakistan. This indicates that Bangladesh has experienced a faster rate of structural change than the two of its neighbors. Over the years, Bangladesh has undergone a stable intersectoral movement of economic activity, structural transformation, since its independence (Mujeri and

Mujeri 2020). It also experienced structural change within a sector, i.e., movement of economic activity within different areas of a sector (Mujeri and Mujeri 2021).

[Fig. 7 around here]

The crop is the major subsector for all three countries within the agriculture sector. The growth in crop and cereal crops in Bangladesh is comparable with India and Pakistan. The crop production indices (Fig. 8) show that the crop productivity in Bangladesh was lower than that in India and Pakistan in the 1980s and 1990s but improved sharply since around 2000 to catch up with India and then with Pakistan. Consistent crop production growth has helped Bangladesh keep up with its increasing food demand driven by population growth. Rezitis and Ahammad (2015), using vector error correction model for per-capita agricultural production of Bangladesh, India, and Pakistan, observe that the agricultural output of Bangladesh and India expressed a long-term relationship but have different risk-tolerance and shock-absorbance capacities. The agriculture sector of Bangladesh is more vulnerable to unexpected shocks than India and Pakistan. Bangladesh is relatively more prone to natural disasters than India and Pakistan (World Bank 2012). Its agriculture sector, especially in coastal areas, is highly vulnerable to climate impacts (Chowdhury et al. 2021; Singh and Kumar 2021).

[Fig. 8 around here]

The cereal crop production index (Fig. 9) for Bangladesh was below India till 1999 but became higher than the latter since 2000 and has remained so since then. Pakistan performed better than both India and Bangladesh in cereal crop production. One possible reason for the slower growth of cereal crop production for Bangladesh and India than Pakistan is the emphasis on the crop diversification policy of the former (Rehan et al. 2021). In all three countries, food security is primarily conceived as the availability of cereal crop output or the supply of carbohydrate energy with little emphasis on balanced nutrition. Only very recently, both India and Bangladesh have directed their attention toward nutritional security through a balanced diet and diversified agricultural production (Pant et al. 2014; Islam et al. 2018; Singh et al. 2020).

[Fig. 9 around here]

In all three countries, crop production growth comes from increased input use, technological advancements, and the implementation of policies. Using a two-stage GLS model with heteroskedastic but uncorrelated errors across panels

for cereal crops, we tested each case for possible autocorrelation following Woolridge's (2018) test for autocorrelation in panel data. There was evidence of autocorrelation at a 10% significance level for crops. However, for the case of cereal crops, there was no evidence of autocorrelation at a 10% significance level. Utilizing a three-stage GLS model with heteroskedastic and panel-specific AR (1) model to account for autocorrelation does not show a difference in estimated coefficients between the two models (Table 5). The signs of the regression coefficients were mostly consistent across each model. All inputs showed a positive effect on each output (crop and cereal crop) except labor in all four scenarios and Fertilizer K in Model 3 for the crop production.

While studying only on Bangladesh, we noted that labor positively affected both crops and rice. In contrast, upon inclusion of India and Pakistan in our analysis, the output elasticity coefficient for labor is negative. This is not uncommon in developing countries due to the widespread presence of surplus labor in agriculture, as Talukdar and Chile (2018) explained for Bangladesh. Our analysis reveals that the problem is more severe in India and Pakistan than in Bangladesh. A country can enjoy significant benefits if surplus labor in agriculture is gainfully employed in other productive sectors. This suggests that Bangladesh has been more successful in moving its surplus labor from agriculture into more productive sectors (like the garment and retail sector) as well as rural non-farm employment. It has also been able to export labor to other countries globally.

[Table 5 around here]

The partial regression coefficients for the country dummy variables India and Pakistan are positive, which means that these two countries enjoy more benefits in the production of crops and cereal crops than Bangladesh. Ansari and Khan (2018) study the structural transformation of four South Asian countries (India, Pakistan, Sri Lanka, and Bangladesh) and conclude that agriculture stimulates economic growth in India, Pakistan, and Sri Lanka, but not in Bangladesh.

4.3. Development comparison of Other Human Development Indicators

Bangladesh has surged ahead not only in terms of per capita income but also in other human development indicators. In 2019, Bangladesh was ranked 135 (among 189 countries) with an HDI score of 0.632, a significant progress from a paltry HDI score of 0.394 in 1990 when the United Nations Development Program (UNDP) first reported the HDI indices for countries. In contrast, Pakistan, being far ahead of Bangladesh in 1990, is now ranked below Bangladesh

at 154, with an HDI score of 0.557. With a score of 0.645, India is slightly ahead of Bangladesh. Furthermore, regarding life expectancy at birth, Bangladesh (with a score of 72.6) has overtaken India (score of 69.7) and Pakistan (67.3) in 2019. Bangladesh has also moved ahead of Pakistan in terms of expected and mean years of schooling though India is still ahead of these two countries (World Bank 2021b).

Bangladesh has undoubtedly performed better than India and Pakistan regarding women's empowerment, as Sen (2013) and Basu (2018) noted. For example, though lagging slightly behind India in terms of overall mean years of schooling (as mentioned before), the mean years of schooling for females is higher in Bangladesh. Labor force participation rate in Bangladesh consistently increased over time since the 1990s and surpassed India around 2008 (Fig. 10). Interestingly, labor force participation rate in India remains the same until 2004 and then continue to decline. This might be due to a demographic shift and an overall higher average age of the population in India. The percentage of women aged 15-64 who joins the workforce has steadily increased in Bangladesh (it was only three percent in 1971!) and is now close to 39 percent, which is significantly higher than both India and Pakistan, with the latter two having a value around 22 percent (World Bank 2021a).

[Fig. 10 around here]

Indeed, out of the 4 million workers in the garment industry, about 80 percent are women. Bangladesh's adult female literacy rate has increased consistently to about 72 percent, comfortably more than India (about 66 percent) and Pakistan (around 46 percent) (World Bank 2021a). Such a social and demographic change contribute to economic development as literacy and labor productivity are related.

In summary, Bangladesh has significantly outpaced Pakistan in almost all economic and social development indicators. It has caught up with India regarding per capita real income and has done better in crucial social indicators, especially women's empowerment and economic freedom. However, Bangladesh is still below in terms of agricultural growth and productivity which means there is scope for improvement in this sector.

5. Conclusions and Recommendations

The agriculture sector of Bangladesh has made considerable progress over the past 50 years on nearly all fronts resulting in a sustained increase in production and contribution to food and nutrition security. Although different

subsectors have progressed differently, the overall trend is positive. Many factors contributed to this progress – use of modern inputs (high yielding crop varieties, high productive livestock and poultry breeds, quick-growing fish species, etc.), technology, production practices, and policies are some of those. Agricultural production has also increased export. However, agricultural land, share of employment in the agrarian sector, and its proportion of contribution to GDP have been shrinking over the entire period, though not necessarily at an equal pace. The progress in agricultural productivity, primarily through the vertical increase of production, has slowed down recently. The reduction of agricultural land poses a severe challenge in the growth path of the agricultural sector as it strives to ensure food and nutrition security to a growing population. The calculated output elasticities of each input obtained from our regression models reveal that the contribution of increased use of inputs, with the existing technology, for enhancing productivity is limited, which poses a further challenge. However, challenges open doors of opportunities as well. Possible solutions to face those challenges can be addressed in several fronts. The rate of growth of crop production will likely become slower than we observed in the past simply because of the limitations posed by the increasing scarcity of land, rising production costs, and reduced profitability. However, it is possible to increase crop production with appropriate input substitution, mechanization, and crop diversification. Input substitution and mechanization have been tried in the recent past, as evident from the increase in the mechanical use of draft power and threshing to over 90 percent (Hossen et al. 2020). Policies on ensuring quality machines through competitive markets, providing appropriate training to farmers, increasing affordability through credit, and expanding provisions for spare parts and maintenance facilities can further develop mechanization (Hossen et al. 2020).

Access to appropriate types of credit is vital as farmers are often poor and short of capital. Bangladesh Bank, the Central Bank of Bangladesh, has published agricultural and rural credit policies and programs for each fiscal year for several years. The amount and source of agricultural credit have increased over time. Gradually, agricultural credit disbursement has moved to more formal sectors as many commercial banks and non-governmental organizations contribute to agricultural credit. Despite that, the disbursement share has remained the same for several years (Alauddin and Biswas 2014). Ensuring agricultural credit is more important for farmers of the hazard-prone areas and capital-intensive farming areas, i.e., livestock, poultry, and fisheries. Alam et al. (2016) observe that farm households in hazard-prone areas implement adaptation strategies through diversifying crops, planting trees around the homestead, and home gardening. However, such adaptation strategies are influenced by the availability of capital resources and institutional support.

An apparent drawback of increased mechanization is the reduction of employment in the agriculture sector, contributing to surplus labor and unemployment. Although this seems like a disadvantage, this is an opportunity to employ surplus labor in other productive sectors. Indeed, labor productivity and the wage rate are higher in the manufacturing and construction sectors than in the agriculture sector. A labor movement from agriculture to manufacturing is a positive aspect of economic development. In most developed countries, only a small portion of the labor force is employed in agriculture. For example, using only 1.56 percent of the labor force in agriculture, Canada produces sufficient food grains and meat that feeds itself and exports a substantial quantity (FAO, 2021).

An emphasis on less land-intensive agricultural products, i.e., livestock, poultry, and fish, can increase agricultural production and provide much-needed nutritional balance, contributing to food and nutrition security. Integrated production technology of rice-fish culture, poultry-fish culture, and intensive fish culture technologies exist, which can be refined and adopted with the appropriate motivation, incentive, and training. Ahmed and Garnett (2011) examine the potential for integrated rice-fish culture in Bangladesh and comment that it can provide socio-economic and environmental benefits as well as higher production to mitigate food and nutritional security challenges. Sharmin et al. (2018) conclude that integrated farming can increase profitability and overall economic conditions for farmers in Bangladesh. The increase in profitability of the farming sector depends on productivity and the value-added chain, where Bangladesh has potential. World Bank (2020) recommends harnessing economies of scale through aggregation, agglomeration, creation of formal markets, and removal of regulatory barriers for all public services. It also suggests developing and adopting appropriate production, processing, and transportation technologies and ensuring and improving private sector involvement.

Bangladesh's agricultural development needs a comprehensive strategy supported by research and development (R & D). A coordinated approach of both private and public sectors is required, along with an open economy policy. Private sectors backed by congenial institutional policies should generate the appropriate entrepreneurial ability to harness the efficiency of free-market systems. As businesses and entrepreneurs in Bangladesh are small and conducting R & D for increased production is beyond their means, the government must take the proper initiative to innovate improved technologies. Bangladesh has an expanded network of agricultural research facilities (research institutes and universities) throughout the country. Appropriate utilization of such facilities and available human resources through

suitable policy implementation can improve the efficiency of R&D, resulting in a positive contribution toward agricultural productivity.

In addition to developing appropriate technologies, Bangladesh needs to build an effective mechanism for transferring technologies to their actual recipients for adoption. Studying the impact of agriculture technology adoption in Bangladesh, Mendola (2007) finds a vast scope of enhancing the role of agricultural technology in improving production and reducing poverty. Although Bangladesh has a specific department, the Department of Agricultural Extension (DAE), for disseminating appropriate technologies, which has a record of positive contribution, there are plenty of opportunities for improvements. Using a case of mung bean variety in Southern Bangladesh, de Brauw et al. (2020) find that accurate transformation of knowledge is vitally important as a modest variation of information can lead to the adoption of technology being suboptimal. Karim and Noman (2018) identify areas of improvement and suggest strengthening coordination and cooperation among different actors involved in agricultural technologies, i.e., researchers, policymakers, extensionists, and farmers.

Agricultural development alone cannot move the Bangladesh economy forward at the current or a higher rate. As different sectors of Bangladesh's economy are closely integrated, and causal relationships exist among those (Uddin 2020), a development approach must consider other sectors along with the agriculture sector. Ansari and Khan (2018) conclude that the agriculture sector stimulates economic growth in all South Asian countries except Bangladesh. Bangladesh needs to address the existing challenges in other sectors to ensure that its overall GDP per capita growth rate does not slow down. One way is to emphasize on the holistic approach of economic development strategically driven by the market and economic efficiency. Bangladesh has recently moved from a low-income country to a lower-middle-income country, but its exports and foreign currency earnings remain restricted withing garments and remittances. It is about to lose its tariff-free access to developed country markets like the Generalized System of Preferences of the USA and relying only on a limited export area makes the entire sector vulnerable to external shock. Hence, Bangladesh must seek to diversify its production and exports.

As the economy develops, its comparative advantage will inevitably change, and Bangladesh will lose some of its competitiveness in garment exports. Like China, Vietnam, and other developing countries, Bangladesh gradually needs to shift from garments to higher-value exports. Indeed, countries that have successfully graduated from developing to developed countries in the last 60 years (e.g., South Korea) have all gradually progressed from labor-

intensive, low-value exports like garments to more high-value exports. Indeed, India's exports have recently stagnated after booming in the 2000s (Basu 2018). Hence Bangladesh cannot take export growth as guaranteed and need to be proactive to ensure its export growth does not decline. In terms of human development, it is undeniable that Bangladesh has made significant progress in most human development indicators over the past 50 years, especially those related to health and gender equality. However, there are still areas where it can significantly improve. For example, it can emphasize advanced education to develop a more skilled workforce and reduce poverty and inequality.

Our study has important policy implications. Specifically, it demonstrates that despite several constraints, the agriculture sector still has potential for growth by developing and adopting appropriate technology and realizing efficiency gains from proper input and output mixes. For this to happen, it needs to be supported by implementing appropriate policy and institutions, coordination and communication among different government and non-government departments and lessening production risks through proper adaptation and diversification. For the sustainable economic development, Bangladesh should further focus on diversified export-oriented manufacturing industries instead of focusing on only one export section, i.e., ready-made garments. Bangladesh should also explore agriculture processing and the development of value-added products for export purposes.

Funding:

The authors declare that they did not receive any financial support from any individual or organization for this research.

Conflict of Interest:

On behalf of all authors, the corresponding author states that there is no conflict of interest

Data Availability:

Data used in this paper are mostly publicly available, and the authors cited the source. If required, the authors are willing to provide data if necessary.

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