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Supply and Demand for Cereals in Bangladesh, 2010–2030

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Contents

Abstract	v
Acknowledgments	vi
1. Introduction	1
2. Modeling and Forecasting Rice Supply in Bangladesh	4
3. Modeling and Forecasting Demand for Cereals in Bangladesh	12
4. Assessing the Cereals Supply Deficit/Surplus	23
5. Conclusions	24
Appendix: Supplementary Tables	26
References	28

Tables

2.1—Description of variables used 4

2.2—Estimated *aus*, *aman*, and *boro* yield functions 8

2.3—Total fertilizer function estimates 8

2.4—Total rice area, yield, and production projections 11

2.5—Out-of-sample comparison of actual and projected rice output (’000 tons) 11

3.1—Food item categories. 15

3.2—Expenditure elasticity and own and cross uncompensated price elasticities 17

3.3—Food budget model estimates 18

3.4—Model validation results: Food budget and per capita consumption quantities 19

3.5—Projected food budget per capita at constant 2005 prices, BDT 20

3.6—Projected annual consumption quantities, kilograms per capita 20

3.7—Population projections, in millions 21

3.8—Projected direct demand for rice, in million tons 21

3.9—Projected total (direct + indirect) demand for rice in Bangladesh, in million tons 22

4.1—Range of projected demand, supply, and deficit/surplus, in million tons 23

A.1—Estimated QUAIDS model parameters 26

A.2—Projected direct demand for wheat, in million tons 27

A.3—Projected total (direct + indirect) demand for wheat in Bangladesh, in million tons 27

Figures

1.1—Panel A: Area, production, and yield of rice, 1987–2009; Panel B: Growth rates of rice yield, 1989–2009 2

1.2—Panel A: Wheat area and production, 1972–2008; Panel B: Maize area and production, 1992–2006 2

2.1—Seasonal rice acreage in Bangladesh, 1972–2006 5

2.2—Panel A: Share of area under HYV; Panel B: Share of area irrigated 6

2.3—Seasonal yields of rice 7

2.4—Total fertilizer quantity and seasonal yield forecasts 10

ABSTRACT

Bangladesh remains a net importer of rice despite significant progress in improving yield and production levels. With growing population, planning for future cereal production to meet food security challenges would require projections of future supply and demand for cereals. In this study we attempt to provide forecasts of the demand and supply of cereals in Bangladesh for the period 2015–2030, focusing on rice the main staple in Bangladeshi diets and also the most important crop in Bangladesh's agriculture. A detailed model of the supply of rice in the three main rice growing seasons—*aman, aus, and boro*—is built up through separate acreage and yield functions, which are estimated with data from the Bangladesh Bureau of Statistics. On the demand side, the projections made here consider both direct demand by households and also indirect demand. Household direct demand for 13 food items, including rice and wheat, has been modeled using the quadratic almost ideal demand system specification, whose parameters are estimated using the Household Income and Expenditure Survey, 2005. Both the supply and the demand models have been validated for their forecast performance using past data. The validation exercise shows that the average supply forecast error is just 0.8 percent, while in the case of demand models the forecast error for rice is less than 5 percent in absolute terms. These low forecast errors give a sense of reliability and confidence in the projections carried out here.

Supply and demand projections are made for the years 2015, 2020, 2025, and 2030 under various scenarios. Under alternative conditions that capture land availability constraints facing rice cultivation in Bangladesh, rice supply in 2015 is expected to be in the range of 31.2 to 35.2 million tons, and it is likely to grow to 39 million tons by 2030. Household direct demand projections are made under three scenarios on the growth of real per capita income— 4.2 percent, 3.6 percent, and 3.0 percent. Assuming constant prices, per capita household demand for the year 2030 for rice are projected to be in the range of 183.7 to 192.3 kilograms (kg) per capita per year. The corresponding forecasts for wheat are in the range of 6.5 to 7.1 kg per capita per year in 2030. Combining these with alternative population forecasts from the government of Bangladesh and the United Nations Department of Economic and Social Affairs, the total direct demand for rice in 2030 is projected to be in the range of 31.3 to 42.0 million tons, up from 26.8 to 29.2 million tons in 2015. For wheat, the projection for 2030 is 1.1 million to 1.5 million tons. Adding indirect demand requirements to this, the total demand for rice in 2030 is expected to be in the range of 34.8 million and 52.5 million tons.

The supply and demand projections for rice are then compared, to assess the likely surplus/deficit situation. The estimates show that Bangladesh can face either a surplus or a deficit in rice, depending upon the prevailing supply and demand scenario and intermediate demand requirements. The surplus in 2030 could be about 4.2 million tons, while the deficit could be as high as 13.7 million tons. Our projections also show that surpluses, if any, could increase until 2020, after which they are likely to become smaller, which can be attributed to land availability constrains that will increasingly begin to affect production growth under current technologies. In contrast, deficit projections show a steady rise over time, reflecting the sharp rise in demand under the high population growth scenario.

Keywords: Bangladesh, cereal supply, cereal demand

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1. INTRODUCTION

Bangladesh is primarily an agrarian economy with high population density, where food security remains a major concern. Agriculture, having contributed 23.5 percent of the country's gross domestic product (GDP) during 2009/10, plays a great role in the creation of rural employment and generation of income in Bangladesh and is therefore considered a lifeline of the Bangladesh economy.

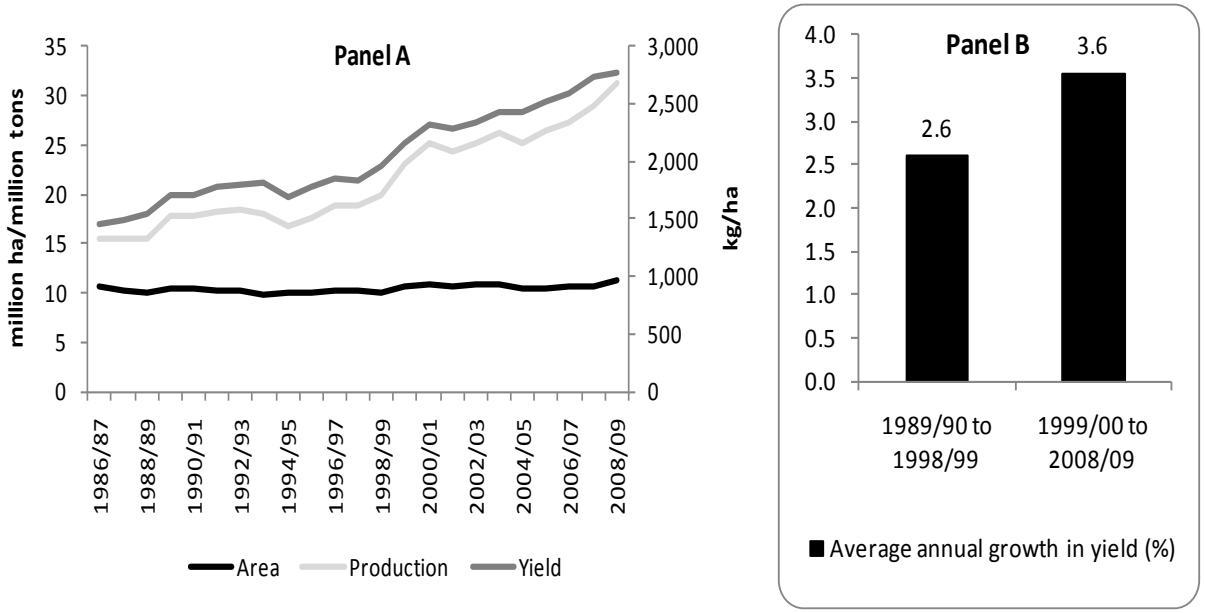
Cereal crops, predominantly rice, are the mainstay of Bangladesh's agriculture. In recent years (the period from 2000 to 2007), Bangladesh's agriculture sector has averaged an annual growth of around 3 percent, on par with, if not more than, some of its South Asian neighbors (World Bank 2009). The structural makeup of the agricultural sector in Bangladesh points toward the importance of the cereal sector. The share of cereals in the total value of agricultural output in the triennium ending 2008 was 53 percent, showing only a slight decline from its share of 55 percent in the triennium ending 1998 (FAO 2010).

Among cereals, the primary position is occupied by rice. In fact, with almost 75 percent of the total cropped area under rice cultivation, it could be said that rice is the primary crop for Bangladesh's entire agricultural sector. In comparison, wheat and maize—the other two cereals having some presence in Bangladesh—are relatively minor crops. Rice production has shown a steady increase in Bangladesh and has even shown signs of acceleration in growth in recent years (see Figure 1.1, Panel A). In particular, the growth rate in rice yields has gone up. In the period from 2000[1] to 2009, the average annual growth rate in yield of rice had reached 3.6 percent, as compared with 2.6 percent in the previous decade (Figure 1.1, Panel B). On the other hand, wheat in Bangladesh has been on a downward trend. From about 0.88 million hectares (ha) (1.9 million tons) in 1999, wheat area and production had fallen to fewer than 0.4 million ha and less than 0.85 million tons, respectively, by 2009 (Figure 1.2, Panel A), and this trend seems set to continue. In contrast, maize has experienced a dramatic upswing in recent years, with production leapfrogging from only 4,000 tons in 2000 to more than 523,000 tons by 2006—a 130-fold increase in just six years (Figure 1.2, Panel B).

Even though Bangladesh has achieved significant progress in agriculture, especially with respect to rice production and yields, the demand for rice still outstrips domestic production, and the country remains a net importer of rice (FPMU 2008). With an expanding population, planning for future cereal production and demand is crucial to meeting the food security challenges in Bangladesh. To facilitate this planning, projections of future supply and demand for cereals are critical. This study is an attempt at carrying out such future projections with a view to assessing the likely gap between supply and demand. Toward this end, models of supply and demand are first developed using the latest available data, which are then used to project supply and demand for the years 2015, 2020, 2025, and 2030 under various scenarios.

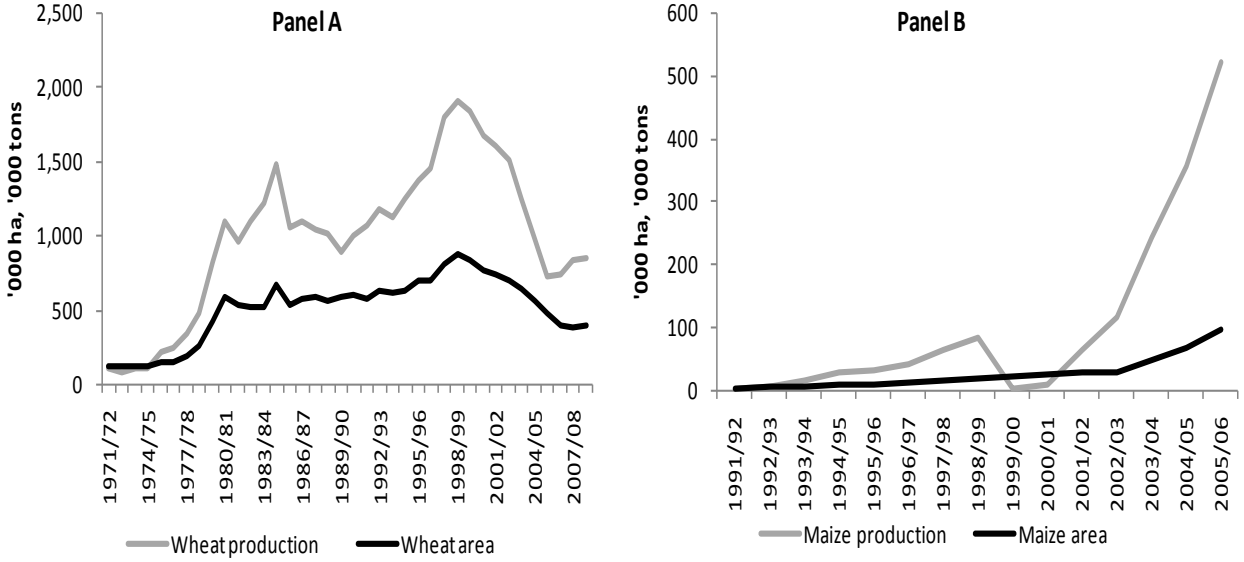
[1] The year 2000 refers to the financial year 1999/2000. This convention is followed throughout this paper.

Figure 1.1—Panel A: Area, production, and yield of rice, 1987–2009; Panel B: Growth rates of rice yield, 1989–2009



Source: MoF 2010.

Figure 1.2—Panel A: Wheat area and production, 1972–2008; Panel B: Maize area and production, 1992–2006



Source: BoS 2007.

Detailed supply modeling is undertaken only for rice, which forms the substantial part of both cereal production and cereal consumption in Bangladesh. Wheat and maize, as mentioned earlier, are relatively minor crops in Bangladesh. In the case of maize, supply modeling has not been carried out here due to (1) the very sharp growth (130-fold increase in just six years) witnessed in its output from very low levels, which makes it difficult to model its supply behavior, and (2) the absence of data on use of inputs

such as seeds and irrigation in maize production. With regard to wheat, it was seen that wheat acreage and production have been consistently declining from their very low levels since the start of the 1990s. If the current trend continues, wheat production could soon dwindle to negligible quantities, and wheat would be likely to occupy an even more minor share of the cereal basket. Bangladesh depends upon imports to meet the majority of its wheat demand, and this is a situation that is likely to continue in the foreseeable future. Hence, supply modeling for wheat was not carried out here.

The household demand model developed here considers 13 food commodity groups, including rice and wheat but not maize, since the database used here, the Household Income and Expenditure Survey (HIES) 2005, provided by the Bangladesh Bureau of Statistics, does not report on maize consumption by households. Demand projections for rice and wheat under alternative scenarios are then made covering both direct (household) demand and indirect demand for seed, feed, other industrial uses, plus wastage. Finally, assessment of the supply–demand gap is carried out only for rice, the main staple food in Bangladesh.

The paper is organized as follows: First the modeling and projection of supply is discussed in Section 2, followed, in Section 3, by a description of the demand modeling and projection exercise. Both of these sections describe the data and methodologies used to model supply/demand and carry out future projections, examine the estimated model results, and end with a discussion of the projection of future supply/demand of rice under various scenarios. Section 4 assesses the projected gap between supply and demand for rice, and this is followed with some concluding remarks in the final section.

2. MODELING AND FORECASTING RICE SUPPLY IN BANGLADESH

Bangladesh has been making significant advances in rice production, as seen previously. Also, from Figure 1.1, seen earlier, it is apparent that this increase in output is mainly due to improvement in yield, rather than an expansion of crop acreage. Indeed rice acreage has remained almost flat, around the 10 million hectare mark for an extended period of time, starting from the early 1980s and continuing to the present. However, as will be seen below, this annual picture of rather flat rice acreage and growing yield levels masks substantial differences in both of these variables across the main rice growing seasons. Because of this variation, the approach taken here is to model rice acreage and yields separately for each of the three rice seasons in Bangladesh. Projections of seasonal rice acreage and yields are then combined to arrive at the annual rice output projections. This approach is preferred instead of the production function approach because it enables us to capture the seasonal differences in the behavior of rice acreage and yields as well as the differences in the drivers of the interseason variations. Since the overall objective here is to forecast future supply, a sparse specification in terms of the explanatory variables used is preferred over very detailed modeling of all the relevant factors. This method ensures that very few auxiliary models are required to specify the future values of the explanatory variables and thus reduces the potential sources of forecast errors.

The source for much of the data used for the supply models was the Bangladesh *Handbook of Agricultural Statistics* (BoS 2007). Data on monsoonal rainfall were collected from the Bangladesh Meteorological Department (BMD 2011). Table 2.1 lists the variables and the corresponding data that were used to specify these variables in the supply models.

Table 2.1—Description of variables used

Variable	Data description	Source
Rice seasonal acreage and (local and high-yielding varieties)	1972–2009, in ’000 hectares (ha)	BoS 2007; MoF 2010
Rice seasonal production (local and high-yielding varieties)	1972–2009, in ’000 tons	BoS 2007; MoF 2010
Rice seasonal yield	1972–2009, in kilograms (kg)/ha	BoS 2007; MoF 2010
Rice seasonal irrigated area	1982–2003, in ha	BoS 2007
Total fertilizer sales	1982–2007, in tons	BoS 2007
Rice price (wholesale)	1982–2006, in Bangladeshi taka (BDT)/ton annual average	BoS 2007
Fertilizer farm-level prices	1991 to 2005, in BDT/50 kg bag, monthly average	BoS 2007
Monsoon rainfall	Monthly rainfall in millimeters June–Sept., 1980–2010	BMD 2011

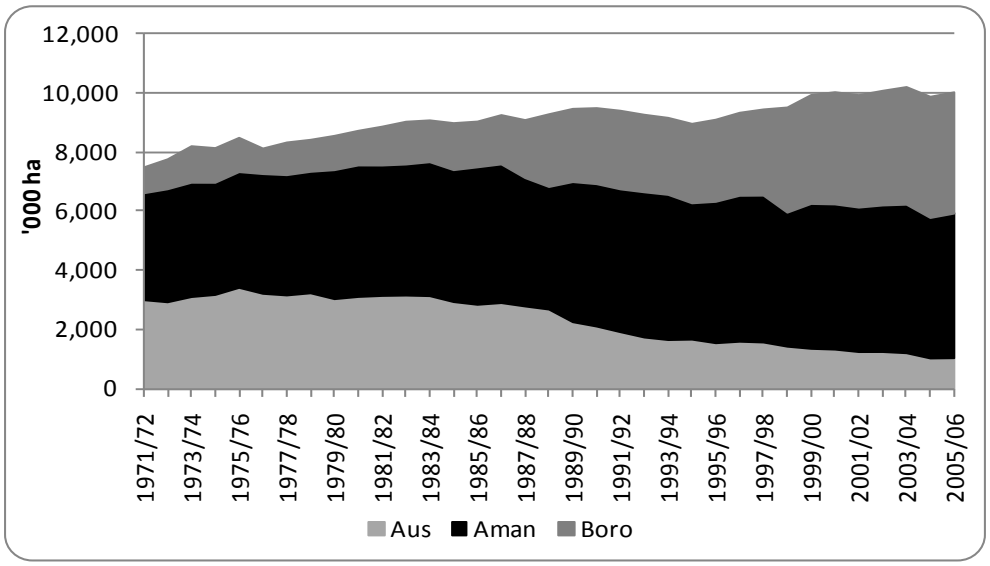
Source: Tabulation by authors.

Rice Acreage, High-Yielding Varieties, and Irrigation

Rice cultivation in Bangladesh extends across three different seasons—*boro,* or dry season, from October to March; *aus,* with sowing in April/May and harvest in July/August; and *aman,* which extends from April/May to November/December. Traditionally the *aman* rice season, which receives the benefit of the monsoons, is the major rice season. However, with the spread of irrigation, *boro* rice, which offers higher yields as compared with *aus* and *aman*, has witnessed a large increase in acreage and consequently higher production. In 1987, for instance, the *aman* acreage was just above 6 million ha, making up 57 percent of the total rice acreage, whereas *aus* and *boro* occupied 27 percent and 16 percent of acreage, respectively. By 2009, *aman* acreage had come down marginally to 5.5 million hectares, whereas *aus* acreage has

decreased much more drastically, to just above 1 million ha from close to 3 million ha in 1987. *Boro* acreage, on the other hand, grew to 4.7 million ha from about 1.7 million ha during this period. Overall, the trend that is observed in rice acreage is that *aman* has remained fairly constant and *aus* has seen a consistent decline, while *boro* has been on an increase (Figure 2.1). The area projections carried out later are based on this observed pattern in the data.

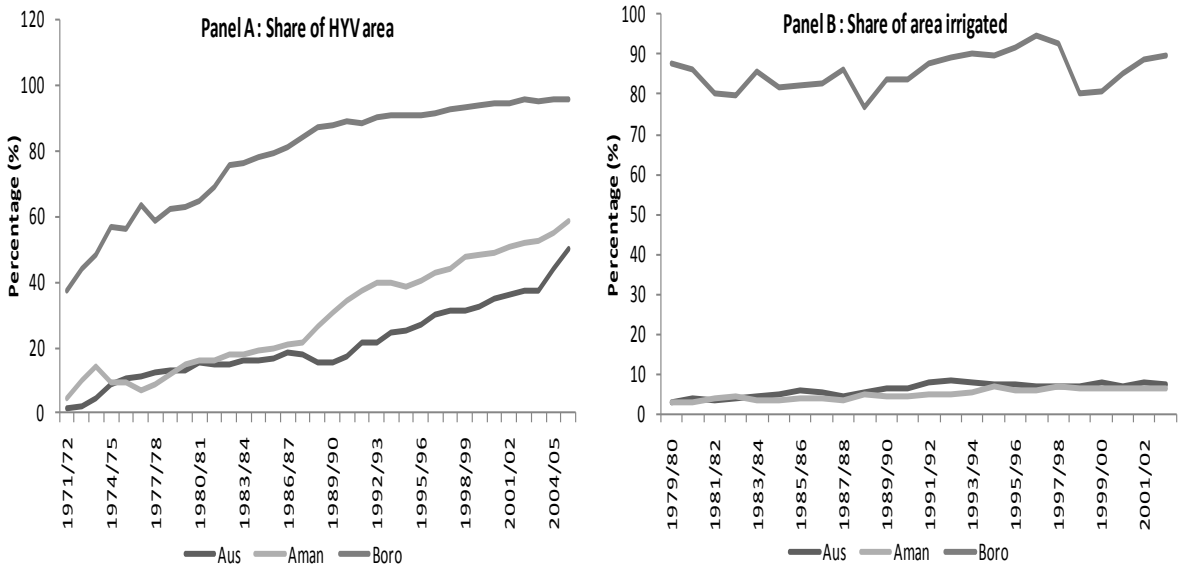
Figure 2.1—Seasonal rice acreage in Bangladesh, 1972–2006



Source: BoS 2007.

The major inputs determining yield are high-yielding varieties (HYV), irrigation, and fertilizer. Data on fertilizer usage is not available on a seasonal or per-crop basis. However, HYV and irrigated area statistics are available separately for *aus*, *aman*, and *boro* (Figure 2.2). For *boro*, we find that both HYV and irrigated area share are fairly high—by 2006 (the latest year for which data are available), nearly 90 percent of *boro* area was under HYV and irrigated, suggesting that it has probably reached 100 percent or saturation point by now. This implies that any future expansion of *boro* acreage will come forth only with an expansion of irrigation facilities, and such new area is most likely to be under HYV cultivation. On the other hand, in the case of *aman* and *aus*, HYV share is much lower, with *aus* being only around 37 percent and *aman* reaching a little less than 60 percent in 2006. Also with *aman* and *aus* receiving rainfall in the monsoon season, very little of the rice acreage in these two seasons is irrigated. In fact, the percentage of irrigated area has remained fairly constant over the long run and is likely to remain so in the future as well. There is, however, still much room for increasing the share of HYV under both *aus* and *aman*, and indeed this share is likely to grow in the future, too, as suggested by the rising trends in HYV acreage in *aus* and *aman* (Figure 2.2).

Figure 2.2—Panel A: Share of area under HYV; Panel B: Share of area irrigated



Source: BoS 2007.

Forecasting *of aus*, *aman*, and *boro* acreages, and their respective HYV and irrigation shares, is undertaken based on the above observed trends and patterns. Rice acreage under *aus* is projected to follow the present declining trend, while the HYV share is expected to increase at the current rate of growth until it becomes 100 percent of the cropped area. The irrigated share, which is nearly flat, is kept constant even in the future, at the long-run average of 7.5 percent.

In the case of aman, it was seen that the acreage is by and large at a constant level, and for the sake of future projections, too, the *aman* acreage is kept fixed at 5.5 million ha. The share of irrigated area is also fixed, in keeping with the past trend, at 5.3 percent of the cultivated area. The HYV share is projected to increase linearly at a constant rate until it hits 100 percent of the acreage.

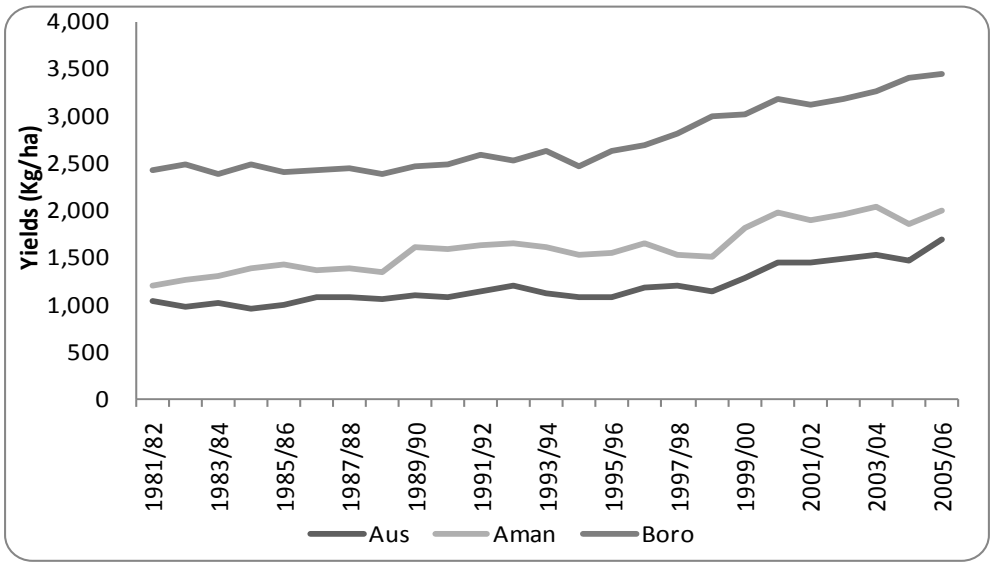
Boro rice, as already seen, has a major percentage of its area already under HYV and irrigation, and we expect both HYV and irrigation to have reached 100 percent of the *boro* acreage by now. Hereafter, HYV area and irrigated area are equal to the *boro* acreage. With *boro* being a dry-season crop, any further increase in acreage is driven basically by the increment in irrigation coverage.[2]

Yield Function Model

Rice yields in Bangladesh show large variance across seasons, with *boro* yields being the highest, followed by *aman*, and the least being *aus* (Figure 2.3). In terms of growth rate, however, *aus* and *aman* yields have grown somewhat faster, at about 1.9 percent, over the past 25 years (1981 to 2005), while *boro* yields grew by only 1.4 percent during this period. Given this interseason difference in yield performance, separate models are developed for the seasonal yields for use later in the projection exercise.

[2] It is conceivable that there are lags in supply response, which are usually attributed to lags in acreage allocation decisions. Since detailed acreage response models are not developed here as such lags in acreage adjustments resulting in lags in supply response are not explicitly captured here, though they are implicitly present in the time trends used here for acreage forecasting.

Figure 2.3—Seasonal yields of rice



Source: BoS 2007.

The seasonal rice yields are modeled as a function of fertilizer intensity (F), share of HYV (H), share of irrigated area (I), and monsoon rainfall (R). F, H, and I are on a seasonal basis, while R is the monsoon rainfall. However, since fertilizer usage is not available by season, F_{season} is defined here as total annual fertilizer per seasonal acreage (A_{season}). Thus the coefficient of F_{season} here does not measure yield response to fertilizer usage but also reflects other factors. The yield function is defined as

$$Y_{season} = f(F_{season}, H_{season}, I_{season}, R). \quad (1)$$

Equation (1) is estimated using various functional forms: linear, log-linear, and log-log, with an AR(1) correction where required. [3] The data used for estimation pertain to the period from 1981 to 2002, for which data on all the variables are available. The yield function is estimated for *aus*, *aman*, and *boro* separately, and the final models that were found most suitable are presented in Table 2.2. In the estimated yield function, the *aus* yield is found to be a function only of the share of HYV in *aus* acreage (H_{aus}), which is consistent with the fact that *aus* is largely not irrigated and that HYV share has some room to increase. Yield in *aman*, too, is driven only by the rise in HYV share, which still has some distance to cover before it reaches 100 percent. Irrigation is found to have a negative coefficient in *aman*. This might be explained by the fact that a negligible (and a rather stable) share of *aman* acreage is irrigated, while yields have grown fairly rapidly during this wet season. In the case of *boro* yields, HYV, fertilizer, and its square term come out significant. The signs of the coefficient of fertilizer (positive) and its square term (negative) suggest that diminishing returns on yields would set in at very high levels of fertilizer application.

[3] Crop yield is usually considered as being influenced by technological factors such as use of fertilizer, water, seed variety, etc., and hence introducing lagged yield level as a regressor in Equation 1 is not considered appropriate though econometrically they could help control for autocorrelation, if any.

Table 2.2—Estimated *aus*, *aman*, and *boro* yield functions

Variable	ln_aus_yld#	Variable	aman_yld#	Variable	boro_yld#
ln_H_{aus}	.371***	I_{aman}	-110.669***	H_{boro}	56.680***
		H_{aman}	24.710***	F_{boro}	2.873*
				sq_F_{boro}	-0.002
Constant	5.880***	Constant	1190.105***	Constant	-3664.593**
Observations	21	Observations	21	Observations	21
df	19	Df	18	df	17
R-square	0.460	R-square	0.705	R-square	0.364
D-W statistic	1.658	D-W statistic	1.787	D-W statistic	2.284

Source: Authors' calculations.
Notes: *** p < 0.01, ** p < 0.05, * p < 0.1, # Prais-Winsten regression estimates.

Given these results on the seasonal yield functions, forecasting *aus* and *aman* yields is fairly straightforward once the percentage of HYV and irrigated acreage during these two seasons is specified. Forecasting *boro* yields, however, requires that the fertilizer usage level itself be forecast first. For this purpose an additional auxiliary model for fertilizer usage is developed next.

Fertilizer Model

Fertilizer usage is modeled as being dependent upon the HYV area (H_ar) and irrigated area (I_ar) in each of the three rice seasons as well as upon the price of fertilizer relative to that of rice. Thus total fertilizer supply function is defined as

$$FERT = f(H_ar_{aus}, H_ar_{aman}, H_ar_{boro}, I_ar_{aus}, I_ar_{aman}, I_ar_{boro}, P_{fert}/P_{rice}). \quad (2)$$

In order to estimate this function, too, various functional forms—linear, log-linear, and log-log—are specified, and where required an AR(1) correction is made. The estimates of the model that were found to be most suitable are presented in Table 2.3. Total fertilizer is found to be dependent on the area of HYV in *aman* and on the area of irrigation in *boro*. Intuitively, this makes sense, because HYV *aman* and irrigated *boro* are the two acreages that have significant room to grow and, as such, would drive the farmers' demand for fertilizer.[4]

Table 2.3—Total fertilizer function estimates

Variable	ln_FERT#
$ln_H_ar_{aman}$	.570***
$ln_I_ar_{boro}$	.611***
Constant	5.880***
Observations	21
df	18
R-square	0.460
D-W statistic	1.658

Source: Authors' calculations.
Notes: *** p < 0.01, ** p < 0.05, * p < 0.1, # Prais-Winsten regression estimates.

[4] Note that the fertilizer term does not appear in the yield function for *aman*, nor does the irrigation term appear in the yield function for *boro;* hence the estimated yield functions reported in Table 2.2 do not suffer from any endogeneity issues.

Rice Output Projections

Future Scenarios

The forecasting exercise is carried out over the period from 2003 to 2030, keeping the data for the year 2002 as the base levels. It may be noted here that data on acreage, yield, and output are available up to 2008, and hence the period from 2003 to 2008 is useful to validate the forecasting power of the models used here.

Future rice production in Bangladesh is projected under three different scenarios—a business-as-usual scenario (BAU), an optimistic scenario (OS), and a pessimistic scenario (PS).These three scenarios each represent a different set of constraints on the growth of cultivated, irrigated, and HYV acreage in the three rice seasons. As mentioned earlier, *aman* acreage is constant while *aus* acreage is declining, even though in both cases irrigation share is constant and HYV share is increasing. In contrast, *boro* acreage is increasing rapidly even though both HYV and irrigation shares for *boro* are near saturation levels. The scenario specification essentially expects these patterns to continue in the future as well. Thus, if a particular variable exhibited a rising, declining, or level trend in the past, it is expected to do the same in the future as well.

Given the past patterns, though the downward trend in *aus* acreage is expected to continue, there will be a progressive shift toward HYV cultivation in *aus*. Similarly, *aman* acreage, too, would increasingly be under HYV, even though there might be no increase in the acreage itself. Of course, HYV share during these two seasons can increase only until it reaches the 100 percent mark, which is its natural limit. In both these seasons, irrigation intensity is expected to remain constant at its current low level. During *boro*, however, there is not much room to increase HYV or irrigation shares since they are already near saturation levels, and they are expected to remain at the 100 percent level even as *boro* acreage expands until all the available cultivable land is brought under *boro* cultivation. Given such natural limits on the trending variables, the scenarios essentially differ only in terms of the speed at which these natural constraints are reached, that is, how many years it takes before the constraints are hit.

In line with past patterns, certain factors are set at the same level under all the three scenarios, as mentioned earlier. Rice acreage under *aman* is assumed to remain constant at 5.5 million ha. So is the irrigation share in *aman* and *aus*, which remains at 5.3 percent and 7.5 percent of the respective acreage across BAU, OS, and PS. Since nearly 90 percent of *boro* acreage was already irrigated by 2002, the latest year for which irrigation data are available, it has been assumed that 100 percent of *boro* acreage was irrigated by 2006 and remains so in the future under all three scenarios.

With regard to HYV, its share in *aman* is set to reach 100 percent under BAU by 2025, while under OS it reaches 100 percent by 2020. Under PS, on the other hand, it is projected to reach 100 percent by 2030. HYV share in *aus* under BAU is assumed to continue to grow at the base average growth rate of 2.5 percent per year until it reaches 100 percent and thereafter to remain at that level. Under OS, the growth rate in HYV is increased slightly to 2.6 percent, while under PS it is reduced to 2.3 percent. HYV in *boro* is assumed to have hit 100 percent by 2008 in BAU and OS, whereas under PS it is assumed to be slightly delayed and reaches 100 percent only by 2011.

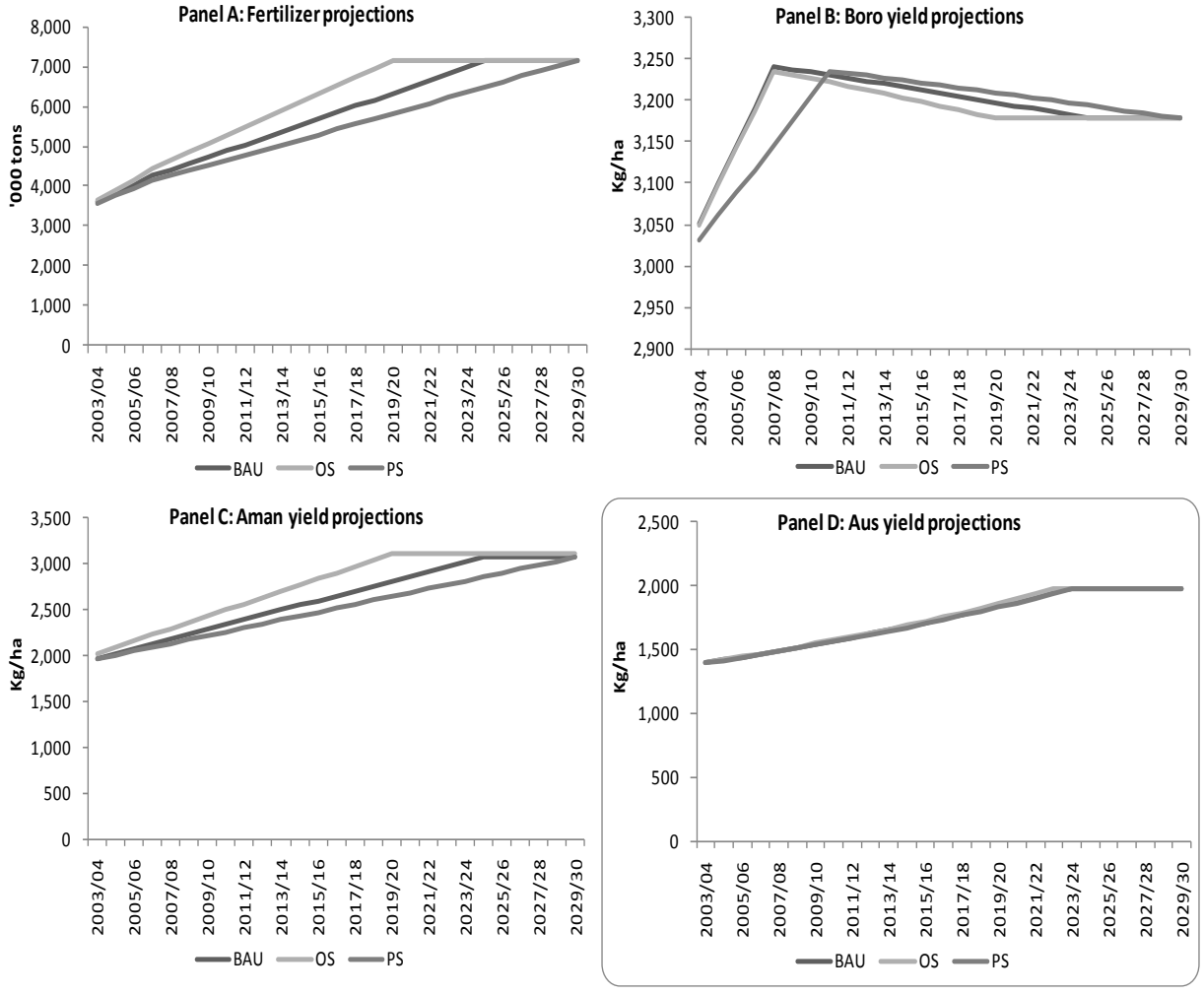
In keeping with the past trend, *boro* acreage is projected to rise continually (as is irrigated and HYV acreage) until it reaches a cap of 6.5 million ha. This cap is dictated by the overall constraint on total cultivable land available in the country. The total cultivable land in Bangladesh has been showing a decline, and it was around 8.4 million ha in 2005. Given this trend, a cap of around 75 to 80 percent of the total cultivable area has been fixed for the area under *boro* rice. *Boro* acreage is assumed to grow linearly at a constant rate and to reach this cap by 2025 under BAU, 2020 under OS, and 2030 under PS.

Future Projections

Under these three scenarios, first the rice acreage under *aus*, *aman*, and *boro* is projected to 2030. Subsequently the HYV and the irrigated acreages are estimated under each of the scenarios. These estimates are used to determine the total fertilizer and, following that, to estimate the seasonal yields. The total rice acreage is constrained to reach a maximum of 12.6 million ha, since acreage in all three seasons has an upper limit (although this limit is lower in the case of *aus*). HYV acreage in all three cases, too, reaches 100 percent at some point in time (at the latest by 2030 under OS). Irrigation share remains constant under *aus* and *aman*, and in the case of *boro* reaches 100 percent quickly and remains there. As *boro* acreage reaches its cap of 6.5 million ha, *boro* irrigated area, too, is bound by this upper limit.

Total fertilizer quantity, too, is bound by an upper limit, since it is driven only by *aman* HYV area and *boro* irrigated area (Figure 2.4, Panel A). *Boro* yields are dependent on both the fertilizer intensity and its square term, which has a negative coefficient, following a quadratic trajectory. Yield reaches a maximum and then declines until it hits a plateau, where fertilizer quantity and *boro* area are at their maximums (Figure 2.4, Panel B). Rice yields in *aman* and *aus* show a linear increase until these, too, reach an upper limit (Figure 2.4, Panels C and D). Across the three scenarios, as mentioned earlier, the difference seen is in the time frame in which the upper limit is reached.

Figure 2.4—Total fertilizer quantity and seasonal yield forecasts



Source: Authors' estimates.

Once the seasonal rice acreage and yield are forecasted, then the product of these two gives the seasonal forecasts for rice output. The seasonal output forecasts are then summed up to arrive at the forecast for total annual rice output (Table 2.4). These projections show that rice output in 2015 is expected to be in the range of 31.2 to 35.2 million tons. By 2030, it is likely to grow to nearly 39 million tons. The projections in this exercise start from 2003. As a result, there are six years for which out-of-sample validation is possible. Comparing these actual outputs with the projected outputs shows the average deviation of the projected from the actual to be 0.8 percent (Table 2.5). This is a fairly acceptable level of margin of error and thus lends greater confidence in the projections carried out here.

Table 2.4—Total rice area, yield, and production projections

Year	Rice area ('000 ha)*			Rice yield (kg/ha)#			Rice production ('000 tons)^		
	OS	BAU	PS	OS	BAU	PS	OS	BAU	PS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2015	12,186	11,760	11,492	2,887	2,778	2,715	35,187	32,670	31,199
2020	12,852	12,249	11,869	3,061	2,930	2,849	39,335	35,883	33,817
2025	12,737	12,737	12,245	3,078	3,063	2,970	39,209	39,010	36,371
2030	12,622	12,622	12,622	3,088	3,073	3,073	38,981	38,782	38,782

Source: Authors' estimates.
Note: *Total rice area is arrived at by summing up the *aus*, *aman*, and *boro* projected acreages. #Total rice yield is estimated as (total projected rice output)/(total projected rice area). ^Total rice production is estimated by summing up (rice acreage)*(rice yield) for each season.

Table 2.5—Out-of-sample comparison of actual and projected rice output ('000 tons)

Year	Actual	Projected	Deviation (%)
2003	26,189	24,653	-5.9
2004	25,156	25,503	1.4
2005	26,530	26,357	-0.7
2006	28,673	27,213	-5.1
2007	25,379	28,100	10.7
2008	27,592	28,758	4.2
Average			0.8

Source: Actual values are from BoS 2007 and MoF 2010; projected values and deviations are authors' estimates.

3. MODELING AND FORECASTING DEMAND FOR CEREALS IN BANGLADESH

This section focuses on developing a set of models that are then used for forecasting the different components of domestic demand for rice and wheat in Bangladesh. The scope here is restricted to domestic demand, since the objective of this paper is to assess the gap between domestic supply and domestic demand. Because the government of Bangladesh does not have a major stocking policy similar to that of neighboring India, any gap between domestic supply and domestic demand is assumed to be met by trade (either imports or exports). Bangladesh has been a net importer of rice and wheat for several decades, and hence export demand for cereals is unlikely to become an issue of concern to the country. As noted earlier, the demand analysis does not cover maize due to lack of data on demand for maize by households.

There have been several attempts in the literature to estimate food demand using Household Income and Expenditure Survey (HIES) data for Bangladesh. Chowdhury (1982) applied the Frisch (1959) method for computing all direct and cross elasticities of demand under condition of want independence with methodological advantage of it over little availability of price data. In contrast, in a method of demand estimation called the food characteristics demand system, Bouis (1989) assumed that marginal utility of consumption of any food depends on the level of consumption of all other foods; he applied this method to estimate corresponding food demand elasticities of Bangladesh using 1973/74 Household Expenditure Survey[5] data. Pitt (1983) and Goletti (1993) used a method called Tobit to estimate the food demand system. Pitt (1983) showed that it is inappropriate to use Tobit in demand analysis for models that have expenditure or budget share as dependent variables. In contrast, Ahmed and Shams (1994) estimate an almost ideal demand system (AIDS) based on primary data from three rounds of a household consumption and nutrition survey conducted in Bangladesh by the International Food Policy Research Institute (IFPRI) over the period from September 1991 to November 1992. The most recent attempt to study demand elasticities for food items in Bangladesh was made by Anwarul Huq and Arshad (2010). This study primarily focused on the estimation of price elasticity, cross-price elasticities, and income elasticity of demand for different food items based on the linear approximate AIDS (LA-AIDS) model with a corrected Stone price index. It was based on a panel of samples from the Bangladesh HIES during the years 1983/84, 1988/89, 1991/92, 1995/96, 2000, and 2005/06.

In this study, we follow the approach in Ahmed and Shams (1994) and Anwarul Huq and Arshad (2010) in specifying a complete demand system for modeling food demand in Bangladesh. In the rest of this section, we first describe the models and data used here, followed by the estimation results and then the demand forecasts under different scenarios.

Methodology and Data

The total domestic demand for individual cereals such as rice and wheat consists of (1) direct demand by households and (2) indirect demand as raw materials in own and other production sectors (that is, seed and feed requirements and wastage). The methodology used to model and forecast these two components of domestic demand is described in detail below.

Household Demand Model

Household direct demand for food items including the two major cereals, rice and wheat, is modeled using the quadratic almost ideal demand system (QUAIDS) developed by Banks, Blundell, and Lewbel (1997). The QUAIDS model relates the shares of different commodities in the total expenditure of a

5 Prior to 2000, the focus of the surveys carried out by the Bangladesh Bureau of Statistics was on household expenditure, and accordingly the surveys were called Household Expenditure Surveys. Since 2000, greater emphasis has been placed on collecting data on income along with expenditure, and hence the surveys are now known as Household Income Expenditure Surveys.

household to the household's budget and the prices of different commodities. The expenditure share of the i^{th} good in the total expenditure (w_i) is defined as

$$w_i = {p_i q_i}/{m}, \tag{3}$$

where p_i is the price of the i^{th} good; q_i is the quantity of the i^{th} good; m is the total expenditure on all the goods, satisfying the constraint $\sum_{i=1}^{n} w_i = 1$; and n is the number of goods in the system. The QUAIDS model for n goods is specified as

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left[\frac{m}{a(\boldsymbol{p})}\right] + \frac{\lambda_i}{b(\mathbf{p})}\left\{ln\left[\frac{m}{a(\boldsymbol{p})}\right]\right\}^2, \tag{4}$$

where $a(\boldsymbol{p})$ and $b(\boldsymbol{p})$ are price indexes, $\boldsymbol{p}$ is the vector of prices, and $\alpha_i, \beta_i, \gamma_{ij}$ and λ_i are parameters to be estimated. The price index $a(\boldsymbol{p})$ is the translog price index, and $b(\boldsymbol{p})$ is the Cobb-Douglas price aggregator, as defined below in Equations (5) and (6), respectively:

$$\ln a(\boldsymbol{p}) = a_0 + \sum_{n=1}^{n} a_i \ln p_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \tag{5}$$

$$b(\boldsymbol{p}) = \prod_{i=1}^{n} p_i^{\beta_i,} \tag{6}$$

The parameters of the QUAIDS model have to satisfy the adding-up condition (additivity), the homogeneity condition, and the Slutsky symmetry restriction, which are given as follows:

Additivity: $\sum_{i=1}^{n} \alpha_i = 1, \sum_{i=1}^{n} \beta_i = \sum_{i=1}^{n} \gamma_{ij} = 0$
Homogeneity: $\sum_{i=1}^{n} \gamma_{ij} = 0 \; \forall \, j$
Symmetry: $\gamma_{ij} = \gamma_{ji}$

Expenditure elasticities for the QUAIDS system are given as $e_i = {\mu_i}/{w_i} + 1$, where $\mu_i = \beta_i + \frac{2\lambda_i}{b(\boldsymbol{p})}\left\{ln\left[\frac{m}{a(\boldsymbol{p})}\right]\right\}$.

The uncompensated price elasticities are given by $e_{ij} = {\mu_{ij}}/{w_i} - \delta_{ij}$, where δ_{ij} is the Kronecker delta and $\mu_{ij} = \gamma_{ij} - \mu_i\left(\alpha_j + \sum_k \gamma_{jk} \ln p_k\right) - \frac{\lambda_i \beta_i}{b(\mathbf{p})}\left\{ln\left[\frac{m}{a(\boldsymbol{p})}\right]\right\}^2$.

Since the QUAIDS model, in Equation (4), is a system of n nonlinear equations, the estimation procedure has to take care of possible cross-equation correlations. Hence, the model parameters are estimated by the nonlinear seemingly unrelated regressions (NLSUR) procedure.

Food Budget Model

Since the focus of this paper is primarily cereals, in this paper the QUAIDS model is estimated for only 13 food commodity groups, as described below. Accordingly, the total expenditure m in the QUAIDS equation (4) refers to that portion of a household's expenditure spent on food items only. For forecasting purposes, it is therefore essential to model the food budget itself. We specify a simple model as follows:

$$\ln FB = \alpha + \beta \ln INC + \mu, \tag{7}$$

where *FB* is food budget per capita and *INC* is a measure of income per capita. Prices (or an aggregate index of food prices) are not considered here because the forecasting exercise is carried out under the assumption of constant food prices. Moreover, data on appropriate prices were not available.

Estimating Seed, Feed, and Wastage

As mentioned earlier, total domestic demand (*T*) for cereals consists of the direct demand (*D*) by households and the indirect demand (*ID*) in the form of seed, raw materials used in various other sectors of the economy (feed), and waste in handling grains at various stages in the supply chain. The QUAIDS model above, coupled with the food budget model, is used to project the direct demand (*D*) for cereals by households. With this estimate of *D, T* and *ID* can then be projected using Equations (8), (9) and (10) below, once an estimate of μ, the fraction of the total demand for a particular commodity that goes toward the indirect demand (*ID*), is known.

$$T = {}^{D}/_{(1-\mu)} \tag{8}$$

$$ID = T \times \mu, \tag{9}$$

$$D + ID = T. \tag{10}$$

An estimate of μ can be derived from the input–output table that describes the intersectoral linkages in the country. Alternatively, it can be taken from the country-specific administrative recommendation or commodity-specific estimates available in the literature. In this study, we have used administrative recommendations as well as estimates from the literature.

Data

The demand parameters of the QUAIDS model are estimated using data from HIES 2005, provided by the Bangladesh Bureau of Statistics. Sampling design involved in obtaining observations on different socioeconomic indicators follows a two-stage stratified random sampling to ensure greater precision in its strategy. In particular, the framework of obtaining sample observations is called integrated multipurpose sampling (IMPS). In the first stage, a total of 504 primary sampling units (PSUs) were selected, and in the second stage 20 households were selected per PSU to represent rural areas, urban areas, and statistical metropolitan areas (SMAs). Thus the total sample size of households used in this demand analysis was 10,080, but it was reduced to 10,069 after removing faulty observations.

Sections 9A and 9B of the HIES provide information on consumption of various food items on a daily (reported for a two-week period), weekly, and monthly basis. The QUAIDS analysis here is based on these consumption data. For our purpose, all the food items are categorized into 13 broad food commodity categories by applying suitable scale factors to convert underlying detailed commodities reported by HIES into one broad commodity group. The available information on consumption in terms of quantity and values of specific commodity groups are finally converted into an annual per capita basis for each household. The 13 broad food groups are presented in Table 3.1. For instance, the HIES data give detailed consumption information on fine rice, medium rice, coarse rice, beaten flat rice, and popped (puffed) rice. These individual rice items are combined into an aggregate rice in our analysis, for which the quantity of flat rice was scaled by a factor of 0.85 to convert it into rice equivalents (that is, 1 kilogram of flat rice is equivalent to 850 grams of rice), while the quantities of the individual rice varieties (fine, coarse, medium) were simply aggregated without any adjustment for quality difference. Similarly, to convert wheat flour to wheat equivalent terms, a factor of 0.95 was used. Table 3.1 reports the scale factors used for various items. It also reports the average expenditure shares for the 13 food items considered here as well as the per capita quantity consumed. In terms of expenditure shares, rice, fish, and vegetables are the three most important items, accounting for more than half the total food

budget of the average household in Bangladesh. Besides these, another fifth of the budget is spent on "others," which is a mix of other cereals, sweetmeats, and dining out.

The food budget model given in Equation (7) is also estimated with the data on food budget and per capita income from the HIES 2005. However, for forecasting purposes, first of all one needs to project the future values of per capita income itself. The HIES 2005 data, being cross-sectional, do not allow us to evaluate the trend in per capita income in the country. Hence, we use an alternative measure of per capita income, namely the gross national income per capita (GNIPC) from the World Development Indicators (WDI) (World Bank 2009),[6] for which time series information is available, permitting us to work out the trend.

Table 3.1—Food item categories

S. no.	Food category	Unit	Constituent food items[#]	Budget share (%)	Quantity consumed per capita per year (kg)
1	Rice	Kg	Fine rice, coarse rice, medium rice, beaten flattened rice (0.85), popped rice	28.5	167.39
2	Wheat	Kg	Flour (0.95)	1.8	5.4
3	Pulses	Kg	Lentils (*musur*), chickling-vetch (*mug*), green gram (*boot*), pea gram (kheshari), mashkalai, others	3.2	5.44
4	Fish	Kg	*Hilsa, rhui* / *katla* / *mrigel* / *kal baush*, *pangash*/ *boal*/ *air*, *kail magur/shinghi/khalisha*, koi, silver carp/ grass carp/ mirror carp, shoal/*gajar/taki, puti* / big *puti* / telapia / *nilotica, mala-kachi/chala-chapila*, shrimp, dried fish, *tangra*/eelfish, sea fish*, baila/tapashi*, others	14.2	16.43
5	Eggs	No.	Hen eggs, duck eggs, others	1.5	34.0*
6	Beef and other meat	Kg	Beef, buffalo, mutton, sheep	4	3.56
7	Bird meat	Kg	Hen, duck, others	2.8	2.78
8	Vegetables	Kg	Potato, *brinjal* (eggplant), white gourd, pumpkin, water gourd, balsam apple, *perbo*l, snake gourd, ribbed gourd, green banana, green papaya, arum, *ol-kachu, kachur-mukhi*, cauliflower, cabbage, bean*, lobeya*, tomato, radish, lady's-finger (okra), spinach, amaranth, basil, others	11.1	85.78
9	Milk	Kg	Liquid milk, powdered milk (100/13), curd casein (paneer), butter, milk drinks, others	3.2	14.9
10	Oils	kg	Mustard oil, soybean oil, *Dalda*, *vanaspati*, ghee, others	5.6	6.58
11	Fruits	Kg	Ripe banana, mango, melon, *bangi*, jackfruit, Leeches, ripe papaya, guava, pineapple, *safeda*, palm, *bedan*a apple (pomegranate), orange, grape, blackberry, *amra*, *kamranga* (star fruit), others	3.3	13.04
12	Sugar	Kg	Sugar, *misri* (rock sugar)	1.1	2.41
13	Others	BDT	Other cereals, Sweetmeat, miscellaneous food, dining out, tobacco and tobacco products, spices	19.8	30.44[$]

Source: Authors' calculations based on HIES 2005 data.

Notes: [#] Figures in parentheses are the scale factors used for unit conversion. * Eggs are in number. $ The item "Others" is an aggregate of disparate items that do not have a standard physical unit of measure; hence, this category is considered to be unit priced and its quantity is measured in BDT per capita per year.

[6] The World Development Indictors report GNIPC in current prices, which we convert to constant prices using the GDP deflator.

Estimation Results

QUAIDS Model

The estimates of the expenditure and price elasticities based on the QUAIDS model are presented in Table 3.2. The estimated parameters of the QUAIDS model are presented in the appendix, Table A.1. Out of the 130 total parameters in our QUAIDS specification, it is observed that 106 coefficients are statistically significant at the 5 percent level. In general, the estimated elasticities conform to the expected behavior for specific food items that are either a necessity or a luxury. From our analysis, the estimated expenditure elasticity of demand for rice is 0.85 and its own-price elasticity is -0.623, giving an indication that this item is a necessity in the food basket of Bangladeshi households. In contrast, wheat has a high expenditure elasticity (1.345) and own-price elasticity (-1.206), suggesting that it is perhaps more of a luxury item in the diets of the people of Bangladesh.

With regard to the other food items, those with expenditure elasticity less than unity are pulses (0.814), fish (0.933), vegetables (0.535), oils (0.784), and others (0.855), while eggs (1.251), beef and other meat (2.318), bird meat (1.974), milk (1.790), fruits (1.796), and sugar (1.766) have relatively high expenditure elasticity. Turning to price elasticities, the food items that show relatively inelastic behavior in terms of their own-price movement in the absence of any compensation, in terms of either price change or income change, are rice (-0.623), fish (-0.579), bird meat (-0.874), vegetables (-0.693), oils (-0.697), and others (-0.419). Food items that are highly responsive to the changes in own prices are pulses (-1.140), beef and other meat (-1.184), and fruits (-1.368). Two items—eggs (-0.956) and milk (-0.967)—also have own-price elasticities that are only slightly less than 1, while sugar (-1.041) has a price elasticity that is slightly higher than 1.

Table 3.2—Expenditure elasticity and own and cross uncompensated price elasticities

S. no.	Commodity group	Expenditure elasticity	Uncompensated price elasticities												
			1	2	3	4	5	6	7	8	9	10	11	12	13
1	Rice	0.850	-0.623	-0.138	-0.184	-0.166	-0.132	0.139	0.048	-0.042	-0.064	-0.136	0.025	0.081	-0.088
2	Wheat	1.345	0.067	-1.206	0.027	-0.014	0.138	-0.061	-0.135	0.138	-0.015	0.094	-0.024	0.121	0.101
3	Pulses	0.814	0.059	0.034	-1.140	0.049	0.119	-0.008	-0.105	0.184	0.169	0.018	-0.068	-0.148	0.049
4	Fish	0.933	0.001	-0.226	0.181	-0.579	0.003	-0.093	-0.495	0.048	0.126	-0.123	0.117	-0.380	0.022
5	Eggs	1.251	0.069	0.120	0.064	0.014	-0.956	-0.064	0.015	0.129	-0.025	0.009	0.043	0.082	0.052
6	Beef and other meat	2.318	0.073	-0.036	0.028	0.012	-0.082	-1.184	-0.023	0.140	0.225	0.034	0.176	0.063	0.032
7	Bird meat	1.974	0.069	-0.177	-0.080	-0.075	0.050	-0.039	-0.874	0.215	0.100	0.161	0.091	-0.465	0.055
8	Vegetables	0.535	0.036	0.094	0.230	-0.064	0.066	0.077	0.405	-0.693	-0.105	0.063	0.040	0.783	-0.095
9	Milk	1.790	0.060	-0.053	0.162	0.047	-0.095	0.090	0.052	0.091	-0.967	0.050	0.027	-0.227	0.035
10	Oils	0.784	0.053	0.225	0.006	-0.048	-0.039	-0.007	0.273	0.145	0.060	-0.697	0.085	-0.201	-0.020
11	Fruits	1.796	0.070	-0.060	-0.073	0.048	0.063	0.059	0.050	0.135	0.033	0.070	-1.368	0.126	0.069
12	Sugar	1.766	0.075	0.091	-0.043	-0.014	0.072	0.004	-0.176	0.191	-0.038	-0.020	0.075	-1.041	0.071
13	Others	0.855	-0.008	0.349	-0.094	-0.057	-0.216	-0.265	-0.138	-0.136	-0.245	-0.279	-0.044	0.053	-0.419

Source: Authors' estimates.

Food Budget Model

In order to use the estimated QUAIDS model for projecting future demand for individual food items, we need to project the food budget entering into the QUAIDS model. The food budget model described in Equation (7) is estimated using the data on food budget and per capita income from the HIES 2005. The model estimates are presented in Table 3.3. Projecting the future food budget requires projecting the future income per capita, for which the time series data on GNIPC from the WDI database (World Bank 2009) are used.

Table 3.3—Food budget model estimates

Log(food budget)	Coefficients
Intercept	6.9893***
Log(income per capita)	0.2140***
Adjusted R-square	0.7623

Source: Authors' estimates.
Note: *** $p < 0.01$.

Model Validation

Before using the estimated QUAIDS and food budget models for forecasting, their forecast performance is first validated with available data for the past. Validation is carried out for two time points in the past, 2000 and 1996, for which data on household demand are available from the earlier rounds of the HIES. The 10-year interval in this validation exercise allows us to assess the medium-term forecasting performance of the QUAIDS and food budget models.

Validation is also carried out for the base year 2005, the year to which the data used in the model estimation pertain. For the base year 2005, two sets of forecasts are first generated to evaluate the model performance. First, demands by commodity are forecast using the actual observed values for the food budget and prices from HIES 2005 (Table 3.4, columns 2 and 3). This helps us evaluate the performance of the QUAIDS model. The forecast errors for rice, wheat, pulses, and eggs are quite acceptable (at about 10 percent or less). It may be noted that all these are either single commodities (such as rice and wheat) or do not involve aggregating diverse constituent commodities, as in the case of pulses and eggs (see Table 3.1). In contrast, fairly large forecast errors are seen in the case of the remaining commodities, all of which involve aggregation over diverse constituent commodities. From the perspective of this paper, which focuses on cereals, especially rice, the low forecast errors are a matter of comfort.

The second set of forecasts for 2005 (Table 3.4, columns 4 and 5) involves forecasting the food budget using the actual observed per capita income as reported in HIES 2005, and then using this predicted value of the food budget in the QUAIDS model to obtain the per capita demands by commodity. This helps us assess the performance of the food budget model. The estimated food budget in this case is 6.2 percent higher than the HIES 2005 observed levels, and the forecast error for rice is just 1.4 percent.

Table 3.4—Model validation results: Food budget and per capita consumption quantities

Item	2005			2000			1996					
	HIES actuals	Set 1 forecasts	Forecast error (%)	Set 2 forecasts	Forecast error (%)	HIES actuals	Forecast values	Forecast error (%)	HIES actuals	Forecast values	Forecast error (%)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Food budget	7,939.8	7,939.8	0.0	8,432.5	6.2	6,887.1	8,264.3	20.0	7,358.8	7,979.3	8.4
Rice	160.5	155.1	-3.3	162.7	1.4	167.4	165.8	-0.9	169.5	161.3	-4.8
Wheat	4.4	4.8	9.5	5.2	18.7	6.3	2.4	-61.5	12.3	2.3	-81.5
Pulses	5.2	5.7	10.1	6.0	15.5	5.7	4.1	-27.2	5.1	4.0	-20.8
Fish	15.4	18.5	20.3	19.5	27.2	14.1	18.9	34.2	16.0	18.3	14.3
Eggs	38.0	34.8	-8.4	37.5	-1.3	38.0	58.1	53.1	23.4	55.5	137.6
Beef and other meat	3.1	2.0	-34.1	2.3	-25.2	3.2	2.6	-19.8	2.8	2.4	-13.4
Bird meat	2.5	3.0	21.3	3.4	35.1	1.5	3.0	101.2	1.5	2.8	93.1
Vegetables	57.3	88.0	53.5	90.3	57.6	51.3	84.3	64.4	55.7	83.1	49.2
Milk	11.8	16.6	40.4	18.3	54.8	10.8	20.7	91.1	11.8	19.6	66.5
Oils	6.0	7.0	15.6	7.3	21.0	4.7	7.5	61.2	3.6	7.3	102.8
Fruits	11.9	9.0	-23.8	10.0	-15.6	10.4	8.7	-16.1	10.1	8.2	-18.9
Sugar	2.2	2.5	11.6	2.7	23.5	1.6	1.7	7.4	1.4	1.6	12.8

Source: Authors' estimates.
Note: Food budget is in BDT at 2005 prices. Per capita consumption quantities are in kilograms for all items except eggs, which are in numbers.

Having assessed the performance of the models for the base year 2005, we now assess the models' prediction performance over time for the years 2000 and 1996, for which relevant data are available from previous rounds of the HIES. It must be noted here that the forecast exercise in this paper is carried out assuming constant 2005 prices, whereas the HIES data for the previous years are in then-current prices. Hence, the observed per capita income and food budget for 2000 and 1996 are first converted to real per capita income and real food budget at 2005 prices using GDP deflators. This real per capita income is used in the food budget model to obtain the predicted food budget, which is then compared with the observed real food budget. The predicted food budget is then used in the QUAIDS model to obtain the predicted per capita consumption quantities. These show that the forecast errors (Table 3.4, columns 8 and 11) for rice are less than 5 percent for both 2000 and 1996. This reinforces our confidence in the models' forecast performance over a reasonably long time period.

Future Scenarios and Projections

The future demand forecasts for the years 2015, 2020, 2025, and 2030 are based on the conditions envisaged under various possible scenarios. These scenarios are based on the projected growth in GNIPC at constant prices taken from WDI (World Bank 2009). We first envisage a business-as-usual scenario (BAU), wherein the current trend in real GNIPC growth at 3.6 percent per capita over the period 2000–2010 is expected to continue. We then consider two alternative scenarios—a pessimistic scenario (PS), wherein the real GNIPC growth is expected to be somewhat lower, at 3.0 percent, and an optimistic scenario (OS) in which the real GNIPC growth is projected to grow at a faster rate of 4.2 percent per year. We use the projected income levels under these alternative scenarios to arrive at the corresponding food budgets, allowing a 0.01 percentage point fall in food budget elasticity over the period in order to

accommodate rise in income and its distributional effect over food and nonfood items. The projected food budgets are tabulated in Table 3.5.

Table 3.5—Projected food budget per capita at constant 2005 prices, BDT

Year	OS	BAU	PS
2015	9,224	9,108	8,994
2020	9,646	9,466	9,288
2025	10,089	9,838	9,592
2030	10,551	10,225	9,906

Source: Authors' estimates.
Note: BAU, OS, and PS refer to business as usual, optimistic scenario, and pessimistic scenario, wherein real per capita income is specified to grow at 3.6, 4.2, and 3.0 percent per year, respectively.

The above projected food budgets in real terms are then used in the QUAIDS model to obtain the projected per capita consumption quantities for each commodity. In this projection, the commodity prices are kept at their 2005 levels. Thus, the demand projections capture only the effects of changes in real income. The demand projections by commodity under the three income scenarios for the years 2015, 2020, 2025, and 2030 are reported in Table 3.6. For the year 2030, the projected demand for rice is in the range of 183.7 to 192.3 kg per capita per year. It is also seen that the forecasts show an increasing trend over the period from 2015 to 2030. The annual increase in per capita rice demand is in the range of 0.85 to 1.2 kg across the scenarios, which is quite modest.

Table 3.6—Projected annual consumption quantities, kilograms per capita

Food items	OS				BAU				PS			
	2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
Rice	174.3	180.2	186.2	192.3	172.6	177.7	182.8	188.0	171.0	175.2	179.4	183.7
Wheat	5.9	6.3	6.6	7.1	5.8	6.1	6.4	6.8	5.7	6.0	6.2	6.5
Pulses	6.4	6.7	6.9	7.1	6.4	6.6	6.8	7.0	6.3	6.5	6.6	6.8
Fish	21.2	22.1	23.0	24.0	21.0	21.7	22.5	23.3	20.7	21.4	22.0	22.6
Eggs[#]	41.9	44.3	46.8	49.5	41.3	43.3	45.4	47.6	40.6	42.3	44.0	45.8
Beef and other meat	2.8	3.0	3.3	3.6	2.7	2.9	3.1	3.4	2.6	2.8	3.0	3.2
Bird meat	3.9	4.2	4.6	5.0	3.8	4.1	4.4	4.7	3.8	4.0	4.2	4.4
Vegetables	93.8	95.5	97.2	98.9	93.3	94.8	96.2	97.7	92.8	94.1	95.3	96.5
Milk	21.1	22.7	24.3	26.1	20.7	22.0	23.4	24.8	20.3	21.4	22.5	23.6
Oils	7.8	8.1	8.4	8.6	7.7	8.0	8.2	8.4	7.7	7.8	8.0	8.2
Fruits	11.6	12.5	13.5	14.5	11.4	12.2	13.0	13.8	11.2	11.8	12.4	13.1
Sugar	3.2	3.4	3.7	4.0	3.1	3.3	3.6	3.8	3.1	3.2	3.4	3.6
Others[$]	53.3	55.5	57.8	60.2	52.7	54.6	56.5	58.5	52.1	53.6	55.2	56.9

Source: Authors' estimates.
Notes: BAU, OS, and PS refer to business as usual, optimistic scenario, and pessimistic scenario, wherein real per capita income is specified to grow at 3.6, 4.2, and 3.0 percent per year, respectively. # Eggs are in numbers. $ Others are in BDT.

To arrive at the total direct demand by households, the per capita demand projections have to be combined with population projections. Population projections for Bangladesh are available from two sources: (1) the Ministry of Planning of the government of Bangladesh and (2) the United Nations Department of Economic and Social Affairs (UN DESA). Both sources provide population forecasts

under four alternative population growth scenarios. The ministry's forecasts are under assumptions that the replacement-level fertility rate (that is, the point at which the net reproduction rate, or NRR, equals 1) will be achieved by the years 2011, 2016, and 2021, respectively, plus the case of a constant fertility rate at the level prevailing in 2004, which was 2.51. Similarly, UN DESA's forecasts are for the cases of low, medium, high, and constant fertility rates.

These forecasts show substantial variation both internally and across the two sources. The government's forecasts are in general higher than the forecasts by UN DESA (see Table 3.7). Moreover, the range of population projections is quite large for each source and across the two sources. For instance, the forecast range for the year 2030 is about 28 million in the government's forecasts, 24 million in UN DESA's forecasts, and 48 million (or roughly one-third of the 2010 population) across the two sources. Given this large range in the population forecasts, a simple average of all the forecasts from the two sources is computed (Table 3.7, column 9). This average of the forecasts shows very close correspondence with the government's forecast under the assumption that NRR = 1 is achieved by 2016.

Table 3.7—Population projections, in millions

	Bangladesh Ministry of Planning				United Nations DESA				
Year	Constant fertility	2021 NRR = 1	2016 NRR = 1	2011 NRR = 1	Constant fertility	High fertility	Medium fertility	Low fertility	Average
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2015	167.5	163.4	161.6	159.0	159.8	160.0	158.3	156.7	160.8
2020	184.1	175.0	172.2	169.5	171.5	171.7	167.3	162.8	171.8
2025	201.2	185.7	182.9	180.2	183.2	183.2	175.2	167.2	182.3
2030	218.3	195.8	192.8	189.9	194.5	193.5	181.9	170.3	192.1

Sources: Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning; United Nations Department of Economic and Social Affairs (UN DESA).
Note: For each year, the average reported in the last column is across all the forecasts from the two sources.

From among these alternative population growth scenarios, we use the highest (government's constant-fertility forecasts—Table 3.7, column 1), the lowest (UN DESA's low-fertility forecasts—Table 3.7, column 8), and the average population growth forecasts (Table 3.7, column 9) in the rest of our analysis. The projected direct demand for rice by households under our three income growth scenarios and for the three population projection scenarios are presented in Table 3.8.[7] These estimates show that the direct demand for rice in 2030 is in the range of 31.3 to 42.0 million tons. It is noteworthy that the range of projections across income scenarios for a given population scenario is relatively small compared with the range of projections across population scenarios for a given income scenario.

Table 3.8—Projected direct demand for rice, in million tons

	High population scenario			Average population scenario			Low population scenario		
Year	OS	BAU	PS	OS	BAU	PS	OS	BAU	PS
2015	29.2	28.9	28.6	28.0	27.8	27.5	27.3	27.0	26.8
2020	33.2	32.7	32.2	30.9	30.5	30.1	29.3	28.9	28.5
2025	37.5	36.8	36.1	34.0	33.3	32.7	31.1	30.6	30.0
2030	42.0	41.0	40.1	36.9	36.1	35.3	32.7	32.0	31.3

Source: Authors' estimates.
Note: High, average, and low population scenarios refer to the population projections reported in columns 1, 9, and 8, respectively, in Table 3.7. OS, BAU, and PS refer to income growth scenarios.

[7] Demand projections for wheat are reported in the appendix, Tables A.2 and A.3.

To estimate the total domestic demand for rice in Bangladesh, it is necessary to calculate the indirect demand for rice toward seed, feed, and wastage. Customarily, in Bangladesh the total seed, feed, and wastage is considered to be 10 percent,[8] which is deducted from gross production to calculate the net production. Miah, Abedin, and Rahman (2010) state that the 10 percent coefficient is an administrative recommendation for Bangladesh. These authors themselves estimate the overall average total seed, feed, and wastage for rice at 1.58, 1.89, and 16.17 percent, respectively, summing up to 19.64 percent. Rounding to 20 percent, we use both of these estimates of the percentage of intermediate demand to total demand (10 and 20 percent) to project the total (direct plus indirect) demand for rice using Equation (8). The projected total demand for rice under the different population and income growth scenarios for the two intermediate demand coefficients is reported in Table 3.9. For the year 2030, our projections of total demand for rice under the alternative scenarios on population, income, and intermediate demand range between 34.8 and 52.5 million tons. The range of projections is highest across population scenarios, followed by the two intermediate demand requirement scenarios, and least across income scenarios.

Table 3.9—Projected total (direct + indirect) demand for rice in Bangladesh, in million tons

	High population scenario			Average population scenario			Low population scenario		
Year	OS	BAU	PS	OS	BAU	PS	OS	BAU	PS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intermediate demand coefficient = 10%									
2015	32.4	32.1	31.8	31.1	30.8	30.5	30.3	30.0	29.8
2020	36.9	36.3	35.8	34.4	33.9	33.4	32.6	32.1	31.7
2025	41.6	40.9	40.1	37.7	37.0	36.4	34.6	34.0	33.3
2030	46.6	45.6	44.6	41.0	40.1	39.2	36.4	35.6	34.8
Intermediate demand coefficient = 20%									
2015	36.5	36.1	35.8	35.0	34.7	34.4	34.1	33.8	33.5
2020	41.5	40.9	40.3	38.7	38.1	37.6	36.7	36.2	35.7
2025	46.8	46.0	45.1	42.4	41.7	40.9	38.9	38.2	37.5
2030	52.5	51.3	50.1	46.2	45.1	44.1	40.9	40.0	39.1

Source: Authors' estimates.
Note: High, average, and low population scenarios refer to the population projections reported in columns 2, 9, and 8, respectively, in Table 3.7. OS, BAU, and PS refer to income growth scenarios.

[8] For example, the Food Security Atlas deducts 10 percent of total net production towards seed, feed and wastage.

4. ASSESSING THE CEREALS SUPPLY DEFICIT/SURPLUS

Having projected both the supply and the demand for rice over the period from 2015 to 2030, we now compare these projections in order to assess the possible surplus or deficit that Bangladesh could face in the future. As seen earlier, both supply and demand projections are made under various scenarios. Hence, we compute the surplus/deficit by taking the maximum and minimum of all supply and demand forecasts. The maximum and minimum values of the supply forecasts correspond to the OS and PS scenario projections reported in Table 2.4, columns 7 and 9, respectively. The maximum (minimum) demand forecasts correspond to the case of high (low) population growth with high (low) income growth (Table 3.9, columns 1 and 9, respectively). The range of surplus/deficit estimates is estimated across all possible combinations of the supply and demand forecasts. These estimates, done separately under the two possible assumptions on the indirect demand requirements, are reported in Table 4.1.

Table 4.1—Range of projected demand, supply, and deficit/surplus, in million tons

Year	Supply projections		Demand projections		Surplus (+) / deficit (-)	
	OS	PS	Max	Min	Max	Min
Intermediate demand coefficient = 10%						
2015	35.2	31.2	32.4	29.8	5.4	-1.2
2020	39.3	33.8	36.9	31.7	7.6	-3.0
2025	39.2	36.4	41.6	33.3	5.9	-5.3
2030	39.0	38.8	46.6	34.8	4.2	-7.8
Intermediate demand coefficient = 20%						
2015	35.2	31.2	36.5	33.5	1.7	-5.3
2020	39.3	33.8	41.5	35.7	3.7	-7.6
2025	39.2	36.4	46.8	37.5	1.7	-10.5
2030	39.0	38.8	52.5	39.1	-0.1	-13.7

Source: Authors' estimates.

Our projections of the future supply and demand show that Bangladesh can face either a surplus or a deficit in rice, depending upon the prevailing supply and demand scenario. The country could face a surplus situation if supply growth occurs as per our optimistic scenario specification and demand growth is relatively slow, driven primarily by slow growth in population and to a lesser extent by slow growth in per capita incomes. When the reverse happens, then deficits are likely to happen. The above estimates of surplus/deficits also reveal a certain pattern over time irrespective of the assumptions on the intermediate demand requirements. The projections of surpluses increase until 2020, after which the surpluses become smaller. In fact, if the intermediate demand requirement is assumed to be 20 percent of total demand, then by 2030 the country is likely to face a deficit in the range of 0.1 to 13.7 million tons. This pattern in the surplus projections can be attributed to our supply scenario specifications, wherein constraints on land availability will increasingly begin to affect production growth under current technologies. The deficit projections show a steady rise over time, reflecting the sharp rise in demand under the high population growth scenario.

5. CONCLUSIONS

In this study we attempt to provide forecasts of the demand and supply of cereals in Bangladesh for the period 2015–2030, focusing on rice, the main staple in Bangladeshi diets and also the most important crop in Bangladesh's agriculture. For this purpose, supply and demand models are first developed. A detailed model of the supply of rice in the three main rice growing seasons—*aman*, *aus*, and *boro*—is built up through separate acreage and yield functions. Both maize and wheat are minor crops in Bangladesh. Supply of maize has not been modeled here due to (1) the very sharp growth (a 130-fold increase in just six years) witnessed in its output from very low levels, which makes it difficult to model its supply behavior, and (2) the absence of data on the use of inputs such as seeds and irrigation in maize production. In the case of wheat, both acreage and output have been showing a steady decline from the already low levels. This trend is likely to continue in the future as well, rendering domestic supply totally insignificant.

On the demand side, the projections made here consider both direct demand by households and also indirect demand. Household direct demand for 13 food items, including rice and wheat, has been modeled using the quadratic almost ideal demand system (QUAIDS) specification. Since only food items have been considered here, a separate model for determining household food budget has also been developed as a function of net income per capita. Indirect demand for rice and wheat has been estimated using administratively recommended coefficients and also those available in the literature.

Both the supply and the demand models have been validated for their forecast performance using past data. The validation exercise shows that the average supply forecast error is just 0.8 percent, while in the case of demand models the forecast error for rice is less than 5 percent in absolute terms. These low forecast errors give a sense of reliability and confidence in the projections carried out here.

Supply and demand projections are made under various scenarios for the years 2015, 2020, 2025, and 2030. The supply scenarios specified here capture the land availability constraints facing rice cultivation in Bangladesh. Total rice acreage is constrained to a maximum of 12.6 million hectares, which under different scenarios may be reached with different speed (that is, by different years). Under alternative conditions, the rice supply in 2015 is expected to be in the range of 31.2 to 35.2 million tons, and it is likely to grow to 39 million tons by 2030.

Household direct demand projections are made under three scenarios on the growth of real per capita income. The growth rates specified are 4.2 percent, 3.6 percent, and 3.0 percent, and the three scenarios are labeled optimistic scenario (OS), business as usual (BAU) scenario, and pessimistic scenario (PS), respectively. In all these three scenarios, prices are assumed constant at the base 2005 levels. Projections of the per capita household demand for the year 2030 for rice are in the range of 183.7 to 192.3 kg per capita per year. The corresponding forecasts for wheat are in the range of 6.5 to 7.1 kg per capita per year in 2030. It is also seen that the forecasts show an increasing trend over the period from 2015 to 2030. The annual increase in per capita rice demand is in the range of 0.85 to 1.2 kg across the scenarios, which is quite modest.

To obtain the total direct demand by households, these per capita consumption forecasts are combined with alternative projections of population growth taken from (1) the government of Bangladesh and (2) the United Nations Department of Economic and Social Affairs (UN DESA). The population forecasts from the two sources show substantial variation, both internally and across the two sources. Hence, an average of the two sets of forecasts has also been used here. Direct demand for rice by households is then projected under the three income growth scenarios and for the three population growth scenarios. These estimates show that the direct demand for rice in 2030 is likely to be in the range of 31.3 to 42.0 million tons, up from 26.8 to 29.2 million tons in 2015. For wheat, the projection for 2030 is 1.1 million to 1.5 million tons.

Total demand, including both direct and indirect demand, is then obtained under two specifications of the indirect demand requirements—10 and 20 percent. For the year 2030, our projections of total demand for rice under the alternative scenarios on population, income, and intermediate demand

range between 34.8 million and 52.5 million tons. It is also observed that the range of the projections is highest across population scenarios, followed by the two intermediate demand requirement scenarios, and least across income scenarios.

The supply and demand projections for rice are then compared, to assess the likely surplus/deficit situation. Our estimates show that Bangladesh can face either a surplus or a deficit in rice, depending upon the prevailing supply and demand scenario and intermediate demand requirements. The surplus in 2030 could be about 4.2 million tons, while the deficit could be as high as 13.7 million tons. Our projections also show that surpluses, if any, could increase until 2020, after which they are likely to become smaller, which can be attributed to land availability constrains that will increasingly begin to affect production growth under current technologies. In contrast, deficit projections show a steady rise over time, reflecting the sharp rise in demand under the high population growth scenario.

The projection exercise carried out here, no doubt, has its limitations arising from data, model specification, and scenario assumptions. It may be noted here that unlike our supply forecasts, our demand forecasts show a larger range and appear to be more sensitive to the assumptions regarding population growth and also intermediate demand requirements. On the supply side, a critical assumption in our scenario specification is that current technologies continue to be used in the future as well—that is, no technological progress has been factored into our projections. Allowing for technological progress would give much higher output forecasts, which could manifest as higher surpluses or lower deficits. On the demand side, the uncertainty in the population projections taken from other sources, and also the lack of good estimates on the intermediate demand requirements, may be mentioned as the main limitations of our forecasting exercise.

APPENDIX: SUPPLEMENTARY TABLES

Table A.1—Estimated QUAIDS model parameters

Food Group	Rice	Wheat	Pulses	Fish	Eggs	Beef and other meat	Bird meat	Vegetables	Milk	Oils	Fruits	Sugar	Others
Gamma	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	0.0909												
2	-0.0032	-0.0036											
3	-0.0053	0.0006*	-0.0047										
4	-0.024	-0.0037	0.0052*	0.0576									
5	-0.0024*	0.0021	0.0018	0.0003*	0.0007								
6	0.0002	-0.0009	0.0009	0.0003*	-0.0013	-0.008							
7	-0.0017	-0.0033	-0.0027	-0.0121	0.0007*	-0.0013*	0.0033*						
8	-0.0116	0.0016*	0.0071	-0.0107	0.0010*	0.004	0.0114	0.0211					
9	-0.0058*	-0.0009	0.0048	0.0048	-0.0014	0.0058	0.0022	-0.0041	0.0009*				
10	-0.0071	0.004	-0.0001	-0.0086	-0.0006*	0.0012	0.0081	0.0025	0.0015*	0.0157			
11	-0.0028	-0.001	-0.0026	0.0049	0.001	0.0046	0.0022	0.0008	0.0010*	0.0026	-0.0121		
12	0	0.0015	-0.0015	-0.0035*	0.001	0.0006*	-0.0051	0.0086	-0.0022	-0.002	0.0017	-0.0004*	
13	-0.027	0.0066	-0.0036	-0.0104	-0.003	-0.006	-0.0018	-0.0317	-0.0067	-0.0174	-0.0001	0.0013	0.0998
Alpha	0.3044	-0.0043*	0.0354	0.0655	0.0037	0.0134	0.0014*	0.2272	-0.0286	0.0751	-0.0237	0.0135	0.3171
Beta	0.0726	0.0056*	-0.0011	0.0269	0.0043	0.0078*	0.0170*	-0.071	0.0209	-0.019	0.0113	0.0026	-0.0779
Lambda	-0.0281	0.0002	-0.0012	-0.0089	-0.0001	0.0111	0.0025	0.0048*	0.0011	0.0017	0.0037	0.0014	0.012

Source: Authors' estimates.
Note: All the coefficients are significant at the 5 percent level of significance except starred (*) ones.

Table A.2—Projected direct demand for wheat, in million tons

Year	High population scenario			Average population scenario			Low population scenario		
	OS	BAU	PS	OS	BAU	PS	OS	BAU	PS
2015	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9
2020	1.2	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0
2025	1.3	1.3	1.3	1.2	1.2	1.1	1.1	1.1	1.0
2030	1.5	1.5	1.4	1.4	1.3	1.2	1.2	1.2	1.1

Source: Authors' estimates.
Note: High, average, and low population scenarios refer to the population projections reported in columns 2, 9, and 8 in Table 3.7. OS, BAU, and PS refer to income growth scenarios.

Table A.3—Projected total (direct + indirect) demand for wheat in Bangladesh, in million tons

Year	High population scenario			Average population scenario			Low population scenario		
	OS	BAU	PS	OS	BAU	PS	OS	BAU	PS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intermediate demand coefficient = 10%									
2015	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0
2020	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.1	1.1
2025	1.5	1.4	1.4	1.3	1.3	1.3	1.2	1.2	1.2
2030	1.7	1.6	1.6	1.5	1.4	1.4	1.3	1.3	1.2
Intermediate demand coefficient = 20%									
2015	1.2	1.2	1.2	1.2	1.2	1.1	1.2	1.1	1.1
2020	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.2	1.2
2025	1.7	1.6	1.6	1.5	1.5	1.4	1.4	1.3	1.3
2030	1.9	1.8	1.8	1.7	1.6	1.6	1.5	1.4	1.4

Source: Authors' estimates.
Note: High, average, and low population scenarios refer to the population projections reported in columns 2, 9, and 8 in Table 3.7. OS, BAU, and PS refer to income growth scenarios.

REFERENCES

Anwarul Huq, A. S. M., and F. M. Arshad. 2010. Demand Elasticities for Different Food Items in Bangladesh. *Journal of Applied Sciences* 10 (20): 2369–2378.

Ahmed, A. U., and Y. Shams. 1994. Demand Elasticities in Rural Bangladesh: An Application of the AIDS Model. *Bangladesh Development Studies* 22 (1): 1–25.

Banks, J., R. Blundell, and A. Lewbel. 1997. Quadratic Engel Curves and Consumer Demand. *Review of Economics and Statistics* 79 (4): 527–539.

BMD (Bangladesh Meteorological Department). 2011. Total Rainfall in Monsoon over Bangladesh. Accessed July 25. http://www.bmd.gov.bd/Monsoon_rain/Bgd_mon_rain.html.

BoS (Bangladesh, Bureau of Statistics). 2007. *Handbook of Agricultural Statistics.* Dhaka, Bangladesh.

Bouis, H. E. 1989. *Prospects for Rice Supply/Demand Balances in Asia.* Working paper. Washington, DC, International Food Policy Research Institute.

Chowdhury, O. H. 1982. Complete Consumer Model: A Preliminary Estimate for Bangladesh. *Bangladesh Development Studies* 10:91–104.

FAO (Food and Agriculture Organization of the United Nations). 2010. FAOSTAT. Accessed July 25, 2011. http://faostat.fao.org/site/339/default.aspx.

FPMU (Bangladesh, Food Planning and Monitoring Unit). 2008. *Food Balance Sheet of Bangladesh.* Dhaka, Bangladesh.

Frisch, R. 1959. A Complete Scheme for Computing All Direct and Cross Demand Elasticities in a Model with Many Sectors. *Econometrica* 27 (2): 177–196.

Goletti, F. 1993. Food Consumption Parameters in Bangladesh. Mimeo, International Food Policy Research Institute, Washington, DC.

Miah, Md. I. A., Md. Z. Abedin, and K. M. M. Rahman. 2010. *Farm Level Availability of Rice and Its Losses: An Assessment Study for Food Policy Options.* Dhaka, Bangladesh: National Food Policy Capacity Strengthening Programme.

MoF (Bangladesh, Ministry of Finance). 2010. *Economic Review.* Dhaka, Bangladesh.

Pitt, M. M. 1983. Food Preference and Nutrition in Rural Bangladesh. *Review of Economics and Statistics* 65:105–114.

World Bank. 2009. World Development Indicators 2009. Accessed July 30, 2011. http://data.worldbank.org/data-catalog/world-development-indicators.

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