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Towards 2021: Examining Alternative Growth Scenarios for Bangladesh

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Bangladesh aims to reach the middle income country status by 2021. This paper uses a dynamic computable general equilibrium model to evaluate the key drivers of growth including population, factor productivity growth and climate change. The results show that small changes in population and productivity growth have a greater impact than climate change and, in a business as usual scenario, 2021 targets would be reached in 2031. For reaching the middle-income country status by 2021, the country requires a 3.5 per cent productivity growth yielding a GDP and GDP growth of $366.1 billion and nearly 12 per cent respectively. It is also estimated that reducing the impact of climate change by 25 per cent would save $5.06 million annually.

Keywords: Bangladesh, Middle Income, Total Factor Productivity, Climate Change, Dynamic Computable General Equilibrium Model

JEL Classification: C68, D24, N5

I. INTRODUCTION

The Government of Bangladesh aspires to offer its people a comparable standard of living to that of middle and high-income countries by 2021, 50 years after having achieved Independence (Planning Commission 2010). The Perspective Plan 2010–2021 aims to reduce the number of people living below the poverty line to 25 million or to 15 per cent of the population. The government is committed to raising per capita income to US$2,000 (Planning Comminssion 2010). Bangladesh's population is increasing at an average annual growth rate of

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1.29 per cent and is projected to reach 247 million by 2050 (BIDS 2013b). Gross domestic product (GDP) growth is estimated at 7.9 per cent (BIDS 2013a). This projection is encouraging since the World Bank estimated that Bangladesh would need to grow between 7 per cent and 8 per cent per year if it is to achieve its development ambitions (World Bank 2011).

There are many variables that can affect Bangladesh's progress towards the 2021 vision. Primary among these variables are population growth, total factor productivity (TFP) growth and climate change. In this paper, we develop a dynamic computable general equilibrium (DCGE) model to evaluate the impact of these drivers on Bangladesh's achievement of middle income status and a per capita income of US$2,000.

DCGE models provide advantages over other analytical frameworks offering a consistent theoretical lens through which socioeconomic and environmental trade-offs may be analysed. This class of models have a high degree of explanatory power where inter-sectoral linkages and resource constraints are prevalent (Banerjee and Alavalapati 2010, 2014). Static or one-period models provide information on the direction of effects and orders of magnitude of policy or environmental shocks in the short or long-run while dynamic models enable a more precise specification of time, illustrating economic transition paths and both short and long-term costs and gains (Cattaneo 1999).

In this paper, a forecast baseline was developed projecting Bangladesh's economy to the year 2050 in the absence of any exogenous shocks. Compared against this forecast, seven scenarios were evaluated: two population growth scenarios, two agricultural total factor productivity growth scenarios and three climate change scenarios. There are many other important variables that may have a significant impact on Bangladesh's economy in the long run. However, the purpose of this paper is to analyse the potential impact of climate change in the long run. Other studies have shown that climate change may be a major concern for Bangladesh's development and food security, given its potential agriculture sector impacts (Banerjee *et al.*, in press, Banerjee *et al.* 2014, Yu *et al.* 2010).

Agricultural production technology for major agricultural products in Bangladesh has changed significantly, particularly from the late 1980s onward. Due to technological progress, production and efficiency have risen markedly. While economic development and industrialisation have reduced agriculture's share of GDP in recent years, down to 17 per cent in 2013 (Ministry of Finance 2014), agriculture is still the largest employer, accounting for 55 per cent of the labour force (Bangladesh Bureau of Statistics 2012). In addition, with food self-sufficiency a policy imperative for the Government of Bangladesh, it is critical to understand how climate change may impact the agricultural sector and the economy in the long run. Given the importance of TFP growth in driving economic performance, additional analyses were conducted around the sensitivity of outcomes to variability of agricultural and economy-wide TFP growth.

In the first two scenarios, a low population growth estimate and a constant fertility high population growth estimate were considered. The third and fourth scenarios evaluated the impact of slower and faster growth in agricultural TFP. The fifth, sixth and seventh scenarios imposed natural climate variability and climate change on the model. The differences in macroeconomic, sectoral and household-level indicators between the forecast baseline and each scenario reflect the effect of each exogenous shock on Bangladesh's economy. How these impacts would affect the achievement of Vision 2021 was considered for each scenario.

This paper is organised as follows. Following this introduction, section II describes the methods and section III develops the forecast baseline and scenarios. Section IV presents the results and their implications for meeting Vision 2021. The final section concludes the paper with a discussion of the key messages and trends arising from the analysis and emphasises the policy implications of the findings.

II. METHODS

The model developed here is based on the International Food Policy Research Institute's (IFPRI) Standard CGE Model and Robinson and Thurlow's dynamic extension to the model (Robinson and Thurlow 2004). This DCGE model is implemented in the General Algebraic Modelling System (GAMS) and solved as a mixed complimentary problem using the PATH solver. The model is documented in detail in Banerjee *et al.* (2103), Lofgren *et al.* (2002) and Robinson and Thurlow (2004).

The DCGE model describes the behaviour of agents in their economic environment; it is a system of equations describing the utility maximising behaviour of consumers, profit maximising behaviour of producers, and the equilibrium conditions and constraints imposed by the macroeconomic environment. Agent behaviour is represented by linear and non-linear first order optimality conditions and the economic environment is described as a series of equilibrium constraints for factors, commodities, savings and investment, the government, and rest of the world accounts (Lofgren *et al.* 2002).

There are three macroeconomic balances in the model: the government current account balance, the current account of the balance of payments and the savings and investment balance. Decisions regarding macroeconomic balances and factor mobility are known as closure rules and are necessary to maintain balance in the economic environment and in factor supply and demand. The choice of closure rules may have a significant impact on model behaviour (Dewatripont and Michel 1987).

For the government closure, tax rates are fixed and therefore government savings, the difference between current government revenues and expenditures, are a flexible residual. A flexible real exchange rate is chosen for the current account of the balance of payments closure which fixes the current account deficit. With transfers between the rest of the world and domestic institutions fixed, the trade balance is fixed. The savings and investment balance is driven by savings with all non-government savings rates fixed. For factor closures, labour, capital and land are fully employed and mobile between sectors. The domestic price index is chosen as the numeraire, which allows for a flexible consumer price index.

2.1 The Data: A Social Accounting Matrix for Bangladesh

The core data source for a DCGE is the Social Accounting Matrix (SAM). A SAM is a statistical representation of an economy describing payments and receipts between economic agents, factors, and intermediate and final goods and services. The most recent SAM for Bangladesh (Khondker and Raihan 2011) was customized for this study. The main adjustments included more agricultural sector detail and greater consistency in activity payments to factors of production. Modifications to the SAM are documented in Banerjee *et al.* (2013). The SAM base year of 2006/07 was chosen since it is the most recent year for which comprehensive data on Bangladesh's economy were available and was considered a relatively normal year, unaffected by the recent global economic crisis and other shocks such as severe weather events.

The SAM was aggregated to 30 sectors, 17 of which are related to agriculture. The sectors in the final SAM are shown in Table I.

TABLE I

ECONOMIC SECTORS IN THE 2006/07 BANGLADESH SAM

Agricultural sectors	Non-agricultural sectors
1. Boro rice	18. Forestry
2. Aman rice	19. Water
3. Aus rice	20. Electricity
4. Wheat	21. Housing
5. Other grains	22. Health
6. Potato	23. Education
7. Vegetables	24. Public administration
8. Pulses	25. Manufactured goods
9. Other crops	26. Construction
10. Fruit	27. Mining and gas
11. Livestock	28. Trade
12. Poultry	29. Transport
13. Fish	30. Services
14. Milled rice	
15. Milled grain	
16. Processed food	
17. Oils	

Factors of production in the SAM include skilled (≥ class level of 10) and unskilled labour (classes 0 to 9) categories, capital and land. There are 11 institutions, 8 of which are households (6 rural households and 2 urban households). Households are disaggregated according to the Household Income and Expenditure Survey classification system. Table II details the characteristics of the household categories in the SAM. Rural agricultural households are described according to their land endowments; non-agricultural households are distinguished by whether or not they are poor. The two urban households types are disaggregated by level of education with less educated households possessing less than or equal to 8^{th} class education and higher educated households possessing greater than 8^{th} class education. The remaining three institutions are the government, firms and the rest of the world. The final two accounts in the SAM are public and private investment, and inventories.

TABLE II

HOUSEHOLD ENDOWMENT CATEGORIES

Household type	
1. Landless (0 ha)	5. Rural non-agricultural poor
2. Marginal (≤ 0.198 ha)	6. Rural non-agricultural non-poor
3. Small agricultural (0.202 to 1.008 ha)	7. Urban educated
4. Large agricultural (agricultural > 1.012)	8. Urban less educated

III. SCENARIO DESIGN

This section describes the forecast baseline and the seven counterfactual scenarios evaluated with the DCGE.

3.1 Forecast Baseline

The forecast baseline modelled Bangladesh's economy from the base year of 2006/07 to 2050. This is the benchmark trajectory of Bangladesh's economy and is the path against which all subsequent scenarios were evaluated. Factors, productivity, yield and the overall economy followed a balanced growth path in the forecast. In this baseline, TFP growth was estimated at 1 per cent for all sectors of the economy. Labour force growth followed population growth and was estimated by the Bangladesh Institute of Development Studies (BIDS 2013). Bangladesh's population was 143,158,850 in 2006/07. BIDS estimated the population would reach 189,700,006 by 2030 and 214,789,999 by 2050 (BIDS 2013b). In the baseline, the average growth rate was taken and population and labour force growth were estimated at 1.164 per cent.

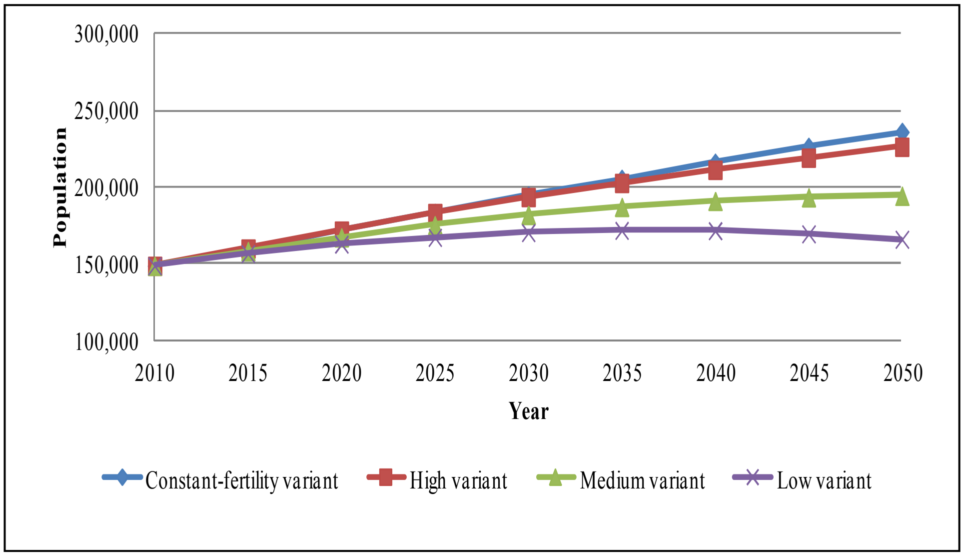
Model elasticity parameters include the Armington elasticity, the Constant Elasticity of Transformation for shifting production between domestic and international markets, the elasticity of substitution between factors, elasticity of substitution between aggregated factors and intermediate inputs, household expenditure elasticity of demand for commodities, and the Frisch parameter. Best estimates of these parameters were obtained from the literature, particularly those compiled by the Global Trade Analysis Project (GTAP, Dimaranan 2006).

3.2 Population Growth Scenarios

Population and labour force growth are important drivers of economic growth. The United Nation's low variant estimate of population growth projected that Bangladesh will reach a population of 165,966,000 by 2050 (figure 1; UN

2010). In a constant fertility scenario, the population was projected to reach 235,944,000 in 2050, greater than the BIDS (2013b) estimate of 214,789,999, which was used in the forecast baseline. In the first two scenarios, the consequences of differing population trajectories for Bangladesh were evaluated. Scenario 1 imposed the low variant estimate with an average rate of growth of 0.40 per cent between 2007 and 2050, while scenario 2 imposed the constant fertility variant with an average rate of growth of 1.51 per cent for the same period.

Figure 1: UN Population Estimates



Source: Population Division of the Department of Economic and Social Affairs of the UN.

3.3 Total Factor Productivity

Agriculture is a key driver of Bangladesh's economic growth and for improving the livelihoods of the country's poor. Economic development and growth that is inclusive and equitable is integral to Bangladesh's 2021 Vision. The fact that 80 per cent of Bangladesh's population resides in rural areas and 54 per cent of the rural population is employed in agriculture emphasizes agriculture's importance in contributing to the livelihood opportunities of the most marginalised (World Bank 2013).

Increasing agricultural production in the past was largely a function of increasing: the area cultivated, irrigation, the number and length of cropping seasons, and yields. In many regions of Bangladesh, the number of cropping seasons is approaching the maximum and there is little scope for increasing cultivable areas due to urban, peri-urban, rural residential and infrastructure developments (Faisal, Islam and Saila 2004). Consequently, increasing crop yields will be the critical pathway to increasing output and meeting food security targets. With increasing land and rural labour scarcity, more will have to be produced with less (Kumar, Mittal and Hossain 2008).

TFP is the component of growth that cannot be explained by growth in factor inputs, namely land, labour and capital (Solow 1957). TFP is a measure of technical progress which is composed of technical change and technical progress. Technical change is an improvement in best production practices, whereas technical progress is a movement towards the best production practices. Technical progress is driven by numerous factors such as human capacity, infrastructure development, research and development and education. There is significant scope to increase technical progress through enhanced production efficiencies and using existing technologies more effectively (Kumar, Mittal and Hossain 2008). With actual adoption rates of modern crop technologies in Bangladesh reported to be approaching the maximum, more effective selection and implementation of technology is critical (Alam, Van Huylenbroeck, Buysse and Begum 2011, Balcombe, Fraser, Rahman and Smith 2007).

In Bangladesh, over the last few decades, TFP growth has been achieved largely by means of the development and/or implementation of high yielding crop varieties, fertiliser and irrigation, as well as investment in physical infrastructure including the construction of better roads and bridges. Rice is by far the Bangladesh's most important staple crop accounting for over 20 per cent of total household outlays and almost 50 per cent of household expenditures on food (Banerjee *et al.* 2013). Between 1951 and 1971, TFP growth for rice was estimated at 0.98 per cent per year. With the introduction of high yielding rice varieties between 1973 and 1989, TFP increased on average by 1.15 per cent per year. This TFP growth contributed to between 40 per cent and 60 per cent of the observed increase in rice output. In the case of wheat, average TFP was estimated at between 0.83 per cent and 0.93 per cent for the same period, though it contributed to between 11 per cent and 19 per cent of growth in wheat production (Dey and Evenson 1991). For the agricultural sector overall, TFP growth was estimated at 0.9 per cent per year between 1980 and 2000 (Coelli and Prasada Rao 2003).

In the third scenario, the impact of a slowdown in agricultural TFP growth was evaluated. In this scenario, TFP growth in agriculture was set to 0.5 per cent, while TFP in non-agricultural sectors remained at 1.0 per cent as in the baseline. In the fourth scenario, agricultural TFP growth was increased to 1.5 per cent, again maintaining a 1.0 per cent TFP growth in all non-agricultural sectors.

3.4 Climate Change

Bangladesh's climate is subtropical monsoonal exhibiting high seasonal variation in precipitation and temperature (Ali 2002). Summers are hot and wet, while winters can be quite dry, resulting in drought in some regions (Yu *et al.* 2010). During the monsoon season, up to two-thirds of the country may become inundated and cyclones and storm surges occur frequently. In a country where water would seem to be abundant, water resources, fundamental for human well-being and economic development, are in fact under great stress (Chowdhury 2010). Sources of water for drinking, agriculture and industry are threatened by saline intrusion in the coastal region of the country, the ingress of polluted surface waters, and arsenic contamination of shallow groundwater (Chowdhury 2010). Major urban centres are challenged to meet rising demand with population growth, rural to urban migration and economic development.

Exacerbating these challenges, Bangladesh is one of the most vulnerable and exposed countries to climate change. Temperatures are projected to rise implying greater crop evapotranspiration and yield losses (Yu *et al.* 2010). Sea level rise is also projected to reduce the supply of arable land, increase storm surges and affect settlement patterns, fisheries and tourism (IWM and CEGIS 2007). Increased surface water inflows into Bangladesh and potentially greater monsoonal precipitation will increase flooding risk during the wet season.

The final three scenarios impose natural climate variability and climate change on the model (Huq 1999, IWM and CEGIS 2007, Yu *et al.* 2010). Natural climate variability was imposed in all three scenarios and accounts for yield losses estimated on the basis of an historical climate series. The impacts of natural climate variability were drawn from Yu *et al.* (2010). Yu *et al.* (2010) estimated climate impacts in the following way:

1. The DCGE was run from the base year to 2050. For each of those years, a random observation from the historical climate series of 1970 to 1999 was drawn.

2. Based on this random draw, crop yield impacts were estimated in a crop modelling framework, which were in turn imposed on the DCGE model as an exogenous shock.
3. The historical record also contained extreme weather events where damages to crops were especially severe. If a severe event year was drawn from the historical series, additional yield impacts were imposed on the DCGE.
4. This process was repeated 50 times to simulate natural climate variability for the entire period of analysis.

In addition to natural climate variability, climate change shocks were imposed in each of the three climate scenarios. The climate change impacts imposed reduced arable land supply due to sea level rise and increased annual flooding, and reduced crop yield due to higher than average temperatures. These shocks were informed by analysis of future climate projections and agricultural crop modelling conducted by Yu *et al.* (2010).

Yu *et al.'s* (2010) estimates for future temperature and precipitation changes were based on analyses of 16 Global Circulation Models (GCMs) for A1B, A2 and B1 emissions scenarios. Results indicated positive temperature changes for every experiment and every month with a median warming of 1.1°C by 2030. No discernible changes in precipitation were found until 2030, though by 2050, some models predicted a trend of increased annual and wet season precipitation. Median estimates predicted precipitation may increase by up to 4per cent over the baseline by 2050 (Thurlow, Dorosh and Yu 2011,2012).

Yu *et al.* (2010) used the Crop Environment Resource Synthesis (CERES) modelling system to estimate climate change impacts on crop output. The authors reported the joint impact on crop output due to changes in temperature and precipitation, coastal and inland flooding, and a carbon dioxide enrichment effect on some crops such as wheat. In the climate change scenarios modelled in this paper, Yu *et al.*'s (2010) average climate change scenario was used, which is the average of the A2 scenarios under all GCMs and the average of the B1 scenarios under all GCMs.

Estimates of sea level rise were generated by the Institute of Water Modelling and the Centre for Environmental and Geographic Information Services (IWM and CEGIS) respectively. Projections by IWM and CEGIS estimated sea level rise of 15 cm in 2030 and 27 cm in 2050; the consequence of these rates of rise was estimated to result in a 1.5 and 2.5 per cent loss of agricultural land in 2030 and 2050 respectively (IWM and CEGIS 2007).

Scenario 5 is the low impact climate change scenario, where crop yield and sea level rise impacts were estimated as 25 per cent less than Yu *et al.*'s (2010) average climate change scenario. Scenario 6 is the average climate change impact scenario. Scenario 7 is a high impact climate change scenario where crop yield and sea level rise impacts were estimated as 25 per cent higher than the average climate change scenario.

IV. RESULTS

Table III provides an overview of Bangladesh's economy in the base year of 2006/07. Gross domestic product (GDP) was over US$69 billion. The investment share of GDP was 25 per cent, while imports surpassed exports by almost US$5 billion.

TABLE III

BANGLADESH MACROECONOMIC AGGREGATES (2006/07)

GDP component		Billions of US$
1. Private consumption (C)		52.18
2. Public consumption (G)		3.82
3. Investment (I)		18.02
	Private	13.77
	Public	3.77
	Change in stock	0.48
4. Exports (X)		13.69
5. Imports (I)		18.49
GDP at current prices		69.23

Figure 2 projects Bangladesh's economy in the baseline. The services sector in the base year accounts for 38 per cent of GDP, increasing its share to 42 per cent in 2050. The agricultural sector declines in importance, from 35 per cent to 13 per cent over the period of analysis. The manufacturing sector experiences a rapid growth, accounting for 23 per cent of GDP in the base year, increasing to 40 per cent by 2050. Energy and mining increases from just 3 per cent to 4 per cent by 2050.

Figure 2: Structure of Bangladesh's Economy in the Baseline

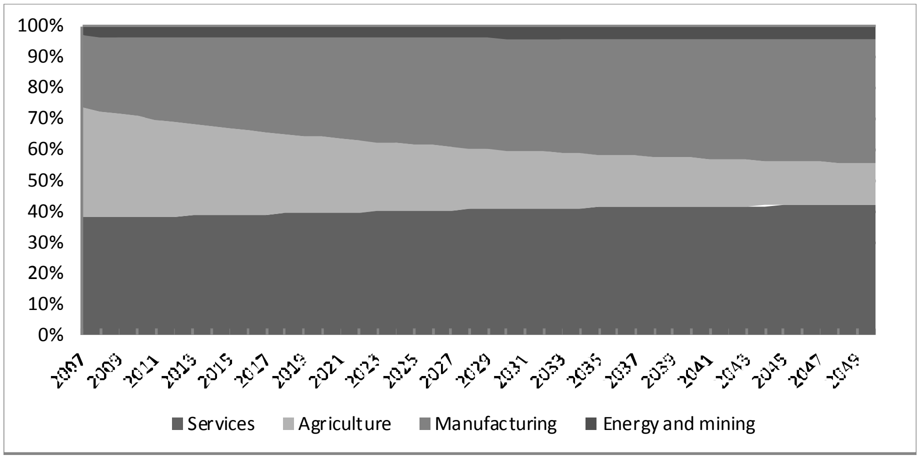


Table IV presents the deviation in average annual growth rate (AAGR) from the baseline for macroindicators. All macroeconomic indicators grew in the baseline and GDP registered at 6.9 per cent.

TABLE IV
DIFFERENCE IN AAGR (%) FROM BASELINE IN MACROINDICATORS

Indicators	Base	UN low	UN high	TFP slow	TFP fast	CC low	CC avg	CC high
Private consumption	6.277	-0.541	0.240	-0.104	0.101	-0.032	-0.039	-0.044
Fixed investment	8.268	-0.617	0.274	-0.054	0.045	0.003	0.008	0.010
Exports	8.615	-0.650	0.291	0.002	-0.007	0.034	0.051	0.058
Imports	7.815	-0.642	0.289	0.002	-0.007	0.033	0.050	0.058
GDP	6.960	-0.573	0.255	-0.083	0.077	-0.017	-0.019	-0.021

In the low fertility population projection scenario, the AAGR of GDP, private consumption, fixed investment, exports and imports was considerably slower than in the baseline. In the constant fertility high population projection scenario, all indicators grew appreciably faster than in the baseline. The impact of slow agricultural TFP growth was to depress private consumption, fixed investment and GDP below forecast. As expected, in the fast TFP growth scenario, all indicators, with the exception of exports and imports, grew faster than forecast. Moving from the low to high climate change scenarios, the negative deviation from the baseline increased for private consumption and GDP, while fixed investment, exports and imports grew faster than in the baseline. These high-level findings illustrate that small changes in population and TFP growth can have a greater overall economic impact than projected climate change.

Table V presents household income deviations in AAGR from the baseline. In the baseline, given steady economic growth, household income grew between 4 per cent and over 5 per cent. Rural non-agricultural non-poor households saw their income grow the fastest in the baseline.

TABLE V

DIFFERENCE IN AAGR (%) FROM BASELINE IN HOUSEHOLD INCOME

Household income	Baseline	Un low	UN high	TFP slow	TFP fast	CC low	CC avg	CC high
Landless	4.316	-0.249	0.102	-0.309	0.298	-0.188	-0.254	-0.290
Marginal	4.584	-0.293	0.118	-0.324	0.311	-0.192	-0.256	-0.292
Small farmers	4.508	-0.291	0.117	-0.324	0.311	-0.192	-0.257	-0.293
Large farmers	4.620	-0.297	0.119	-0.326	0.312	-0.193	-0.256	-0.292
Rural non-agricultural poor	4.230	-0.271	0.109	-0.318	0.305	-0.192	-0.257	-0.294
Rural non-agricultural non-poor	5.015	-0.336	0.134	-0.339	0.324	-0.193	-0.255	-0.290
Urban less educated	4.114	-0.208	0.085	-0.297	0.287	-0.191	-0.261	-0.299
Urban educated	4.381	-0.328	0.131	-0.334	0.319	-0.192	-0.254	-0.290

When the UN's low population estimate was imposed, overall income growth slowed considerably for all household categories, particularly in the case of rural non-agricultural non-poor and urban educated households. Imposing the UN's constant fertility estimate, household income grew faster for all household categories. Again, it was the rural non-agricultural non-poor and urban educated that were most affected by the shock. The impact of slow TFP growth on household income was negative and substantial for all households to a similar degree, while faster TFP growth resulted in higher household income growth for all household categories. With climate change impacts, household income grew slower. The negative impact on household income increased with increasing projected climate change impacts. All household categories appeared to demonstrate a similar susceptibility to climate change shocks.

Given the direct relationship between climate change and agricultural sectors, it is interesting to explore in some detail how agriculture is impacted. Table VI presents the high climate change impacts on imports, exports, domestic output, composite output, which is an aggregate of domestic and imported goods and services and composite price. Most agricultural imports grew slower; one notable exception is that of milled rice, imports of which grew over 0.7 per cent faster. Agricultural exports grew even slower than forecast, especially those of milled rice. Key sectors including manufacturing, construction and transportation grew more quickly. Domestic agricultural sector output grew more slowly for all subsectors except for forestry, while output of key non-agricultural sectors grew more quickly. Composite output grew more slowly for most agricultural sectors and more quickly for key non-agricultural sectors. All prices with the exception of paddy and milled rice were negatively impacted. The results give us an idea about the more deepening of the manufacturing and services sectors in the economy within the 2030 period. Due to climate change, agriculture seems to take a major drawback in terms of production and export, however, the apparent loss is compensated largely by the increase in output and export of the industrial and service sector. Thus the scopes and strategies of coping of the economy towards those latter sectors would be very important in the long run.

TABLE VI

HIGH CLIMATE CHANGE IMPACT DIFFERENCES IN AAGR (%) FROM BASELINE

Commodity	Imports	Exports	Domestic output	Composite output	Composite Price
Paddy			-0.444	-0.444	0.297
Wheat	-0.022	**-0.182**	**-0.147**	-0.022	**-0.282**
Other grains	-0.031	**-0.204**	**-0.166**	-0.032	**-0.282**
Potato	-0.002	**-0.132**	**-0.096**	-0.029	-0.274
Vegetables	-0.009	**-0.108**	**-0.068**	-0.034	-0.269
Pulses	-0.008	**-0.096**	-0.053	-0.044	-0.254
Fruit	0.010	**-0.116**	**-0.065**	-0.029	-0.261
Other crops	0.019	**-0.078**	**-0.051**	0.015	**-0.281**
Livestock	0.342	-0.533	-0.196	-0.193	**-0.014**
Poultry	0.080	-0.101	-0.032	-0.030	**-0.227**
Fish	-0.026	-0.019	-0.022	-0.022	**-0.285**
Forestry			0.004	0.004	**-0.295**
Milled rice	0.746	**-1.363**	-0.678	-0.361	0.144
Milled grain	-0.035	-0.012	-0.020	-0.020	**-0.288**
Processed food	-0.002	-0.119	-0.049	-0.045	**-0.260**
Oil	-0.034	-0.015	-0.022	-0.029	**-0.284**
Electricity	-0.036	-0.004	-0.010	-0.011	**-0.291**
Water	-0.037	-0.005	-0.011	-0.013	**-0.291**
Housing			-0.015	-0.015	**-0.290**
Health			-0.035	-0.035	**-0.290**
Education			-0.014	-0.014	**-0.292**
Public admin/def	-0.017	0.010	0.003	-0.001	**-0.290**
Manufacturing	-0.017	0.059	0.030	0.013	**-0.290**
Construction	-0.006	0.014	0.010	0.010	**-0.291**
Mining and gas	-0.002	0.032	0.019	0.019	**-0.289**
Trade			0.021	0.021	**-0.292**
Transportation	-0.003	0.025	0.017	0.015	**-0.292**
Services	-0.001	0.008	0.006	0.006	**-0.285**

Note: Values in bold indicate that rates of change were negative in the baseline.

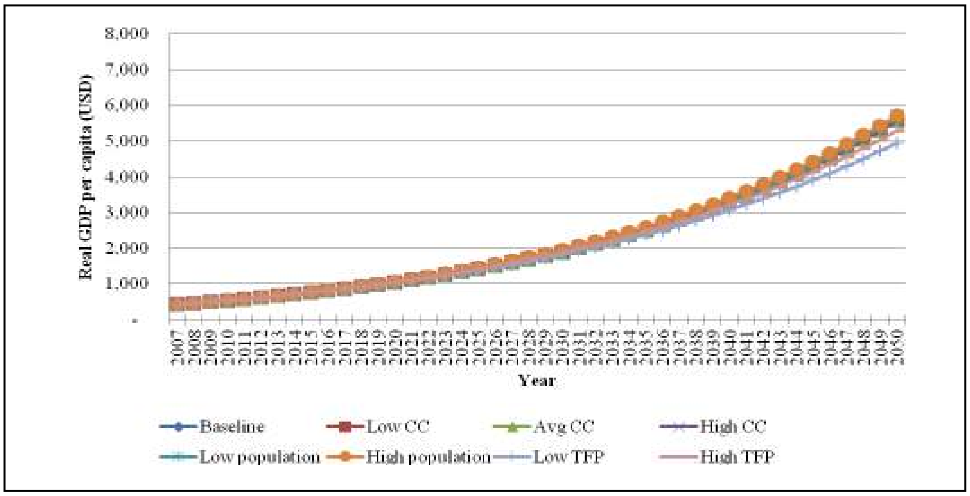
Figure 3 projects GDP per capita for each of the seven scenarios. In the forecast baseline, the 2021 Vision is reached not in 2021, but 10 years later in 2031 with a GDP of US$385.6 billion and growth rate of 6.9 per cent.

The low population growth scenario also has the per capita income target met slightly later in 2032 with a GDP of US$359.4 billion and rate of growth of 6.4 per cent, the lowest GDP growth rate of all scenarios considered. The high population growth scenario has the target met in 2031 with a GDP of US$408.5 billion and rate of growth of 7.2 per cent. The higher rate of population growth, which directly determines the size of the labour force, yielded the highest rate of GDP growth.

In the low agricultural TFP growth scenario, the per capita income target is met in 2032 with a GDP of US$403.7 billion and rate of growth of 6.88 per cent, the second lowest GDP growth rate of all scenarios considered. The high TFP growth scenario has the target met in 2031 with a GDP of US$392.7 billion and rate of growth of 7.04 per cent, the second highest GDP growth rate of all scenarios considered.

In the low climate impact scenario, the target US$2,000 per capita income was reached in 2031, with a GDP and GDP growth of US$382.4 billion and 6.9 per cent respectively. In the average and high climate impact scenarios, attainment of the target was delayed by one year to 2032, with a GDP of US$408.1 billion and US$407.9 billion respectively. GDP growth in the average and high climate impact scenarios were both 6.9 per cent.

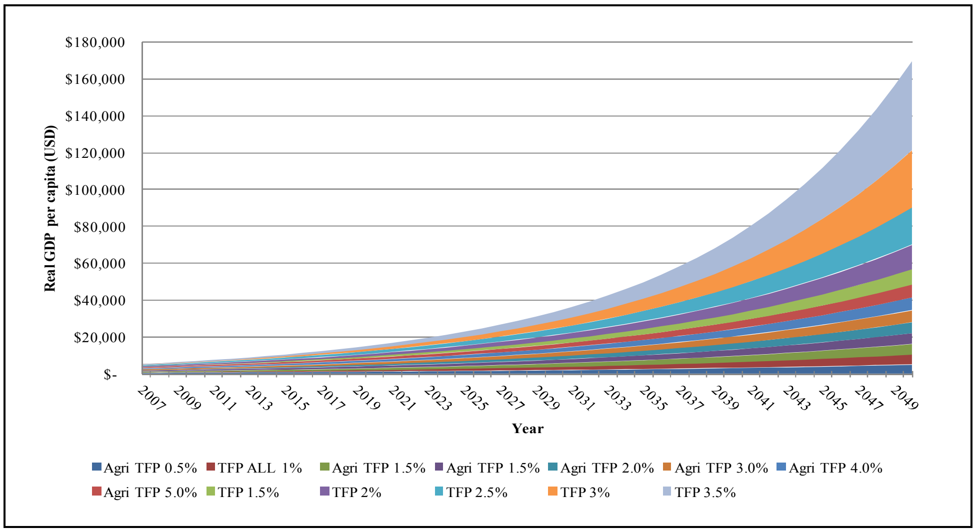
Figure 3: Real GDP per capita (US$)



Government policy and incentives as well as public and private investment can play an important role in fostering faster TFP growth. Given the potential to use TFP growth as a policy lever, the impact of variability in TFP growth on achieving the 2021 was explored. Figure 4 shows per capita income for different rates of TFP growth for the agricultural sector alone and different rates of economy-wide TFP growth.

An agricultural sector TFP of 0.5 per cent had Vision 2021 reached in 2032. Increasing growth in agricultural TFP to between 1 per cent and 2 per cent had the target reached 1 year earlier. An agricultural TFP of between 3 per cent and 4 per cent had the target per capita income reached by 2030 and a 5 per cent agricultural TFP had the target reached by 2029.

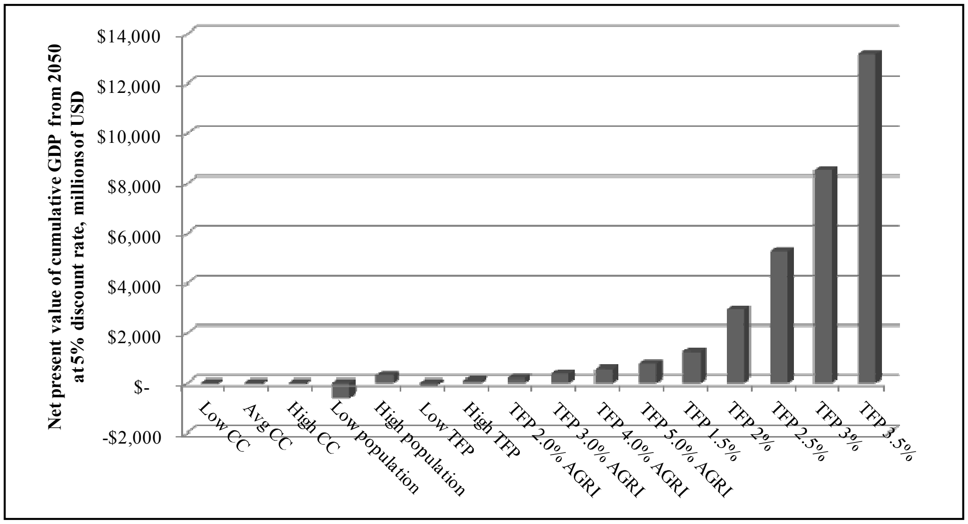
Figure 4: Vision 2021 and TFP Growth



Small changes in economy-wide TFP growth were found to have a significant impact on the rate at which the 2021 target was met. An economy-wide TFP of 1 per cent had the target reached by 2031. Increasing economy-wide growth by just 0.5 per cent had the target reached by 2028. A TFP of 2 per cent, 3 per cent and 4 per cent had the target reached by 2026, 2024 and 2023 respectively. A TFP of 5 per cent was required for the target to be met by 2021. This rate of TFP growth yielded a GDP of US$366.1 billion and GDP growth of 11.9 per cent.

Figure 5 shows the difference in discounted cumulative net present value of GDP to 2050 between the 7 scenarios and additional TFP experiments using a 5 per cent discount rate. There are a number of interesting features of this figure. First, an increase from 1 per cent to 1.5 per cent in agricultural TFP would yield US$92.07 million in economic gains by 2050. Increasing economy-wide TFP from 1 per cent to 1.5 per cent had a much more pronounced effect, generating US$1,237.47 million in benefits. Finally, reducing the impact of climate variability from high to low would save the Bangladesh economy US$5.06 million.

Figure 5: Net Present Value of Cumulative GDP from 2050 (millions of US$)



V. DISCUSSION AND CONCLUSIONS

In this paper a DCGE model was developed to explore the impact of key drivers of change on Bangladesh's economy and achieving the 2021 Vision of a per capita income of US$2,000 per person. A baseline forecast projecting the economy to 2050 was established against which seven scenarios were evaluated. The first and second experiments modelled low and high population growth. The impact of variability in TFP growth was explored in the third and fourth scenarios. In the final three scenarios, low, average and high climate change impacts were considered.

In the baseline, GDP growth was projected at 6.9 per cent which is within the range of projections made by industry experts. In the low population growth scenario, GDP, private consumption, fixed investment, exports and imports grew considerably slower than forecast, while in the high population growth scenario, all indicators grew faster. In the slower TFP growth scenario, all macroeconomic indicators were depressed below forecast. The slower TFP growth scenario had a more profound impact than the slow population growth scenario. All indicators grew faster in the high TFP growth scenario. Moving from the low to high climate change scenarios, the negative deviation from forecast increased for private consumption and GDP, while fixed investment, exports and imports grew faster than in the baseline. The main message that emerges from these results is that small changes in population and TFP growth can have a greater overall economic impact than projected climate change.

In the baseline, steady economic growth led to rising household incomes on the order of between 4 per cent and 5 per cent. Lower rates of population growth slowed overall income growth, while higher population growth had income growing more rapidly. Rural non-agricultural non-poor and urban educated households were most sensitive to variability in population growth rates. Slower TFP growth also slowed household income growth, while higher TFP growth led to faster income growth, as would be expected. Increasing climate change impacts had an increasingly negative impact on households with all household categories appearing to be equally susceptible.

Exploring in greater detail the climate change impacts on sectoral activity, most agricultural imports grew slower, except for milled rice. This was symptomatic of climate impacts on the rice cultivation sector. Domestic shortfalls in rice, Bangladesh's most important staple crop, increasingly were made up with imported rice. Domestic and composite agricultural sector output grew more slowly in most cases. Factors of production were reallocated from agriculture to other sectors generating higher returns and as a consequence, output of these non-agricultural sectors grew more quickly. This was true in all scenarios, with agriculture's economic importance accounting for a declining share of GDP. All prices, except the paddy and milled rice sectors, were negatively impacted, again a direct result of climate impacts on the rice sector.

The results from the climate change shock reported in the present study are comparable to other recent analyses of climate change impacts on agriculture. For example, a study undertaken by Yu *et al.* (2010) reports that in an average climate change scenario climate change reduced the GDP growth from 4.44 per cent to 4.38 per cent for a cumulative loss in total value added of US$128.55 billion and a discounted loss of US$25.73 billion. This amount was equal to an average drop in GDP of US$570 million per year or 1.15 per cent of total GDP. This study shows low climate change impacts reducing GDP growth by -0.017 and high climate change impacts reducing growth by -0.021. Reducing climate change impacts from high to low would save Bangladesh's economy US$5.06 million in present value terms.

Key differences in the Yu *et al.* (2010) study and the current study were related Yu *et al.*'s assumed rate of land expansion of 1 per cent per year declining to 0.5 per cent per year by 2050; a labour supply growth and population growth rate projection of 2 per cent, with a higher rate of skilled labour growth, and; a 2 per cent rate of agricultural TFP growth and 2.5 per cent for industry and services. Furthermore, Yu *et al.* (2021) did not report on the contribution of agricultural imports in meeting domestic shortfalls, which, in the present study, was projected to become a very important component of domestic supply.

In the forecast baseline, the 2021 Vision of an income per capita of US$2,000 was attained by 2031, with a GDP of US$385.6 billion and GDP growth of 6.9 per cent. The TFP shocks had the greatest influence on the rate at which the 2021 Vision was achieved. The low TFP growth scenario had the target reached in 2037 with a GDP of US$432.7 billion and rate of growth of 6 per cent. The high TFP growth scenario had the target met much earlier, in 2028 with a GDP of US$375 billion and rate of growth of 7.9 per cent. For the 2021 Vision to be met in 2021, ceteris paribus, it was estimated that a TFP growth of 5 per cent would be required, yielding a GDP of US$366.1 billion and GDP growth of 11.9 per cent.

Crop yield impacts and sea level rise are only two potential climate change impacts that were considered in this analysis. Not evaluated was, for example, the potential for a trend of increasing intensity and frequency of extreme weather events. These events could include cyclonic storms, severe flooding and severe drought. With sea level rise, saline intrusion is also a concern where saltwater pushes its way upstream, contaminating groundwater supplies and rendering once cultivable land unmanageable (Faisal, Islam and Saila 2004). The inclusion of such climate change impacts would exacerbate the economy-wide and agricultural sector responses presented here. The role of the state will be critical in creating the right mix of regulation and incentives for greater adaptation and resilience to climate variability and change. Furthermore, climate change projections and their impacts on agriculture are subject to a great deal of uncertainty with different projections leading to differential outcomes with regards to the economy, food security and ultimately societal well-being.

A central finding of this study is that overall, population growth dynamics and TFP growth have more profound effects on the economy than projected climate change. Numerous other drivers of change not considered here could also prove to have significant impacts including urbanisation, the changing age structure of the population, external migration and remittances, infrastructure development and exogenous shocks to the economy such as the agricultural commodity price shock that occurred in 2008.

Bangladesh has been adapting to natural climate variability and change for decades. As waterlogged areas have increased, for example, research efforts into crop varieties tolerant of such conditions have been stepped-up. With groundwater extraction for irrigation in some areas of the country's northwest beginning to show signs of stress, various policies and programmes have been implemented to encourage water saving technologies and a shift in agricultural development towards coastal regions. Salt-tolerant crops and appropriate management strategies are being pursued to overcome the challenges characteristic of coastal regions. The development of high yielding varieties and other technological innovations will also help meet growing demand. Nonetheless, to keep pace, public and private investment in research and development will be critical to continue to encourage innovation (Ministry of Food and Disaster Management 2006).

Investment in research and development and the implementation and refinement of those technologies already known to enhance productivity will be critical to offset potentially negative climate change impacts. As the results presented here have indicated, small gains in factor productivity can translate to large gains in output and growth. Greater efficiency in resource use can facilitate factor reallocation in the economy, reallocating factors to those sectors contributing the most to growth and enhanced well-being. The manufacturing and service sectors are critical engines of growth in Bangladesh's economy and will contribute substantively towards achieving national development goals. On the other hand, agriculture is the largest employer in the country and a critical stepping stone for many out of poverty. A two-pronged policy approach will be required to provide incentives to fuel the country's engines of economic growth while enhancing productivity in the countryside to lift the rural poor out of poverty and increase off-farm employment opportunities.

With population growth, increased per capita consumption and increasing resource scarcity, Bangladesh will have to do more with less (Alam *et al.* 2011, Balcombe *et al.* 2007). Judicious planning and consideration of the trade-offs inherent in achieving sustainable growth will test political capacity and will. Reducing poverty by 32 per cent in the last 20 years, Bangladesh has demonstrated it is up for the challenge.

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