Griffith UNIVERSITY
Queensland, Australia

Griffith Business School

DISCUSSION PAPER SERIES

Economics and business statistics

Climate change, crop productivity and regional growth disparity in Bangladesh: What does a district-level regional CGE model tell us?

Sudeshna Paul, Athula Naranpanawa, Jay Bandaralage and Tapan Sarker

2018-03

Series editors Dr Nicholas Rohde and Dr Athula Naranpanawa **ISSN** 1837-7750

Department of Accounting, Finance and Economics

Climate change, crop productivity and regional growth disparity in Bangladesh: what does a district-level regional CGE model tell us?

Sudeshna Paul, Athula Naranpanawa, Jay Bandaralage and Tapan Sarker

Abstract

Regarding the Agriculture sector in Bangladesh, climate change has been portrayed as having one of the most potentially significant negative impacts on the national macroeconomic environment. However, while the existing literature makes reference to estimations of the impacts of climate change on the national economy, it has presented little detailed evidence regarding its impacts on different regions or regional disparities. This study utilises a sixty-four administrative district-level Computable General Equilibrium (CGE) model to project the growth disparities and income loss under "pessimistic", "medium" and "optimistic" climate-induced crop productivity loss scenarios by 2030. Even though the percentage changes in gross regional products of most of the districts are declining, the growth disparities among the 64 districts are not likely to change significantly by 2030. However, poor populations in poverty-stricken districts are expected to experience relatively greater average income loss.

Keywords: Climate change; Crop productivity; Regional disparities; Computable General Equilibrium model; Bangladesh

JEL Codes: Q540, R110, D580

1. Introduction

Global climate change is real and is one of the greatest challenges facing the world today. It has attracted global attention because of its threat to humanity and the multidimensional nature of the threat that it poses at each of the global, regional and local levels (Bandara and Cai, 2014, IPCC, 2014). Agriculture is expected to become the most vulnerable sector to climate change. A number of studies have projected the extent of global crop yields losses, cropland productivity reduction and its corresponding economic impacts for different time horizons (for example, Cline, 2007, Hertel et al., 2010, and Chalise et al., 2017). Developing countries in particular will be more affected as evidenced by recent studies which posit that climate change induced crop yield losses will impact more prominently on the existing inter or intra-regional growth disparities and poverty in developing countries as compared to those of developed countries (Iglesias et.al., 2012 and Leichenko and Silva, 2014).

This study focuses on Bangladesh, a highly vulnerable country located in the South Asia, which has already started experiencing various climate-related extreme events and is likely to experience even more throughout the twenty-first century (Shahid et al., 2016). In particular, the agricultural sector in Bangladesh has, in recent years, been greatly affected by different climate events such as temperature rise, precipitation changes, and salinity intrusions (Ali, 2006, Ruane et al., 2013). It has been projected that the country's annual mean temperature is likely to increase between 1.6°C to 3.1°C, corresponding with a mean sea level rise of 0.88cm, by the end of this century (MOEF, 2005, Rajib et al., 2011, Yu et al., 2010). Therefore, it is likely that climate variability and change could also potentially exacerbate the existing growth disparity, poverty and food insecurity problems in Bangladesh (Ahmed et al., 2009, Amin, 2008, Rahman and Salim, 2013; Skoufias et al., 2011, Wheeler and von Braun, 2013).

There is a growing body of empirical research using sophisticated analytical techniques to examine the impacts of climate change in Bangladesh along with other South Asian countries (see e.g, ADB, 2014, Bandara and Cai, 2014, Cai et al., 2016, Hertel et al., 2010). However, there is a paucity of literature examining the link between temperature increase and impacts on agriculture in the context of Bangladesh. The two main categories of climate-change impact studies related to Bangladesh in terms of the modelling techniques used reply on biophysical modelling without any detailed treatment on economic cost (Chen et al., 2012, Iqbal and Siddique, 2014, Knox et al., 2012, Ruane et al., 2013), and partial equilibrium modelling[1] by incorporating the economic costs are used to analyse the impacts of climate change (IFPRI, 2013, Kobayashi and Furuya, 2011, Sarker et al., 2012, Yu et al., 2010). Many researchers have pointed out the limitations of using partial equilibrium modelling framework while analysing the impacts of climate change due to its inability to capture the global and economy wide impacts of climate change (see, for example, Robinson et.al, 2014). Notably, a few studies are based on the general equilibrium framework[2] to simulate the macroeconomic impacts of climate change and sea level rise either nationally or regionally (ADB, 2014, Banerjee et al., 2015, Thurlow et al., 2012, Yu et al., 2010). Among them, Yu et al. (2010) developed a regional Computable General Equilibrium (CGE) model to examine the economic impacts of climate change and sea level increase for 16 agro-ecological regions in Bangladesh. However, none of the previous studies have developed a multiregional district-level CGE model to explore the impacts of climate change at the sub-national level. Therefore, the main contribution of this study is to develop the first ever district-level regional CGE model for Bangladesh and, in turn, facilitate understanding of the likely district-level growth disparities and average income loss due to climate change by the year 2030.

The remainder of this paper is structured as follows. Section 2 provides an overview on poverty and literature on the impact of climate change in Bangladesh. Section 3 presents a brief description of the district-level "top down" CGE model of the Bangladesh economy. Section 4 discusses simulation results and the final section provides the concluding remarks and policy recommendations.

2. A Brief Overview of Poverty in Bangladesh and a Summary of Literature on the Impacts of Climate Change

Bangladesh is an agrarian country where the agricultural sector plays an important role in the economy, contributing 20% to the national GDP and 48% to total employment (ADB, 2014). It is also one of the most densely populated countries in the world, where 31.5% of the total population (159 million) live below the country's national poverty line (World Bank, 2014).

---

[1] Partial equilibrium model estimates the economic impact of any external shocks for a few markets, while it does not consider the economy wide impacts (Bandara, 1991).

[2] General equilibrium model estimates the impact of any external shock, not only on the directly affected sectors of the economy, but also all the sectors of the economy through spill-over effects.

The absolute number of poor population in each district of Bangladesh can be measured by using the 'Head Count Rate' (HCR) (see World Bank, 2011). HCR provides the percentage of people living below the upper or lower poverty lines as a share of total population[3]. An upper poverty line specifies a higher level of per capita household expenditure than the lower poverty line and therefore accounts for a 20% higher number of poor population on average compared to the lower poverty line. According to the lower poverty line, the maximum and minimum percentages of the poor population are 44.3% and 0.8%, respectively. Similarly, according to the upper poverty line, the maximum and minimum percentages of the poor population are 63.7% and 3.6%, respectively. In this paper we have selected, out of 64 districts, the top ten least poverty-stricken districts (less percentage of poor population) and the bottom ten poverty-stricken districts (a larger percentage of poor population) to report the results of impact of climate change on regional disparity and poverty in Bangladesh. Figure 1 represents the 20 selected districts of Bangladesh. Among them, the ten poverty-stricken districts are also aligned with the 15 backwards districts of Bangladesh, identified by Khondker and Mahzab) (2015) while preparing the Seventh five year plan of Bangladesh, BBS (2015). The report has also identified a total of 21 indicators made up of 11 economic and 10 non-economic regional disparity indicators to address the disparity among the "backwards" districts in Bangladesh. In Appendix A, we have reported key economic indicators for ten least poverty and ten poverty-stricken districts in Bangladesh. Therefore, it can be seen that those districts where greater proportions of people are engaged in agriculture also have the higher percentage of the poor population and lower per capita monthly consumption expenditure.

[3] In 2010, poverty lines for 16 different regions were calculated by using price index and cost of basic need (CBN) methods. For more details, (see World Bank, 2011, pp 153-154)

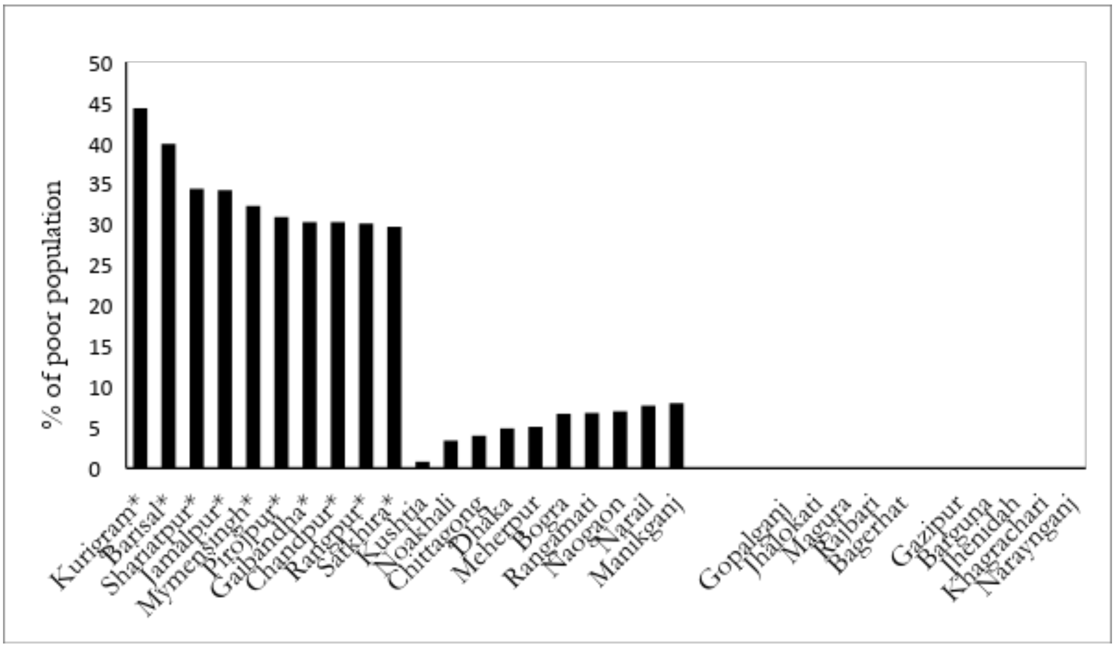

Figure 1. Percentage of poor population in ten poverty-stricken districts with (*) and ten least poverty-stricken districts of Bangladesh

Sources: compiled based on (BBS, 2013), (World Bank, 2011) and (UNWFP[4], 2009)

The relationships among climatic events, agricultural loss, poverty and growth disparity are complex in nature. It is evident that the extent of divergence and income inequality has increased from 2005 to 2010 compared to the previous two consecutive five-year periods (Khondker and Mahzab, 2015). In considering the regional growth disparities, there is a paucity of literature analysing the inter-district growth disparities and the reasons behind those disparities in Bangladesh (Amin, 2008, Khondker and Mahzab, 2015, Rahman, 2007, Rahman and Kazal, 2015; Rahman and Salim, 2013). According to the existing literature, the key stimulating factors behind the growth disparities among regions are inequalities in income, different rates of total factor productivity growth in agriculture and disparities in the cropland productivity in Bangladesh (Amin, 2008, Rahman, 2007, Rahman and Kazal, 2015). Moreover, the overall agricultural productivity growth due to technological progress is higher in Chittagong, Rajshahi, and Rangpur districts and lowers in Dhaka and Khulna districts respectively (Rahman and Salim, 2013).

A report by the UNDP (2009), estimated that a larger percentage of crop production loss could potentially increase the poverty impacts by the same amount towards the end of this century.

4 United Nations World Food Programme (UNWFP, 2009)

Along with that, the economic growth loss might also vary from 1% to 17%. Therefore, it is necessary to explore in detail how climate-induced crop productivity losses might affect the district level growth disparities and average income loss of the poor population within Bangladesh in the near-future.

A modicum literature has projected the impacts of climate change on crop productivity in Bangladesh (See Table 1 for more details). Of these studies, all have examined the extent of crop productivity loss at the national level, while only two of those studies have captured the economic impacts for the divisional and agro-ecological zone level for Bangladesh (ADB, 2014, Yu et al., 2010).

Table 1. A brief summary of literature on climate change impacts on crop production across regions in Bangladesh*

Source	Projection periods	Bangladesh and subregions	Crops	Crop loss (%)
(ADB, 2014)	2030 2050 2080	Khulna division(1), Barisal divion (2), Chittagong division (3)	Rice[5] Aus (a) Aman(b) Boro(c)	**2030: (average loss)** -2.53(1) -2.96(2) -4.93(3) **2050:** -5.56(1) -6.76(2) -15.2(3) **2080:** -13.1(1) -15.2(2) -19.9(3)
(Chen et al., 2012)	2020-2040	Bangladesh	Rice	-2
(Cline, 2007)	2070-2100	Global	All Crops	-10 to -25
(Yu et al., 2010)	2030 2050 2080	16 regions including coastal within Bangladesh	Rice Aus(a) Aman(b) Boro(c) Wheat(d)	**2030** -0.27(a) -0.37(b) -3.06(c) +2.05(d) **2050** -1.52(a) -0.62(b) -4.74(c) +3.44(d)

5 According to the cropping seasons, quality, and characteristics, there are three types of rice in Bangladesh: Aus, Aman and Boro.

(IFPRI, 2013)	2050:	Bangladesh	Rice Wheat Maize Sugarcane	-6.6 to -7.5 -18.7 to -20.4 -1.4 to -2.8 -10.6		
(Knox et al., 2011)	2020, 2050 2080	Bangladesh	Rice	-5 to -10		
(Hertel et al., 2010)	2030	Global		"Low"	"Medium"	"High"
			Rice	-10	-3	4
			Wheat	-10	-3	4
			Oilseeds	-10	-3	4
			Grains	-17	-10	-3
			Sugar	0	0	0
			Cotton,	-10	-3	4
			Other crops	-10	-3	4

*The data are available for different CO_2 emission scenario of Special Report on Emission Scenarios (SRES) (IPCC, 2000). The A2 scenario has employed for this study.

3. Multiregional CGE Model for Bangladesh

In this study, we develop a comparative static multiregional "top-down" CGE model for Bangladesh which consists of 64 districts[6]. To our knowledge, this is the first attempt to develop a district-level CGE model for Bangladesh. The theoretical structure and empirical implementation of this model closely follows the well-known ORANI model of the Australian economy and its "top-down" regional extension (Dixon et al., 1982). The database for the base year (2007) of the core model of the Bangladeshi economy is obtained from the Global Trade and Analysis Project (GTAP) version seven database (Narayanan et al., 2008). District-level data from sources such as the Bangladesh Bureau of Statistics (BBS, 2013), World Bank, Statistical Yearbook of Bangladesh, Ministry of Environment and Forestry, World Food Programme (UNWFP, 2009) are used to develop the "top-down" regional extension. The national level economic impact projections are disaggregated into district-levels. This model consists of 17 commodities produced by 17 industries with a "one-to-one" relationship[7]. The district-level data sets have been compiled in the following way. First, we have collated the district-level secondary economic data for the 17 sectors and 64 districts for the year 2010-2011. Following this, we have calculated the proportions or contributions of every industry

6 Bangladesh has a total of eight divisions with 64 districts. In this paper the words 'districts' and 'regions' are used interchangeably.

7 In this paper, we have considered one aggregated manufacturing, mining and service sectors in our model.

sector towards the total production[8] after calculating the total production for different industries within 64 districts. While calculating the proportions, we choose the total amount of land area for production (in acres) rather than the outputs for agricultural sectors, to minimize the year to year variation among proportions. In case of livestock industries, such as production, we have taken either total number of farm holdings or total employment. Further, for fishing, mining, manufacturing and services we chose the total number of employment across 64 districts. In case of any missing data, this study has considered the average of proportions of other districts within one division.

The theoretical structure of the model is based on neoclassical economic theory. First, producers, consumers, and other agents in the market are price takers. Second, producers are profit maximisers and consumers are utility maximizers. Also, the production function is of the nested type where there is a combination of which combine both 'Leontief' and 'Constant elasticity of substitution' (CES) production functions. Third, there are two types of inputs of production: primary factors of production, which include capital, land and labour (skilled and unskilled labour); and imported and domestic intermediate inputs of production. Fourth, all markets are assumed to be cleared or in equilibrium at all times. Last, government expenditure and household numbers are exogenously determined in the model.

The regional disaggregation of that model is based on the ORANI Regional Equation System (ORES) (Dixon et al., 1982). ORES is based on a technique developed by Leontief, Morgan, Polenske, Simpson and Tower (LMPST, 1965) so as to disaggregate the results of the national input-output data into regions. This method is more popular for disaggregating the national level simulation results into different regions and has been used by other researchers worldwide in a "top-down" manner (for other applications see Butt and Bandara, 2009, Dixon et al.,2007, Naranpanawa and Arora, 2014).

We do not present the equation system of the core national model of the Bangladesh economy since the structure of the Bangladesh national model closely follows the ORANI model (Dixon et al., 1982). A brief description of the 'regional balance equations for local

8 "If, X= the total area allocated for rice production for district Dhaka;

and, Y= the total area allocated for rice production for 64 districts. Therefore, the proportion of area used to produce rice in district Dhaka = X/Y".

commodities' and 'household consumption at regional-level for the "top-down" regional extension model are presented.

Below is the description of the LMPST model which has been modified for use with the national level ORANI model[9]

Required set names and its components[10] for our model:

U= all commodities ($1 \dots 17$)
K= all industries ($1 \dots 17$)
N= industries producing national commodities (national industries) ($1,2$)
M=industries producing local commodities (local industries) ($1, \dots 15$)
H= national commodities ($1,2$)
L= local commodities ($1, \dots .15$)
R= number of regions ($1 \dots 64$)
S = sourcing of commodities, domestic (s=1), imports (s=2)

First, the activity levels for the national industries can be defined by

$Z_n^r = \quad Z_n G_n^r$ for all n ϵ N and $r \epsilon\ R = 1 \dots 64$ (1)

Where, Z_n^r is the output of industry n in region r and G_n^r is the base- period proportion of the aggregate output of industry n which is produced in region r. Since G_n^r is constant, the equation becomes (if we transform equation 1 as percentage change form):

$z_n^r = \ z_n$ (Since, dG_n^r =0) for all n ϵ N and $r = 1 \dots 64$ (2)

If there is an increase in the aggregate output of any national industry by 1%, then the output of that industry will increase by 1% for each region. Also, it can be assumed that the commodity composition of output in national industries is constant across all regions.

In case of local commodities, aggregate output of any local commodity in a region must be equivalent to the aggregate demand for the commodity in that region, that is:

9

101 N.T: industry and commodity classifications in ORANI are such that no industry can produce both local and national commodities together, which implies N∩M is empty.

$$
\begin{aligned}
X_{(i1)}^{(0)r} = & \sum_{n\in N} \left(A_{(i1)n}^{(1)} Z_n^r\right) + \sum_{m\in M} \left(A_{(i1)m}^{(1)} Z_m^r\right) + \sum_{n\in N} \left(A_{(i1)n}^{(2)} Y_n^r\right) + \sum_{m\in M} A_{(i1)m}^{(2)} Y_m^r \\
& + X_{(i1)}^{(3)r} + X_{(i1)}^{(5)r} + \sum_{u\in U} \sum_{s=1}^{2} \sum_{n\in N} \sum_{h=1}^{2} A_{(i1)}^{(us)nh} X_{(us)n}^{(h)r} \\
& + \sum_{u\in U} \sum_{s=1}^{2} \sum_{m\in M} \sum_{h=1}^{2} A_{(i1)}^{(us)mh} X_{(us)m}^{(h)r}) \\
& + \sum_{u\in U} \sum_{s=1}^{2} \sum_{h=3,5} A_{(i1)}^{(us)h} X_{(us)}^{(h)r} + \sum_{u\in U} A_{(i1)}^{(u1)4} X_{(u1)}^{(4)r},
\end{aligned}
$$

$i \in L = 1,2 \ \& \ r = 1, \dots, 64$ (3)

Where,

$X_{(i1)}^{(0)r}$ = aggregate output of local commodity i in region r;

$A_{(ik)k}^{(h)}$ = direct input of domestically produced commodity i required per unit output ($h = 1$) or capital information ($h = 2$) in industry k;

$A_{(i1)}^{(us)kh}$= the input of domestically produced commodity i required as a margins service per unit direct flow of commodity u from source s to industry k for purpose h;

$Y_{\square}^{r}$ = total investment demand by national industries in region r;

$Y_{\square}^{r}$ = total investment demand by local industries in region r;

$A_{(i1)}^{(us)h}$ = the input of domestically produced commodity i required as a margins service per unit direct flow of commodity u from source s to final demand category h; A represents the technology. However, in this model the technology in each industry is independent of its regional location.

$X_{(i1)}^{(3)r}$ = household demand for domestically produced commodity i in region r;

$X_{(i1)}^{(5)r}$ = other final demand for domestically produced commodity i in region r;

$X_{(u1)}^{(4)r}$ = the export volumes demand of domestic commodity u from region r; we assume for fixed regional sourcing for international trade;

$X_{(us)n}^{(h)r}$ = regional input demand from national industries for commodity u from source s for per unit output h;

$X_{(us)m}^{(h)r}$= regional input demand from local industries for commodity u from source s for per unit output h;

$X_{(us)}^{(h)r}$ = regional household ($h = 3$) and other ($h = 5$) final demand for commodity u;

The percentage change form of equation is:

$$
\begin{aligned}
x_{(i1)}^{(0)r} = & \sum_{n \in N} \left(a_{(i1)n}^{(1)} + z_n^r\right) B_{(i1)n}^{(1)r} + \sum_{m \in M} \left(a_{(i1)m}^{(1)} + z_m^r\right) B_{(i1)m}^{(1)r} + \sum_{n \in N} \left(a_{(i1)n}^{(2)} + y_n^r\right) B_{(i1)n}^{(2)r} \\
& + \sum_{m \in M} \left(a_{(i1)m}^{(2)} + y_m^r\right) B_{(i1)m}^{(2)r} + x_{(i1)}^{(3)r} B_{(i1)}^{(3)r} + x_{(i1)}^{(5)r} B_{(i1)}^{(5)r} \\
& + \sum_{u \in U} \sum_{s=1}^{2} \sum_{n \in N} \sum_{h=1}^{2} (a_{(i1)}^{(us)nh} + x_{(us)n}^{(h)r}) B_{(i1)}^{(us)nhr} \\
& + \sum_{u \in U} \sum_{s=1}^{2} \sum_{m \in M} \sum_{h=1}^{2} (a_{(i1)}^{(us)mh} + x_{(us)m}^{(h)r}) B_{(i1)}^{(us)mhr} \\
& + \sum_{u \in U} \sum_{s=1}^{2} \sum_{h=3,5} \left(a_{(i1)}^{(us)h} + x_{(us)}^{(h)r}\right) B_{(i1)}^{(us)hr} \\
& + \sum_{u \in U} \left(a_{(i1)}^{(u1)4} + x_{(u1)}^{(4)r}\right) B_{(i1)}^{(u1)4r},
\end{aligned}
$$

$$i \in L, r = 1, \ldots, 64 \qquad (4)$$

Where, B represents the sales shares of domestically produced commodity i towards region r for different purposes and $a's$ represent technical changes. According to the input-output table, the sale shares represent the proportion of sales of total output to industries, households, investments, exports and others out of total sales.

Further, we can establish the relation between base period costs and sales shares. We can assume that in the base period, the relative quantities of goods $(i1)$ used for facilitating the domestic $(s = 1)$ and import $(s = 2)$ components of each commodity, flow to each industry in each region reflecting the relative values of these components,

$$B_{(i1)}^{(us)khr} = B_{(i1)}^{(u\cdot)khr} S_{(us)k}^{(h)r}, \; i \in L, \; u \in U, \; s = 1,2 \; k \in K, \; h = 1,2 \; r = 1,2 \ldots 64 \quad (5)$$

Where,

$B_{(i1)}^{(us)khr}$ = regional sales shares of facilitating the domestic commodity i required as a margin services per unit direct flow of commodity u from source s to industry k for purpose h;

Where, S represents the cost shares;

$S_{(us)k}^{(h)r}$ = the share of commodity u from source s in the total cost of commodity u used for the purpose of h in region r.

With the equation (5), it can be stated that if two-thirds of the cost of commodity u used as an input to industry k in region r are accounted for by the domestically produced commodity u and one-third by the imported u, then under the equation (5), we assume that two-thirds of the wholesale margins involved in delivering u commodity to industry k in region r are associated with the delivery of domestic commodity u and one-third is associated with the delivery of imported u.

Further, the two following assumptions along with no technical changes lead to equation 6 and equation 7[11]

If there are no changes in relative prices of domestically produced commodity i from alternative sources, then a 1 % increase in activity levels by industry k (z_k^r) leads to a 1% increase in each of the $x_{(us)k}^{(1)r}$. Therefore, constant returns to scales exist in equation 6.

And

$$\sum_{s=1}^{2} x_{(us)k}^{(1)r} B_{(i1)}^{(us)k1r} = z_k^r B_{(i1)}^{(u\cdot)k1r}, \quad i \in L, u \in U, k \in K, r = 1, \ldots, 64 \quad (6)$$

---

[11] If we assume that the national model assumptions also hold for regional levels (For more details, please see the details from Dixon et al., 1982, p- 263 for regional modelling equations, p- 81 for the assumption behind equation 6, and p- 96 for the assumptions behind equation 7).

And

if we also assume Leontief Production function and CES combination of inputs from domestic and foreign sources while constructing the fixed capital for an industry

$$\sum_{s=1}^{2} x_{(us)k}^{(2)r} B_{(i1)}^{(us)k2r} = y_k^r B_{(i1)}^{(u\cdot)k2r}, \quad i \in L, u \in U, k \in K, r = 1, \ldots ,64$$

(7)

If we assume that $a's = 0$, combined with equation (6) and equation (7), equation 4 simplifies to,

$$x_{(i1)}^{(0)r} = \sum_{n \in N} \left(B_{(i1)n}^{(1)r} + \sum_{u \in U} B_{(i1)}^{(u\cdot)n1r} \right) z_n^r + \sum_{m \in M} \left(B_{(i1)m}^{(1)r} + \sum_{u \in U} B_{(i1)}^{(u\cdot)m1r} \right) z_m^r$$
$$+ \sum_{n \in N} \left(B_{(i1)n}^{(2)r} + \sum_{u \in U} B_{(i1)}^{(u\cdot)n2r} \right) y_n^r + \sum_{m \in M} \left(B_{(i1)m}^{(2)r} + \sum_{u \in U} B_{(i1)}^{(u\cdot)m2r} \right) y_m^r$$
$$+ B_{(i1)}^{(3)r} x_{(i1)}^{(3)r} + B_{(i1)}^{(5)r} x_{(i1)}^{(5)r} + \sum_{u \in U} \sum_{s=1}^{2} \sum_{h=3,5} B_{(i1)}^{(us)hr} x_{(us)}^{(h)r}$$
$$+ \sum_{u \in U} B_{(i1)}^{(u1)4r} x_{(u1),}^{(4)r} \quad i \in L, r = 1, \ldots ,64$$

(8)

The above equations can be solved by providing the values of the right-hand side variables. Moreover, we will also be able to solve equation (8) for percentage changes in regional outputs of local commodities but we need to express each of these equation's variables as functions of (i) to make those variables exogenous at the regional-level.

While solving the equations related to regional investments, this model will assume that the proportion of investment by each industry will be similar to the current output proportion.

3.1 Household consumption at the regional-level:

For household consumption, we assume that each region contains a link between regional consumption and regional labour income.

We assume that,

$$X_{(us)}^{(3)r} = f_{(us)}^{r}\left(X_{(us)}^{(3)}, \frac{V^r}{V}\right), \qquad u \in U, s = 1,2, r = 1, \dots ,64 \tag{9}$$

Therefore, the household consumption in each region is a function of $[X_{(us)}^{(3)} = aggregate\ household\ consumption\ of\ commodity\ (us), commodity\ u\ from\ source\ s]$ and

$$\frac{V^r}{V} = \frac{Total\ wage\ bill\ in\ region\ r}{Economy\ wide\ aggregate\ wage\ bills}.$$

The percentage change equations for equation (9) will be,

$$x_{(us)}^{(3)r} = \alpha_{(us)}^{r} x_{(us)}^{(3)} + \gamma_{(us)}^{r}(\vartheta^r - \vartheta), \qquad u \in U, s = 1,2, r = 1, \dots ,64$$
(10)

Where, $\alpha_{(us)}^{r}$= the elasticity in region r of consumption of good (us) with respect to the aggregate consumption of good(us).

$\gamma_{(us)}^{r}$ = the elasticity in region r to the consumption of good (us) with respect to the share of region r in the economy's aggregate wage bill.

$(\vartheta^r - \vartheta)$= difference between regional wage bill and the economy wide aggregate wage bill;

If we assume that:

$$\alpha_{(us)}^{r} = 1 \tag{11}$$

And$\gamma_{(us)}^{r} = \epsilon_{(us)}\, \gamma\ , o \le \gamma \le 1,\ u \epsilon U,\ s = 1,2, r = 1,2 \dots 64$ (12)

$[N.T{:}\ \gamma = parameter\ that\ signifies\ the\ relation\ between$

$regional\ income\ with\ aggregate\ regional\ consumption]$

And $\epsilon_{(us)} = economy\ wide\ household\ expenditure\ elasticity\ of\ demand\ for\ good\ u\ from\ source\ s$

However, for our long run simulation, the suitable assumption is,

$$\gamma_{(us)}^{r} = 1 \tag{13}$$

Therefore, substituting long run assumption into equation (10) it becomes,

$$x_{(us)}^{(3)r} = x_{(us)}^{(3)} + (\vartheta^r - \vartheta) \quad u \epsilon U,\ s = 1,2, r = 1,2 \dots 64 \tag{14}$$

Thus, the changes in regional consumption levels fully reflect the changes in the regional allocation of labour income.

Further, the regional wage bill variable can also be expressed in terms of wage rates and industry-specific employment levels,

$$V^r = \sum_{k \in K} \quad (P_{(g+1,1)k}^{(1)} X_{(g+1,1)k}^{(1)r}), \quad r = 1, \dots ,64$$

(15)

Where,

$P_{(g+1,1)k}^{(1)}$ = the wage rate variable for industry k without regional subscript;

And

W_k^r = the share of industry k in the aggregate wage bill of region r;

$X_{(g+1,1)k}^{(1)r}$ = the employment levels in industry k in region r ;

Further, the percentage form of equation (15) which includes the employment by regions as well as industry,

$$\vartheta^r = \sum_{k \in K} \quad (p_{(g+1,1)k}^{(1)} + x_{(g+1,1)k}^{(1)r}) W_k \quad r = 1,2,,,,64 \tag{16}$$

Where, the weights W_k represents the shares by industries in the aggregate wage bill for the economy;

Secondly, the economy-wide wage bill is

$$V = \sum_{k \in K} \quad (P_{(g+1,1)k}^{(1)} X_{(g+1,1)k}^{(1)}),$$

(17)

Further, the economy-wide wage bill can be expressed as percentage form equation,

$$\vartheta = \sum_{k\in K} \quad (p^{(1)}_{(g+1,1)k} + x^{(1)}_{(g+1,1)k})W_k$$

(18)

To determine the regional employment $x^{(1)r}_{(g+1,1)k}$, the model assumes that the percentage change in employment per unit of output in industry k in each region r is similar because of the percentage change in employment per unit of output in industry *k* for the country. That is,

$$x^{(1)r}_{(g+1,1)k} - z^r_k = x^{(1)}_{(g+1,1)k} - z_k, \qquad k \in K, r = 1, \dots, 64 \qquad (19)$$

Equation (19) seems to be a satisfactory assumption for our long run simulation model because it is reasonable to assume that the labour-capital ratio moves uniformly across regions. This assumption is possible as because we have already specified that the wage rates and capital can move across regions. Therefore, while solving other equations, this model assumes the changes to be exogenous in its regional allocation for government current expenditure and fixed regional sourcing for international exports from regions.

Finally, regional consumption demand can be achieved by substituting equation (19) into equation (10) from equation (19) into equation (16) and then into (10), and by using (2), (11) and (12):

$$x^{(3)r}_{(us)} = x^{(3)}_{(us)} + \varepsilon_{(us)}\gamma[\sum_{k\in K} \quad (W^r_k - W_k)\left(p^{(1)}_{(g+1,1)k} + x^{(1)}_{(g+1,1)k}\right) + \sum_{m\in M} \quad W^r_m(z^r_m - z_m)] \quad u \in U,\ s = 1,2,\ r = 1,2 \dots 64 \qquad (20)$$

The above-mentioned LMPST approach is based on the following technical assumptions. First, there is no technological difference among industries in each region. Secondly, each region contains two types of commodities, “Local” and “National”. In any region, the maximum amount of the output of “Local” commodities can adjust to satisfy the intermediate and investment demand by other industries along with household demand within that region. The “National” commodities are those for which the regional output expands in accordance with the national output. Finally, the regional pattern of production is independent of regional pattern of demand for “National” commodities. The detailed description of the LMPST model is heavily drawn from Dixon et al (1982, Ch-6).

For the sake of the “top-down” model, this paper has assumed manufacturing and service as to be “National” industries and agriculture and mining as to be “Local” industries. Manufacturing products and services are trading among different districts. However, agricultural crops can be considered as a little-traded commodity as it seems that the majority of farmers in most of the districts in Bangladesh are subsistence or small landholding farmers. According to BBS, (2016), the percentage of small (0.05-2.49 acres), medium (2.50-7.49 acres) and large farm (7.50 acres and above) holdings farmers in overall Bangladesh are 84.27%, 14.19% and 1.54% respectively. Moreover, the proportions of small farmers (62.35% to 89%) are greater compared to the medium (10% to 19%) and large holdings farmers (1.06% to 3.15%) across all divisions in Bangladesh respectively. Therefore, the primary sources of the total demand for majority of the agricultural crops within one district are largely fulfilled through the district productions of those crops. Although the “top-down” model has some limitations, such as, being unable to project the regional-level policy results, it does provide many advantages because of its data convenience and regional-level modelling assumptions while projecting and disaggregating the national-level policy shocks across regions.

4. Regional Impacts of Climate Change: Simulation Results

In this study, we conducted three long-run simulation experiments to examine the near future (2030) impacts of climate change on the national and district-level growth disparities and income loss through climate-induced agricultural productivity loss in Bangladesh. In the long-run closure, we assume that investors have adequate time to alter the industry-level capital stocks in response to the productivity shock, thus allowing industry level capital stocks to be determined endogenously at exogenous rates of return. In the labour market, we assume full employment in the economy; that is, we adopt the conventional long-run labour market assumption of exogenous national employment while allowing the national real wages to be endogenously determined. Furthermore, real household and real government consumption are assumed to be determined endogenously. In this simulation, the trade balance (as a percentage of GDP) and the nominal exchange rate are exogenous to the model where the nominal exchange rate is considered as the numeraire[12]. This CGE model was solved using the software GEMPACK (Harrison and Pearson, 1998).

In our model simulations, we have reduced the total factor productivity for six crops, including paddy, wheat, oilseeds, grains, cotton, and others for 2030. Similar to a recent CGE modelling study by Chalise et al., (2017) we did not calculate the crop productivity shocks but have chosen from literature. First, we have reviewed and compared all the possible shocks in Table 1. Finally, we have selected the crop productivity loss shocks from Hertel et al., (2010). We have taken those shocks ("low", "medium", "high"; see previously mentioned in Table 1) over the ones presented in other studies because of two key reasons: first, this study has considered a range of crop productivity shocks from "most likely" to "most unlikely" scenarios of climate change for

Bangladesh by 2030. Secondly, the estimated crop productivity loss, taken from other existing studies, also lies within that range of these losses.

The above three simulations were carried out with the model using numerical values of shocks across agricultural sectors as given below.

- The 'low-productivity' (or "pessimistic") scenario (0 to -17%) represents large crop productivity loss due to extreme climate impacts with frequent temperature change, high crop sensitivity to temperature change and low positive carbon fertilization.
- The 'most likely/central case' (or "medium") scenario (0 to -10%) represents the climate impacts on crop productivity loss.

12 Additionally, agricultural land, all technological change, demand for inventories by commodity, all sales tax rates and commodity specific shifters, foreign prices of imports and exports, number of households and their consumption preferences and real unit cost of 'other cost tickets'(Production subsidies etc.) are also assumed to be exogenous in this model.

- The ‘high-productivity’ (or “optimistic”) scenario (-3% to +4%) represents the lower crop productivity loss or any potential gain to slow temperature change and high carbon fertilization effect.

The key results of the above simulations at the national and regional-levels are presented in the following two sub-sections.

4.1 Macroeconomic and industry Results:

Table 2 depicts the national-level macroeconomic variables results from three simulations for Bangladesh. According to Table2, the real GDP is likely to experience significant negative growth rate from 1.04 to 3.50 percent under the “medium” to “pessimistic” climate scenarios by 2030. This can largely be attributed to the direct productivity loss occurring in the agricultural sector. In addition to the direct effect, other industries, which are connected to those affected agricultural industries having backward and forward linkages, would also project to contract, which indirectly contributes to the real GDP loss. Furthermore, average real wages and aggregate capital stock are projected to fall by one to four percent compared to the base year as a result of the contraction of agricultural industries. This would, in turn, contribute negatively to the real GDP growth. Following this result, real household consumption is expected to experience a negative effect of between one and three percent. We have incorporated international trade in our model via export and import sourcing of each commodity following the small country assumption in the international trade literature. The high crop productivity loss is likely to have more negative impacts on the total national exports volume of -0.56% followed by -0.17% and 0.25% for “medium” and “optimistic” crop loss scenario respectively. As the total exports volume from Bangladesh is likely to decrease by 2030, this will have reverse impacts on the price level of exportable commodities from Bangladesh to its trading partners. The price level, measured by the Bangladesh local currency is also likely to increase from 0.08% for “medium” crop loss scenario to 0.31% for “pessimistic” crop loss scenario. However, the price is likely to decrease by -0.11% in case of positive crop productivity “optimistic” scenario. Further, the total volumes of imports are likely to decrease for both “pessimistic” to “medium” crop loss scenario. As shown in Table 2, the results across the three scenarios (from “pessimistic” to “optimistic”) suggest that the lower the climate-induced agricultural productivity loss due to the positive effects of carbon fertilization, the more likely it is that positive economic growth will be stimulated. An aggregate capital stock is projected to increase by 1.78 percent under the “optimistic” scenario. Similarly, the average real wage is expected to increase by 1.83 percent compared to the base year as a result of an increase in labour demand from expanding industries. This could then positively stimulate the real GDP growth rate by 1.36 percent under this scenario. According to Appendix B, the national industry-level value added loss for paddy and wheat sectors are likely to be 4.16% and 14.88%, respectively, due to the "pessimistic" scenario of climate change. Similarly, manufacturing and service sectors are projected to contract by 4.97% and 2.22%, respectively. These results are consistent with other recent national-level CGE studies for Bangladesh. For example, Thurlow et al. (2012) found that the national rice production loss will be 8.8% from the year 2005 to 2050. A recent study by Bandara and Cai (2014) projected a 1.6% decline from baseline in real GDP for Bangladesh by 2030. Similarly, ADB (2014) estimated a paddy production loss of -0.68% due to the temperature increase from 0.9°C to 1.9°C by 2030. These estimated results are consistent with our "medium" simulation results of -1.16% real GDP losses under the likely range of 1.0°C to 1.5°C temperature increase.

Table 2. Projections of national macroeconomic variables for "pessimistic", "medium" and "optimistic" scenarios by 2030

National Macroeconomic variables	"Pessimistic" Simulation 1)	"Medium" (Simulation 2)	"Optimistic" (Simulation 3)
Real GDP	-3.50	-1.04	1.36
Aggregate real investment expenditure	-3.88	-1.11	1.41
Average real wages	-4.89	-1.43	1.83
Real Household consumption	-3.50	-1.06	1.39
Aggregate real government demand	-3.50	-1.06	1.39
Exports volume	-0.56	-0.17	0.25
Exports price	0.31	0.08	-0.11

Imports volume	-1.60	-0.49	0.67
Consumer price index	-1.75	-0.54	0.73
Aggregate capital stock, rental weights	-4.66	-1.37	1.78

% change from the base year

4.2 Regional Results

The combined impacts of temperature, precipitation changes and carbon fertilization are likely to have negative growth impacts for all districts of Bangladesh in the “pessimistic” climate scenario. However, there will be moderate impacts under the “medium” scenario, and positive-growth impacts under the “optimistic” climate change scenario by 2030 (see Appendix C for Gross District Domestic Products (GDDP) in 64 districts). While the average district-level gross domestic product across 64 districts is projected to fall under “pessimistic” and “medium” scenarios by 2.60% and 0.77%, respectively, it is projected to increase under the “optimistic” scenario (+0.99%). The minimum percentage loss of GDP is 1.15% for Patuakhali district in the Barisal division and the maximum loss is 4.80% for Munshiganj district in the Dhaka division according to the “pessimistic” productivity loss scenario. However, it is evident that the regional growth results are not significantly dispersed among the 64 districts by 2030.

To identify growth disparity more effectively, we have also calculated the coefficient of variation (C_V)[13] of factor cost GDP before and after the simulation for both the 64 districts and the 20 selected districts (10 poverty-stricken and the 10 least poverty-stricken districts). The coefficients of variation for the 64 and 20 selected districts are 1.29, 1.47 and 1.29, 1.48 before and after the simulation for the “pessimistic” scenario respectively.

[13] Coefficient of variation (C_V) = (Standard Deviation/Mean). To calculate and compare the C_V, initially, we have calculated the base year factor cost GDP for twenty districts followed by calculating the coefficients of variation before conducting the simulation. Later, we have again calculated the new factor costs of GDP for those similar districts through reducing the amount of GDP by the resulting percentage change gross district product loss after conducting the simulation. Finally, the coefficient of variation has been calculated for those new sets of GDP for 2030.

The district-level results indicate that, in general, both poverty-stricken and least poverty-stricken districts are likely to be affected negatively due to climate change, however, the extent of losses between poverty-stricken and least poverty-stricken districts are different and worthy of note (see Table 3). Among all the selected districts, Kushtia, a high-income district, will be affected negatively under "pessimistic" and "medium" scenarios where the gross region product loss is projected to be 3.68% and 1.09%, respectively, by 2030. Moreover, a reduction of growth by approximately 2.5% and 2.43 % under the "pessimistic" climate scenario is projected for the capital city Dhaka or Dhaka district and the high-income district Chittagong respectively. Also, the growth loss is expected to be minimal (-1.45%) for districts like Meherpur under the "pessimistic" climate scenario due to the diversity of crop production within that district. Among the poverty-stricken districts, Kurigram, which is the highest-ranking poverty district, will be negatively affected due to the contraction of agriculture industries in the general and paddy sector in particular. Finally, if the climate change impacts are "optimistic", it is likely to benefit both poverty-stricken and least poverty-stricken districts. Figure 2 demonstrates the comparison of growth results for all 20 selected districts for "pessimistic", "medium" and "optimistic" climate scenarios.

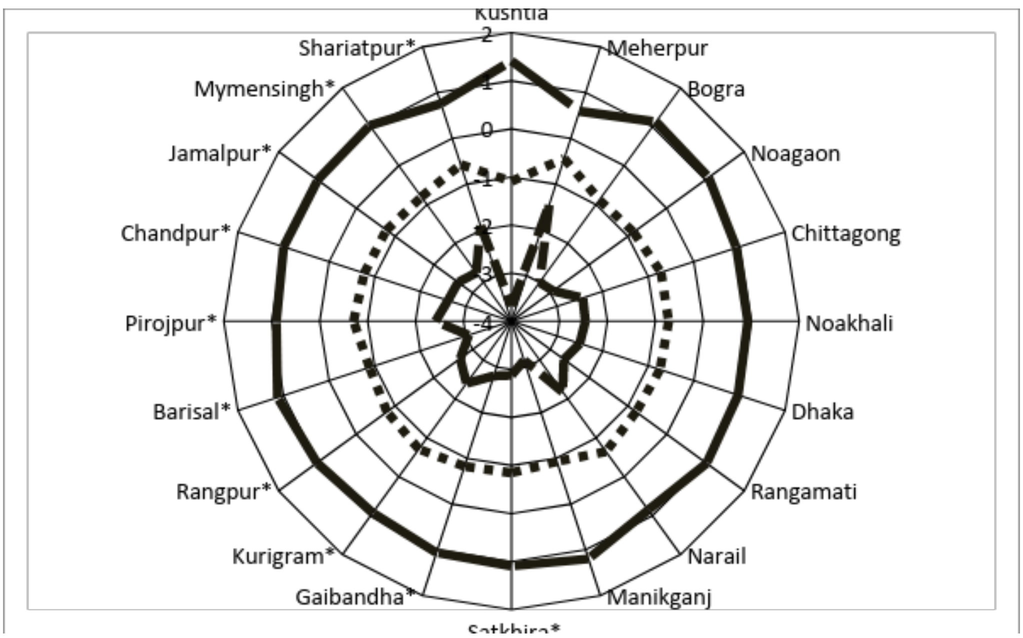

Figure2. Comparison of growth results for twenty districts under "pessimistic", "medium" and "optimistic" scenarios by 2030.

"Pessimistic" scenario "Medium" scenario "Optimistic" scenario

Table 3.

Projections of percentage change in GDDP under different climate change scenarios by 2030

Poverty-stricken Districts	"Pessimistic"	"Medium"	"Optimistic"	Least poverty-stricken districts	"Pessimistic"	"Medium"	"Optimistic"
Kurigram	-2.40	-0.71	0.92	Kushtia	-3.68	-1.09	1.41
Barisal	-3.06	-0.88	1.13	Noakhali	-2.45	-0.72	0.92
Shariatpur	-1.90	-0.57	0.76	Chittagong	-2.43	-0.71	0.93
Jamalpur	-2.62	-0.77	0.99	Dhaka	-2.50	-0.74	0.96
Mymensingh	-2.75	-0.80	1.03	Meherpur	-1.45	-0.44	0.59
Pirojpur	-2.41	-0.70	0.90	Bogra	-3.00	-0.87	1.12
Gaibandha	-2.80	-0.82	1.06	Naogaon	-2.92	-0.84	1.08
Chandpur	-2.60	-0.77	0.99	Manikganj	-3.14	-0.93	1.19
Rangpur	-2.67	-0.79	1.01	Narail	-2.18	-0.64	0.85
Satkhira	-2.87	-0.84	1.09	Rangamati	-2.64	-0.79	1.03

% change from base case

It is evident from the district-level industry results presented in Appendixes D1 and D2 that the extent of value added loss for the agricultural sector varies substantially from one district to another. As previously described, this is dependent on the proportion of different agricultural crop production among different districts and the resulting amount of crop loss due to climate change. For example, if we consider the paddy sector under the "pessimistic" scenario, it is evident that the value-added loss is highest in Dhaka (7.41%) followed by Rangamati (6.93%), Chittagong (6.66%) and Kushtia (6.69%) compared to poverty-stricken districts such as Kurigram (3.61%), Barisal (4.98%), Jamalpur (3.37%) and Mymensingh (4.27%). The key reason is the strong forward and backward linkage effects among different industries within these districts. According to our model assumption, all agriculture and mining industries are 'Local' industries, whereas service and manufacturing sectors are 'National' industries. Therefore, if any of the service or manufacturing sectors experience value added contraction nationally due to climate shocks, the results are similar for all 64 districts. Moreover, the growth-contraction for those 'National' industries can simultaneously create some multiplier effects for 'Local' commodity sectors through reducing the output demand for those commodities. Therefore, even if paddy industry contributes less towards the base year GDP in any districts (say, e.g., Dhaka); we might find a large value-added loss for paddy in that district. Because manufacturing and service sectors (and for some districts, agriculture) are greatly towards the base year district-level GDP at factor cost for majority of the least poverty-stricken districts, the value-added loss is also expected to be higher for industries related to manufacturing and service sectors among those districts. Therefore, the current simulation results are consistent with the evidence that most of the economic losses for the Bangladesh economy are connected to the other value-added sectors related to agriculture (Yu et al., 2010).

Tables 4 and 5 represent how different industries are likely to contribute towards the percentage changes of gross district domestic products (GDDP) loss (Table 3) for 20 districts under the "pessimistic" climate scenario by 2030. According to Tables 4 and 5, the service sector evidently contributes mostly towards growth contraction for both the poverty-stricken and least poverty-stricken districts in Bangladesh resulting from "pessimistic" climate change scenario by 2030. On the one hand, among the poverty-stricken districts, it can be observed that the paddy sector contributes the most towards the growth reduction in comparison to the other crop sectors (see Table 4). This result can be expected as majority of the poverty-stricken districts are generally specialized in paddy production. Among all those districts, the paddy sector in Barisal district contributes mostly towards the GDDP loss followed by the manufacturing sector. Similarly, for the highest poverty-stricken district, Kurigram, the major contributions towards GDP loss are expected to come from the paddy and plant based fibres (jute and cotton) sector after considering the service sector loss. It can also be noted that the plant-based fibres industry contributes relatively more towards the growth loss than the manufacturing industries for districts like Shariatpur. On the other hand, among the least poverty-stricken districts, the manufacturing sector contributes greatly to industrial districts such as Kushtia, Dhaka, and Chittagong when considering percentage change loss in GDDP (see Table 5). In addition, agriculture sectors (both plant-based fibres such as jute and cotton, and other crop sectors) are likely to greatly contribute towards the growth loss for those districts. For example, districts such as Naogaon, Bogra, Kushtia and Manikganj are likely to experience substantial growth reduction not only through the manufacturing loss but also through paddy production loss. Those losses are expected to be -0.71%, -0.60%, -0.45% and -0.43% in the paddy sector and -0.39%, -0.43%, -0.70%, and -0.31% in the manufacturing sectors respectively. Moreover, if any service sector (e.g., transport) has any direct link with the manufacturing sector, the resulting impacts will also increase for those districts (Naranpanawa and Arora, 2014)[14].Our predicted regional results are also consistent with previous findings by Kobayashi and Furuya (2011) where the resulting growth in Rajshahi region (which includes both Naogaon and Bogra districts) is likely to be affected to a greater degree due to the loss in the paddy sector by 2050. Unlike other industries, vegetables, as well as plant-based fibres (cotton and jute), can positively contribute towards growth for Meherpur district even under the "pessimistic" scenario. This could be one of the key reasons behind the reduced growth loss condition of Meherpur district (within Khulna division) even under the "pessimistic" scenario by 2030.

14 This paper has considered an aggregated manufacturing and service sectors; therefore we do not identify the more disaggregated resulting impacts or any direct link between manufacturing and service sectors.

Table 4. Projection of the industry contribution towards the gross district domestic products (GDDP) for poverty-stricken districts under "pessimistic" scenario by 2030

Sectors name	Mymensingh	Jamalpur	Shariatpur	Barisal	Pirojpur	Chandpur	Gaibandha	Kurigram	Rangpur	Satkhira
Paddy rice	-0.57	-0.38	-0.18	-0.68	-0.43	-0.30	-0.47	-0.37	-0.41	-0.42
Wheat	0.00	-0.02	-0.03	0.00	0.00	-0.01	-0.01	-0.05	-0.01	0.00
Other Cereal grains	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	-0.01	0.00
Vegetables, fruits, nuts	0.00	0.01	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Oil seeds	0.00	-0.05	-0.03	0.00	0.00	-0.01	0.00	-0.02	0.00	-0.01
Sugar cane	-0.02	-0.06	-0.01	-0.01	-0.01	-0.01	-0.04	0.00	-0.02	-0.01
Plant-based fibres	-0.14	-0.18	0.18	-0.12	0.00	-0.12	-0.21	-0.11	-0.16	-0.21
Other Crops	-0.03	-0.13	-0.22	-0.22	-0.03	-0.03	-0.02	-0.05	-0.07	-0.03
Cattle, sheep, goats	-0.03	-0.01	0.02	0.00	-0.01	-0.01	-0.04	-0.03	-0.03	-0.03
Other Animal Products	-0.02	-0.06	-0.01	-0.02	-0.02	-0.03	-0.02	-0.01	-0.02	-0.02
Raw milk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wool, silk-worm cocoons	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	-0.02	-0.01	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	-0.42
Fishing	-0.08	-0.03	-0.03	-0.20	-0.03	-0.14	-0.01	-0.03	-0.04	-0.09
Mining	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01
Manufacturing	-0.26	-0.17	-0.15	-0.42	-0.21	-0.17	-0.24	-0.16	-0.22	-0.32
Services	-1.60	-1.56	-1.49	-1.42	-1.70	-1.80	-1.75	-1.60	-1.71	-1.35

% change from the base year

Table 5. Projection of the industry contribution towards the gross district domestic products (GDDP) for ten least poverty-stricken districts under "pessimistic" scenario by 2030

Sectors name	Kushtia	Narail	Meherpur	Bogra	Naogaon	Noakhali	Chittagong	Rangamati	Dhaka	Manikganj
Paddy rice	-0.45	-0.35	-0.16	-0.60	-0.71	-0.33	-0.20	-0.10	-0.02	-0.43
Wheat	-0.05	-0.03	-0.18	0.00	-0.03	0.00	0.00	0.00	0.00	-0.01
Cereal grains	-0.01	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01
Vegetables, fruits, nuts	0.00	0.01	0.05	0.00	0.00	0.00	0.00	-0.01	0.00	0.00
Oil seeds	-0.01	-0.05	-0.06	-0.02	-0.03	0.00	0.00	-0.01	-0.01	-0.12
Sugar cane	-0.07	-0.03	-0.04	-0.01	-0.02	0.00	0.00	0.00	0.00	-0.05
Plant-based fibres	-0.64	0.18	0.64	-0.25	-0.14	0.00	0.00	-0.07	-0.02	-0.25
Other Crops	-0.29	-0.30	-0.21	-0.04	-0.03	-0.05	-0.05	-0.07	0.00	-0.28
Cattle, sheep, goats	-0.05	0.03	0.05	-0.02	-0.02	0.00	-0.01	-0.01	0.00	-0.04
Other Animal Products	-0.01	-0.01	-0.01	-0.02	-0.02	-0.03	-0.01	-0.01	0.00	-0.01
Raw milk	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wool, silk-worm cocoons	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forestry	0.00	0.00	0.00	0.00	0.00	-0.07	-0.08	-1.06	0.00	0.00
Fishing	-0.02	-0.01	-0.01	-0.06	-0.09	-0.17	-0.02	-0.02	0.00	-0.11
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00
Manufacturing	-0.70	-0.24	-0.15	-0.43	-0.39	-0.17	-0.31	-0.22	-0.52	-0.31
Services	-1.44	-1.40	-1.36	-1.56	-1.47	-1.66	-1.78	-1.08	-1.95	-1.56

% change from the base year

However, when we consider the average income loss of the poor population due to climate change within poverty-stricken and least poverty-stricken districts, it is more likely that the average percentage change of income loss[15] for former districts is likely to be greater compared to the latter districts under both "pessimistic" and "medium" scenarios. Because the pattern of growth losses for both types of districts are not likely to be changing significantly by 2030, the poor population in the former districts might face more average income loss compared to the poor population in the latter districts. If the effect of climate change becomes worse ("pessimistic"), then the percentage change of average income loss of the poor population in the ten poverty-stricken districts is likely to be 0.81% by 2030. In making this observation, however, the loss is projected to be relatively lower (0.14%) for those ten least poverty-stricken districts. Similarly, under the "medium" climate scenario the income loss for poverty-stricken districts is 0.25%. However, the average income losses for the ten least poverty-stricken districts are 0.04% which is near to zero. Our results support previous findings (Hertel et al., 2010) that climate change affects Bangladesh more negatively because of its larger poor population. Figure 3 depicts the percentage change of average income loss due to climate change by 2030 for 20 selected districts of Bangladesh. It is projected that all those poverty-stricken districts will experience greater income loss due to a "pessimistic" and "medium" crop productivity loss scenario compared to the least poverty-stricken districts. Further, districts like Barisal and Kurigram might experience maximum income loss due to the near future climatic shocks; however, districts such as Kushtia and Meherpur might expect relatively minimal income loss by 2030.

[15] The average percentage change of income loss for poor population in district is $A = Y^{l} * X^{l} 100$, if the percentage of poor population of district $'A' = X^{l}\ \%$ and the simulated percentage change loss of $GDDP = Y^{l}\%$, (Assumption: any income gain or loss after simulation is equally distributed within that district).

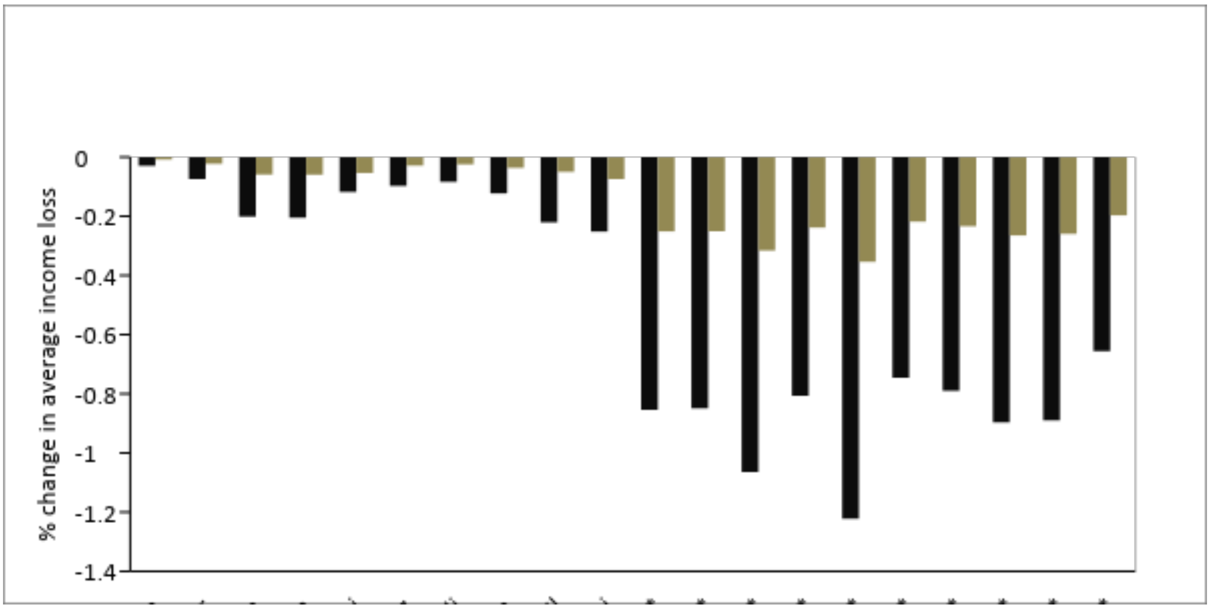

Figure3. Comparison of average income loss of poor population between poverty-stricken and least poverty-stricken districts in Bangladesh under the "pessimistic" and "medium" scenario by 2030.

5. Conclusion and Policy Implications

This study aimed to identify the near future economic impacts of climate change for the 64 districts in Bangladesh by developing a "top-down" multi-regional CGE model. Overall, our results indicate that significant negative impacts will occur on the national macroeconomic variables in Bangladesh through lowering the country's real GDP, average real wages, and real household consumption if the climate conditions become moderate to worse. Even if all 20 selected districts are likely to be negatively affected by the national agriculture loss due to climate change, the extent of loss might differ from one district to other. According to Akter and Basher (2014), it is essential to consider the interregional growth disparities and poverty dynamics of Bangladesh to propose the national-level strategies to combat external shocks. According to our general equilibrium model results, although climate change is responsible for reducing economic growth at the national and district-level, the growth disparity is not likely to be very significant among 64 districts of Bangladesh by 2030 compared to the base year 2007. The main reason is the balanced growth losses between poverty-stricken and least poverty-stricken districts by 2030. Since the majority of the poverty-stricken and some least poverty-stricken districts are agriculture intensive, it can be expected that a part of the growth contractions are likely to be driven by the direct agriculture sector loss. Moreover, the growth loss is likely to be even higher for least poverty-stricken districts where the manufacturing sector contribution is higher than the factor cost GDP in the base year for that district. Therefore, all 64 districts are likely to be affected according to that district's contributions from agriculture, manufacturing and service sectors towards their base year GDP. However, it is more likely that the average income loss of poor population will be greater for those in poverty-stricken districts than those in least poverty-stricken districts under the "pessimistic" and "medium" scenarios. Though, the percentage change of average income loss of the poor population under the "medium" and "pessimistic" climate conditions is not alarming, it might have substantial impacts on the district-level poverty in a developing country such as Bangladesh. These findings will also support the fact that climate change might accentuate the existing food insecurity problem in the near future within Bangladesh (Yu et al., 2010). Therefore, the results of this study will not only guide the policy makers of Bangladesh but they will also assist other South Asian countries in formulating and analysing the impacts of national and district-level policies towards climate change adaptation for 2030.

As agriculture is the central sector in most of the "backwards" districts in Bangladesh and forms the key livelihood for the majority of the population, this study will provide the projections of how the macroeconomic conditions of Bangladesh will be affected due to agricultural loss by 2030. There are many policy implications of this study. First the study results suggest that policymakers in Bangladesh should design a district specific adaptation program so that districts can adapt to the near future impacts of climate change. Secondly, poor populations in relatively more vulnerable districts require necessary financial or skilful assistance from not only the central organisation but also the non-governmental organisations (NGOs). Finally, results support the need for regional policy analysts and policy makers to devote special attention to specific districts that have already started facing the seasonal food insecurity problem (e.g., Northern Kurigram district, which is more vulnerable to seasonal food insecurity compared to other regions; see Ahamad et al., 2013). These policy implications would also support the Bangladesh government in designing district-specific programs targeting reduction in poverty and regional disparities in the face of the future climate change threat. To conclude, future research is recommended to address the limitations of this study as this study has not incorporated the inter-district trade data due to the unavailability of district-level trading data and input-output tables at district-level. Therefore, detailed district-level trade transaction data are required to develop comprehensive district-level CGE models with inter-district trade data.

References

ADB., 2014. Assessing the Costs of Climate Change and Adaptation in South Asia. Asian Development Bank, Metro Manila, Philippines.

Ahamad, Mazbahul Golam; Rezai Karim Khondker; Zahir Uddin Ahmed; and Fahian Tanin. 2013. "Seasonal food insecurity in Bangladesh: Evidences from northern areas". *Mitigation and Adaptation Strategies for Global Change* 18, no. 7: 1077-1088.

Ahmed, A. Syud; Noah S. Diffenbaugh; Thomas W. Hertel. 2009. "Climate volatility deepens poverty vulnerability in developing countries". *Environmental Research Letters* 4, no. 3: 034004.

Akter, Sonia, and Syed Abul Basher. 2014. "The impacts of food price and income shocks on household food security and economic well-being: Evidence from rural Bangladesh". *Global Environmental Change* 25: 150-162.

Ali, Abu Muhammad Shajaat. 2006. "Rice to shrimp: Land use/land cover changes and soil degradation in Southwestern Bangladesh". *Land Use Policy* 23, no. 4: 421-435.

Amin, Shohel Reza, and Umma Tamima. 2008. "Regional divergence of income and allocation of public facilities in Bangladesh". *Bangladesh Research Publications Journal* 1, no.1: 22-37.

Bandara, S. Jayatilleke; 1991. "Computable general equilibrium models for development policy analysis in LDCs". *Journal of Economic Surveys* 5, no. 1: 3-69.

Bandara, S. Jayatilleke, and Yiyong Cai. 2014. "The impact of climate change on food crop productivity, food prices and food security in South Asia". *Economic Analysis and Policy* 44, no. 4: 451-465.

Banerjee, Onil; Mahzab, Moogdho Mahzab; Selim Raihan; and Naibul Islam. 2015. "An Economy-wide analysis of climate change impacts on agriculture and food security in Bangladesh". *Climate Change Economics* 6, no 1: 17, 1550003.

Bangladesh Bureau of Statistics (BBS). 2013. "Statistical Yearbook of Bangladesh". Statistics and Informatics Division, Dhaka, Bangladesh. Available at http://www.bbs.gov.bd/.

Bangladesh Bureau of Statistics (BBS). 2015. "Seventh Five Year Plan", Planning Commission, Bangladesh. Available at http://www.plancomm.gov.bd/7th-five-year-plan/

Bangladesh Bureau of Statistics (BBS). 2016. "Yearbook of Agricultural Statistics-2015". Statistics and Informatics Division, Bangladesh. Available at http://www.bbs.gov.bd/

Butt, Shoaib Muhammad, and Jayatilleke S. Bandara. 2009. "Trade Liberalisation and Regional Disparity in Pakistan", Routledge, Madison Ave, NY.

Cai, Yiyong; Jayatilleke S. Bandara; and David Newth. 2016. "A framework for integrated assessment of food production economics in South Asia under climate change". *Environmental Modelling & Software* 75, 459-497.

Chalise, Sudarshan; Athula Naranpanawa; Jayatilleke S. Bandara; and Tapan Sarker. 2017. "A general equilibrium assessment of climate change–induced loss of agricultural productivity in Nepal". *Economic Modelling*, 62, 43-50.

Chen, Chi-Chung; Bruce McCarl, and Ching-Cheng Chang. 2012. "Climate change, sea level rise and rice: global market implications". *Climatic Change* 110, nos. 3-4: 543-560.

Cline, William. R. 2007. "Global warming and agriculture: Impact estimates by country". Centre for global development, Peterson Institute for International Economics, Washington, DC, USA.

Dixon, Peter B.; B. R. Parmenter; John Sutton; and D. P. Vincent. 1982. "ORANI: A Multisectoral Model of the Australian Economy". North-Holland Publishing Company, Amsterdam, NY.

Dixon, B. Peter; Maureen T. Rimmer, and Marinos E. Tsigas. 2007. "Regionalising results from a detailed CGE model: Macro, industry and state effects in the US of removing major tariffs and quotas". *Papers in Regional Science* 86, no 1: 31-55.

Harrison, W.; Ken Pearson. 1998. "Documentation of the GEMPACK software system". Centre of Policy Studies and Impact Project. Victoria University, Melbourne, available at http://www.copsmodels.com/gpnews.htm.

Hertel, Thomas. W.; Marshall B. Burke, and David B. Lobell. 2010. "The poverty implications of climate-induced crop yield change by 2030". *Global Environmental Change* 20, 577-585.

International Food Policy Research Institute (IFPRI). 2013. "Agriculture and adaptation in Bangladesh: Current and projected impacts of climate change". Accessed July 2013, available at http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/127767.

Iglesias, Ana; Luis Garrote; Soina Quiroga; and Marta Moneo. 2012. "A regional comparison of the effects of climate change on agricultural crops in Europe". *Climatic Change* 112, no. 1: 29-46.

Intergovernmental Panel on Climate Change (IPCC). 2000. "Emissions Scenarios". Retrieved from http://www.ipcc.ch/search/searchspecialreports.shtml

Intergovernmental Panel on Climate Change (IPCC). 2014. "Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability". Cambridge University Press, Cambridge, UK and NY, USA, pp. 1-32.

Iqbal, Kazi, and Abu Siddique. 2014. "The Impact of Climate Change on Agricultural Productivity: Evidence from Panel Data of Bangladesh". Discussion Paper 14.29, available at http://www.business.uwa.edu.au

Khondker, Bazlul Haque, and Moogdho Mim Mahzab. 2015. "Lagging Districts Development. Background Study Paper for Preparation of the Seventh Five-Year Plan, Bangladesh". Available at http://catalog.ihsn.org/index.php/citations/41877.

Knox, Jerry; Tim Hess; Andre Daccache; and Tim Wheeler. 2012. "Climate change impacts on crop productivity in Africa and South Asia". *Environmental Research Letters* 7, 034032.

Knox, Jerry W.; T.M. Hess; A. Daccache; and M. Perez Ortala. 2011. "What are the projected impacts of climate change on food crop productivity in Africa and South Asia?" Systematic Review Final Report, Department of International Development, Cranfield University, UK, pp. 77.

Kobayashi, Shintaro, and Jun Furuya. 2011. "Comparison of Climate Change Impacts on Food Security of Bangladesh". *Studies in Regional Science* 41, no. 2: 419-433.

Leichenko, Robin, and Julie A. Silva. 2014. "Climate change and poverty: vulnerability, impacts, and alleviation strategies". Wiley Interdisciplinary Reviews: *Climate Change* 5, 539-556.

Leontief, Wassily; Alison Morgan; Karen Polenske; David Simpson; and Edward Tower. 1965. “The economic impact--industrial and regional--of an arms cut”. *The Review of Economics and Statistics* 47, no. 3, 217-241.

Ministry of Environment and Forest (MOEF), 2005. “National Adaptation Programme of Action”. Final report prepared with the Joint initiative by MOEF and UNFCC. Available at http://unfccc.int/national_reports/napa/items/2719.php.

Naranpanawa, Athula, and Rashmi Arora. 2014. “Does trade liberalization promote regional disparities? Evidence from a multiregional CGE Model of India”. *World development* 64, 339-349.

Narayanan, Badri G.; Terrie L. Walmsley; Editors. 2008. “Global Trade, Assistance, and Production: The GTAP 7 Data Base”, Centre of Global Trade Analysis, Purdue University, available at http://www.gtap.agecon.purdue.edu/databases/v7/v7_doco.asp.

Rahman, Sanzidur. 2007. “Regional productivity and convergence in Bangladesh agriculture”. *The Journal of Developing Areas* 41, no. 1: 221-236.

Rahman, Sanzidur, and Ruhul Salim. 2013. “Six decades of total factor productivity change and sources of growth in Bangladesh agriculture (1948–2008)”. *Journal of Agricultural Economics* 64, no. 2: 275-294. doi: 10.1111/1477-9552.12009.

Rahman, Sanzidur, and Mohammad Mizanul Haque Kazal. 2015. “Determinants of crop diversity in the regions of Bangladesh (1990–2008)”. *Singapore Journal of Tropical Geography* 36, no. 1: 83-97.

Rajib, Mohammad Adnan; Md. Mujibur Rahman; and Edward A. McBean. 2011. “Global warming in Bangladesh perspective: Temperature projections up to 2100”. In Paper presented at the proceedings of the Global Conference on Global Warming, Lisbon, Portugal, July 11-14.

Robinson, Sherman; Hans van Meijl; Dirk Willenbockel; Hugo Valin; Shinichiro Fujimori; Toshihiko Masui; Ron Sands; Marshall Wise; Katherine Calvin; Petr Havlik; Daniel Mason d’Croz; Andrzej Tabeau; Aikaterini Kavallari; Christoph Schmitz; Jan Philipp Dietrich; and Martin von Lampe. 2014. “Comparing supply-side specifications in models of global agriculture and the food system”. *Agricultural Economics* 45, no. 1: 21-35.

Ruane, Alex C.; David C. Major; Winston H. Yu; Mozaharul Alam; Sk. Ghulam Hussain; Abu Saleh Khan; Ahmadul Hassan; Bhuiya Md. Tamim; Al Hossain; Richard Goldberg; Radley M. Horton; and Cynthia Rosenzweig. 2013. "Multi-factor impact analysis of agricultural production in Bangladesh with climate change". *Global Environmental Change* 23, no.1: 338-350.

Sarker, Abdur Rashid Md.; Khorshed Alam; and Jeff Gow. 2012. "Exploring the relationship between climate change and rice yield in Bangladesh: An analysis of time series data". *Agricultural Systems* 112, 11-16.

Shahid, Shamsuddin; Xiao-Jun Wang; Sobri Bin Harun; Supiah Binti Shamsudin; and Tarmizi Ismail. 2016. "Climate variability and changes in the major cities of Bangladesh: Observations, possible impacts and adaptation". *Regional Environmental Change* 16, no. 2: 459-471. Skoufias, Emmanuel; Mariano Rabassa; and Sergio Olivieri. 2011. "The poverty impacts of climate change: A review of the evidence". Policy Research Working Paper Series, no. WPS 5622. Washington, DC: World Bank. Accessed April 2011, available at http://documents.worldbank.org/curated/en/2011/04/14004825/poverty-impacts-climate-change-review-evidence-poverty-impacts-climate-change-review-evidence.

Thurlow, James; Paul Dorosh; and Winston Yu. 2012. "A stochastic simulation approach to estimating the economic impacts of climate change in Bangladesh". *Review of Development Economics* 16, no. 3: 412-428.

United Nations development Programme (UNDP). 2009. "Policy study on the probable impacts of climate change on poverty and economic growth and the options of coping with adverse effect of climate change in Bangladesh". A joint project by General Economics Division, Bangladesh Planning Commission, BBS and UNDP, Bangladesh.

United Nations World Food Programme (UNWFP). 2009. "Updating Poverty Maps of Bangladesh". Accessed February 2009, available at https://www.wfp.org/content/updating-poverty-maps-bangladesh,
http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/LatestReports/Bangladesh_ZilaUpazila_pov_est_2010.pdf.

World Bank. 2011. "Bangladesh- Household income and expenditure survey: key findings and results 2010". Washington, D.C: World Bank. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/16622/785590NWP0Bang00

Box0377348B0PUBLIC0.pdf?sequence=1,
http://documents.worldbank.org/curated/en/2011/06/16494498/bangladesh-household-income-expenditure-survey-key-findings-results-2010,

World Bank, 2014. "Demographical Data for Bangladesh". Available at http://data.worldbank.org/country/bangladesh.

Wheeler, Tim, and Joachim von Braun. 2013. "Climate change impacts on global food security". *Science* 34, no. 6145: 508-513.

Yu, Winston H.; Mozaharul Alam; Ahmadul Hassan; Abu Saleh Khan; Alex C. Ruane; Cynthia Rosenzweig; David C. Major; and James Thurlow. 2010. "Climate Change Risks and Food Security in Bangladesh". Earthscan, London, UK.

Appendices

Appendix A: Economic indicators of regional disparity for 20 districts in Bangladesh

Districts name	Per capita Gross Domestic Products(tk[16])	Per capita Monthly Consumption expenditure(tk)	Intensity of Cropping (Gross Cropped area/Net cropped area)*100 (%)	Population engaged in agriculture (%)	Extreme poor population (%) (lower poverty line)
Kushtia	35036	3643.749	200.49	19	0.8
Noakhali	29565	3946.559	164.35	15.4	3.4
Chittagong	55281	3681.251	163.39	6.2	4
Dhaka	66548	3584.024	138.16	2.3	4.9
Meherpur	36414	2859.55	164.5	26.5	5.1
Bogra	34396	2284.358	217.12	20.2	6.7
Rangamati	36934	2748.746	159.49	36.9	6.8
Naogaon	36223	2475.49	179.38	29.2	7
Narail	37911	2349.041	170.81	32.8	7.7
Manikganj	35347	2370.655	170.67	19.6	8
Kurigram*	35107	1630.714	196.86	27.3	44.3
Barisal*	37934	1993.92	171.04	24.4	39.9
Shariatpur*	30277	2077.256	154.65	19.7	34.4
Jamalpur*	32922	1674.713	190	36.1	34.2
Mymensingh*	32629	2214.928	182.67	22.4	32.3
Pirojpur*	33453	2048.377	143.09	16.7	30.9
Gaibandha*	29090	1853.592	188.63	25.5	30.3
Chandpur*	31998	1970.103	166.5	22.7	30.3
Rangpur*	32222	2420.708	207.25	22.1	30.1
Satkhira*	37083	2014.214	150.64	30.4	29.7

Source: (BBS, 2015) and (Khondker & Mahzab, 2015)

[16] Taka (tk) is Bangladesh currency. 1 Bangladeshi tk = 0.012 US dollar.

Appendix B: National-level industry valued added loss due to different climate scenario by 2030

Sectors	"Pessimistic"	"Medium"	"Optimistic"
Paddy rice	-4.16	-1.17	1.45
Wheat	-14.88	-4.61	6.40
Other Cereal grains	-13.80	-8.62	-2.78
Vegetables, fruits, nuts	0.01	-0.00	0.00
Oil seeds	-9.96	-3.13	4.39
Sugar cane	-4.61	-1.32	1.67
Plant-based fibres	-7.48	-2.40	3.43
Other Crops	-5.80	-1.76	2.38
Cattle, sheep, goats	-1.44	-0.40	0.47
Other Animal Products	-2.85	-0.86	1.02
Raw milk	-1.35	-0.37	0.44
Wool, silk-worm cocoons	16.93	5.00	-6.14
Forestry	-2.37	-0.71	0.92
Fishing	-2.68	-0.77	0.97
Mining	-0.08	0.00	-0.02
Manufacturing	-4.97	-1.48	1.81
Services	-2.22	-0.67	0.87

% change from the base year

Appendix C: Impacts on Gross District Domestic Products (GDDP at factor cost) for 64 districts by 2030

Districts Name	"Pessimistic"	"Medium"	"Optimistic"
Bagerhat	-2.60	-0.77	0.99
Chuadanga	-2.58	-0.80	0.94
Jessore	-3.04	-0.89	1.16
Jhenaidah	-2.79	-0.83	1.06
Khulna	-2.40	-0.71	0.92
Kushtia	-3.68	-1.09	1.41
Magura	-2.70	-0.80	1.05
Meherpur	-1.46	-0.44	0.59
Narail	-2.19	-0.65	0.86
Satkhira	-2.88	-0.85	1.09
Bogra	-3.00	-0.88	1.13
Joypurhat	-2.65	-0.78	1.00
Naogaon	-2.93	-0.85	1.08
Natore	-3.17	-0.94	1.22
Chapai Nawabganj	-2.74	-0.80	1.03
Pabna	-3.53	-1.05	1.36
Rajshahi	-2.84	-0.84	1.09
Sirajganj	-3.77	-1.11	1.43
Dinajpur	-2.53	-0.75	0.93
Gaibandha	-2.80	-0.83	1.06
Kurigram	-2.40	-0.71	0.93
Lalmonirhat	-2.50	-0.75	0.93

Nilphamari	-2.34	-0.69	0.88
Panchagarh	-1.58	-0.46	0.58
Rangpur	-2.68	-0.79	1.01
Thakurgaon	-3.00	-0.90	1.14
Habiganj	-2.58	-0.75	0.97
Maulvibazar	-2.72	-0.79	1.01
Sunamganj	-1.73	-0.50	0.63
Sylhet	-2.22	-0.65	0.84
Barguna	-1.73	-0.51	0.66
Barisal	-3.06	-0.89	1.13
Bhola	-1.21	-0.37	0.50
Jhalokati	-2.20	-0.65	0.83
Patuakhali	-1.15	-0.35	0.48
Pirojpur	-2.42	-0.71	0.91
Bandarban	-2.78	-0.83	1.08
Brahmanbaria	-2.74	-0.81	1.04
Chandpur	-2.61	-0.77	1.00
Chittagong	-2.44	-0.72	0.93
Comilla	-2.01	-0.60	0.77
Cox's bazar	-2.38	-0.71	0.92
Feni	-2.61	-0.77	0.99
Khagrachari	-2.45	-0.72	0.94
Laxmipur	-2.71	-0.79	1.02
Noakhali	-2.46	-0.72	0.93
Rangamati	-2.65	-0.79	1.03
Dhaka	-2.50	-0.74	0.97

Faridpur	-2.79	-0.83	1.10
Gazipur	-2.86	-0.84	1.08
Gopalganj	-2.27	-0.67	0.88
Jamalpur	-2.62	-0.77	1.00
Kishorganj	-3.06	-0.90	1.15
Madaridpur	-2.11	-0.63	0.84
Manikganj	-3.15	-0.93	1.20
Munshiganj	-4.80	-1.38	1.75
Mymensingh	-2.75	-0.80	1.03
Narayanganj	-2.89	-0.85	1.10
Narsingdi	-2.86	-0.84	1.09
Netrokona	-2.40	-0.70	0.89
Rajbari	-2.25	-0.68	0.90
Shariatpur	-1.91	-0.57	0.76
Sherpur	-2.40	-0.70	0.90
Tangail	-3.33	-0.98	1.26
Average loss	**-2.60%**	**-0.77%**	**0.99%**

% change from the base year

Appendix D1: Industry-level value added loss for ten least poverty-stricken districts under "pessimistic" scenario

Sectors name	Kushtia	Narail	Meherpur	Bogra	Naogaon	Noakhali	Chittagong	Rangamati	Dhaka	Manikganj
Paddy rice	-6.69	-3.17	-2.03	-5.65	-4.65	-3.84	-6.66	-6.93	-7.41	-5.61
Wheat	-14.56	-13.95	-15.08	-14.29	-14.30	-13.85	-14.35	-14.39	-14.47	-14.32
Other cereal Grains	-14.36	-13.20	-12.73	-14.38	-14.40	-14.61	-14.80	-14.73	-13.93	-14.02
Vegetables, fruits, nuts	-0.31	0.95	1.16	-0.10	0.14	0.00	-0.29	-0.41	-0.52	-0.09
Oil seeds	-10.84	-9.29	-8.03	-10.54	-10.31	-10.31	-10.86	-10.72	-10.95	-8.58
Sugar cane	-5.27	-4.67	-3.60	-5.76	-5.37	-5.80	-5.78	-5.73	-5.88	-4.93
Plant-based fibres	-11.73	1.68	5.27	-16.84	-19.25	-22.68	-22.67	-19.87	-22.45	-13.94
Other Crops	-6.25	-4.99	-4.81	-6.43	-6.24	-5.98	-6.41	-6.38	-7.92	-5.99
Cattle, sheep, goats	-3.06	3.84	2.40	-1.84	-1.06	-0.16	-2.30	-3.09	-3.91	-2.20
Other Animal Products	-3.40	-1.47	-1.21	-3.17	-2.82	-3.02	-3.25	-3.44	-2.51	-3.09
Raw milk	-0.12	7.77	7.87	0.98	3.10	3.22	-2.05	-0.30	-2.30	1.01
Wool, silk-worm cocoons	-9.58	-20.99	-17.53	-23.44	-28.25	-28.01	-29.36	1.62	-30.19	-27.83
Forestry	-2.34	-2.04	-1.95	-2.22	-2.20	-2.03	-2.31	-2.59	-2.31	-2.14
Fishing	-3.74	-1.40	-0.93	-3.00	-2.54	-2.67	-3.34	-3.51	-4.11	-2.88

Appendix D2: Industry-level value added loss for ten poverty-stricken districts under "pessimistic" scenario

Sectors name	Mymensingh	Jamalpur	Shariatpur	Barisal	Pirojpur	Chandpur	Gaibandha	Kurigram	Rangpur	Satkhira
Paddy rice	-4.27	-3.37	-4.02	-4.98	-3.90	-5.13	-4.94	-3.61	-4.94	-5.93
Wheat	-14.03	-13.50	-13.96	-14.20	-13.93	-14.06	-14.11	-14.43	-14.20	-14.26
Other cereal Grains	-14.42	-14.35	-13.92	-14.39	-14.39	-14.72	-14.34	-13.95	-14.15	-14.94
Vegetables, fruits, nuts	0.10	0.17	0.49	0.11	0.09	-0.18	-0.08	0.26	-0.06	-0.24
Oil seeds	-10.45	-9.12	-9.31	-10.65	-10.39	-10.36	-10.48	-9.88	-10.61	-10.61
Sugar cane	-5.27	-4.26	-5.15	-5.70	-5.64	-5.54	-4.94	-5.63	-5.28	-5.67
Plant-based fibres	-17.55	-8.52	2.36	-19.85	-22.73	-15.72	-13.14	-3.09	-15.18	-15.99
Other Crops	-6.32	-5.78	-5.43	-5.78	-6.07	-6.34	-6.62	-5.89	-6.18	-6.72
Cattle, sheep, goats	-1.61	-0.77	1.75	-0.25	-0.80	-1.84	-2.16	-1.13	-2.09	-2.75
Other Animal Products	-2.85	-2.81	-2.29	-2.78	-2.85	-3.31	-3.14	-2.60	-3.10	-3.40
Raw milk	3.68	3.82	6.86	2.81	3.76	1.06	2.28	4.93	0.40	0.15
Wool, silk-worm cocoons	-26.06	-25.75	-20.51	-29.01	-27.89	-28.05	-19.78	-23.76	-27.34	-28.37
Forestry	-2.09	-2.05	-1.89	-2.23	-2.15	-2.15	-2.19	-2.06	-2.12	-2.31
Fishing	-2.55	-2.53	-2.01	-2.46	-2.62	-3.00	-3.12	-2.37	-2.89	-3.14

% change from the base year