



Effects of Climate Change on Economic Growth: An Engineering Aspect

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ABSTRACT

Climate change is one of the greatest environmental challenges facing the world today. It is recognized that climate change and its associated extreme events will have a wide range of effects on the environment and socio-economic sectors. Recent experiences of the nation have shown that Bangladesh is vulnerable to climate change. This study has attempted to investigate the effects of climate change on economic growth over a period 1980 to 2022 for this study. The empirical findings show that climate change with a proxy variable of temperature has a significant and negative impact on economic growth proxies by real GDP. Conversely, climate change with a proxy variable of rain fall has a significant and positive impact on economic growth on average. Along with these proxy variables other explanatory variables incorporated in the model such as population and human capital having negative-significant and positive-significant impacts on economic growth respectively. Thus, in order to solve the severe impact of climate change with an increase in temperature, climate-related programs (mitigation and adaptation) and policies which reduce the emission of greenhouse gases via using alternative energy sources should be implemented.

Keywords: *Climate Change, Economic Growth, Engineering Aspect, Greenhouse effect*

INTRODUCTION

In the economic history of the 20th century, environmental issues gradually become more prominent. During the Great Depression of the 1930s soil erosion drew attention, and in the 1950s and 1960s concerns about pesticide use and air pollution emerged. Only in the last decades of the 20th century, however, did environmental degradation gain recognition as fundamental challenge to the whole economic growth process. In the global economy of the 21st century, on the other hand climate-related considerations will be a determining factor in shaping economic development (Stern, 2006).

According to the Stern review (2006), the scientific evidence is now overwhelming and declaring that climate change is a serious global threat and demands an urgent global response. It will affect the basic elements of life for people around the world: access to water, food production, health and the environment. Consequently, hundreds of millions of people could suffer hunger, water shortages and coastal flooding as the world warms.

Climate change presents a unique challenge for economics: it causes the greatest and widest ranging market failure ever seen. The economic analysis must therefore be global, deal with long-time horizons, have the economics of risk and uncertainty at centre stage and examine the possibility of major, non-marginal change. Using the results from formal economic models, the review estimates that if we do not act, the overall costs and risks of climate change will be equivalent to losing 5% of global GDP each year, now and forever. Conversely, the costs of action-reducing greenhouse gas (GHG) emissions to avoid the worst impacts of climate change - can be limited to around 1% of global GDP each year. This indicates that there is still time to avoid the worst impacts of climate change and, so prompt as well as strong action is clearly warranted. It must be based on shared vision of long-term goal and agreements on frameworks that will accelerate action should be on the basis of mutually reinforcing approaches at regional, national, and international level.

Climate change is one of the main problems affecting the global environment that is critical to human welfare. Climate change refers to a long-run increase in average surface temperature which goes under the name "global warming" or sometimes the "greenhouse effect". It is caused by increases in greenhouse gases such as carbon dioxide (CO²), methane (CH₄), and nitrous oxide (N₂O), plus three fluorinated industrial gases: hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulphur hexafluoride (SF₆). Under normal (i.e., pre-industrial) conditions, greenhouse gases in the earth's atmosphere serve to raise the temperature of the earth's surface making it habitable. With no greenhouse gases at all, the surface of the earth would be about 30°C cooler than it is today, making human life impossible. However, an increase in the greenhouse gas content of the earth's atmosphere beyond the global balance leads to an increase in average global temperature.

CLIMATE CHANGE IN BANGLADESH

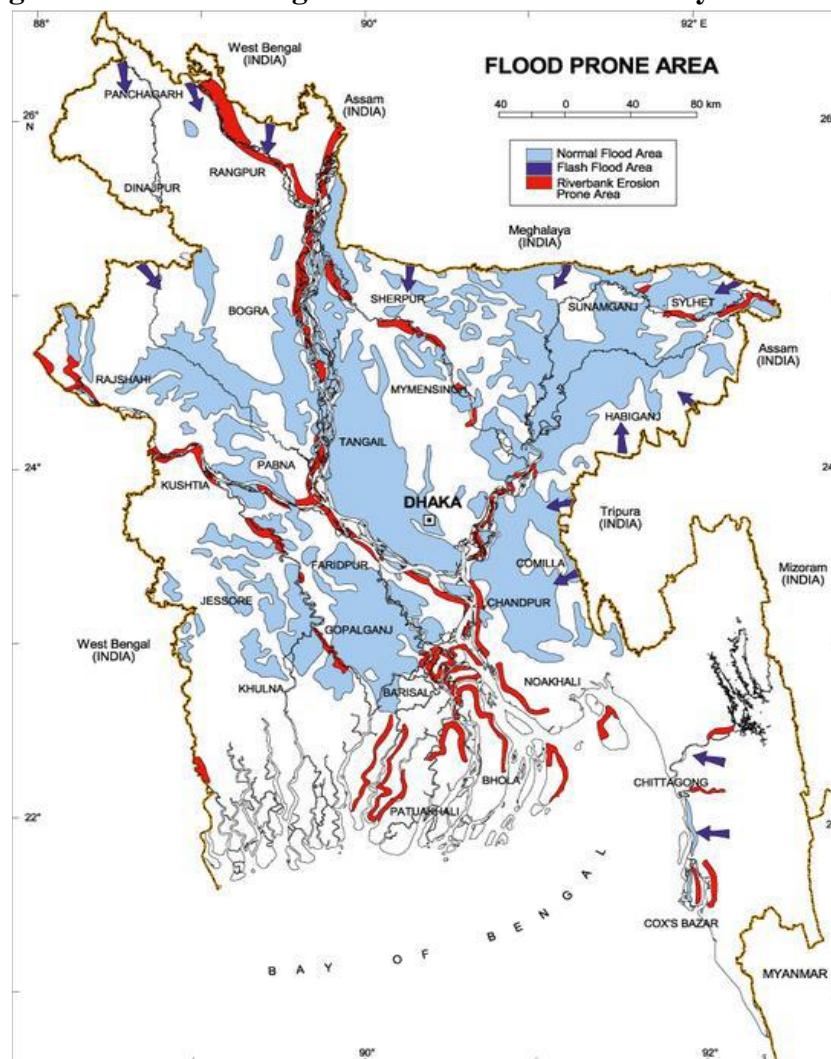
Climate change is recognized as common weather conditions of an area characterized by its own inside dynamics and by altering in exterior factors that concern temperature (Trewartha et al., 1980). United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as the change resulting from long term direct and indirect behavior that induces changes in the compared time which are much more than the natural modify (Daily Star, 2011d). On the other hand, the weather is a set of all the phenomena occurring in a given atmosphere at a given time (IAC, 2011).

Geographically, Bangladesh is situated in the steamy area (FAO, 2011). Natural disaster is a general occurrence and till today Bangladesh is facing numerous disasters, and climate change is the major cause behind it (Daily Star, 2011a). Bangladesh lies on a deltaic plain with five major river systems: the Jamuna-Brahmaputra, the Padma-Ganges, the Surma-Meghna, the Padma-Meghna, and the Karnaphuli. Although altitudes up to 105 m above sea level occur in the northern part of the plain, most elevations are less than 10 m above sea level; elevations decrease in the coastal south, where the terrain is generally at sea level. These geographical features make Bangladesh vulnerable to natural disasters, such as floods and cyclones, and the high levels of poverty increase the enormity of the challenges that the country is likely to face from climate change (ICDDR B, 2011) (Figure 1).

Bangladesh is one of the most densely populated nations on Earth. It has more people than geographically massive Russia (Envoinfo, 2011). Bangladesh ranked fifth most vulnerable country to climate change and hunger in an Action Aid research report. In the World Risk Index 2011, jointly conducted by United Nations University (UNU), Germany and the Institute of Environment and Human Security said that Bangladesh ranked sixth among countries that are most vulnerable to natural disasters, while second among the Asian countries (Daily Star, 2011e). Bangladesh is a very low energy consuming country, and it is pursuing a low carbon growth path, while building its resilience to climate change and reducing the risk of climate change, which shows national development (Daily Star, 2009). Bangladesh is projected to be 0.5 to 0.2°C warmer

than today by the year 2030. The 30 years mean summer temperature in Bangladesh is 27.5°C and the mean summer temperature is relatively higher during the monsoon than during summer. Winter is the driest season in Bangladesh. The 30 years mean winter rainfall amounts to about 64 mm with a variability of around 53%. By 2030, the best estimate projection is for monsoon rainfall to increase by 10 to 15% and winter rainfall by 5 to 10% (Kafiluddin, 2005).

Figure 1: Areas in Bangladesh and their vulnerability to flooding.



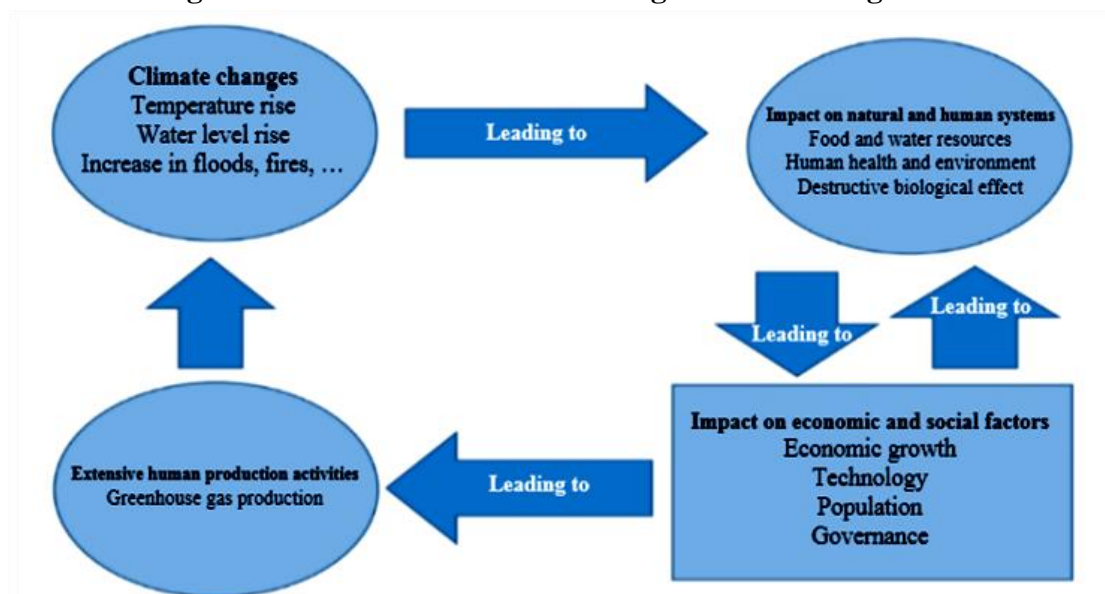
Source: http://www.banglapedia.org/httpdocs/Maps/MF_0103A.GIF

ECONOMIC GROWTH AND CLIMATE CHANGE

Climate change involves long-term shifts in temperature and weather patterns. Whereas natural factors similar to solar cycles can influence climate, since the 1800s, human being activities, mostly the flaming of fossil fuels such as coal, oil, and gas, have become the most important driver of climate change. The impact of climate change on economic growth has been explored through hypothetical and investigational research. There are several suggested channels through which climate change affects the economy. Firstly, climate change disrupts ecosystems through events like floods, droughts, erosion, species extinction, and adverse weather conditions, which can harm economic growth. Secondly, resources are diverted to mitigate the negative consequences of global warming, reducing the resources available for investment in physical infrastructure, research and development, and human capital. From a theoretical standpoint, the link between climate change and economic growth can be established at both micro and macro levels. At the macro level, it affects both production levels (e.g., agricultural output) and the economy's capacity to foster growth and productivity by influencing investment and institutional factors. At the micro level, various factors, including workforce health and productivity, come into play. Nordhaus (1991) introduced a fundamental framework that integrated climate change into the economic system, leading to the development of the Regional Integrated

model of Climate and Economy (RICE). Integrated Assessment Models (IAMs) are employed to evaluate the impact of global climate change by incorporating dynamic descriptions of energy and economic systems, weather systems, and the resulting climate impacts. These models have been widely used to assess climate policies and combine economic activities with simplified weather systems. Linking Earth System Models (ESMs) with socioeconomic frameworks is a challenging but essential task for conducting scientific research on climate change impacts. Some researchers have adopted endogenous growth frameworks to analyze the macroeconomic effects of climate change.

Figure 2: The Effect of climate change on economic growth



Source: Hideg et al. (2022) and Barker (2001)

OBJECTIVES OF THE STUDY

Given the importance of agriculture in Bangladesh, loss of its productivity due to climate change will affect the entire economy- real GDP. The prospect of climate change dictates the way economic activities will be practiced and provides a signal for the adjustment of existing climate change related programs-mitigation and adaptation-and climate change polices at macro level.

The general objective of this research paper is to assess the impact of climate change on the Bangladeshi economic growth at macro level and provide some policy options following the findings for the achievement of societal well-being/ welfare.

The specific objectives of this study include:

1. To quantify the impact of climate variables on economic growth-measured by a country's real gross domestic product.
2. To suggest recommendations which enable to manage or control climate-related impacts on economic growth at country level.

SIGNIFICANCE OF THE STUDY

In addition to its global nature, it is now widely recognized that climate change will have a large scale effect on economic outcomes. As a result, studying the economic impacts of climate change will help the country formulate effective policies, take adequate mitigation and adaptation actions and ensure active participation on global climate change agreements. Specifically, the study on climate change may contribute to the existing perception on the trends and impacts of climate change on economic growth and it will provide some policy recommendations that would help in designing the right policy related to climate change so as to reduce the negative impact of climate variability on Bangladeshi economic growth at national level. The research effort and previous literature on the impact of climate change-economic growth relationship was based on cross country or panel data and specific crop productivity. However, this study follows time series

approach providing some insights about impact of climate change on economic growth when a single country is considered. Thus, this study will be used as a ground for further country specific analysis of climate change-economic growth relationships.

LITERATURE REVIEW

Few natural phenomena have attracted the attention of so many scientific fields or elicited so many hypotheses as have climate changes. The possibility that different causes active at different time scales adds to the challenge. One of the simplest and most persistent holds that the sun is a variable star and that the changes in the kind and amount of energy emitted alter the solar constant. A full understanding of the climate system and explanations of past climates logically lead to prediction of future climates (Critchfield, 2003).

Various statistical probabilities can be calculated for broad applications in long-range planning of human affairs. In view of the impact of climate on human activities, it is logical to inquire whether manipulation of the climate system might produce benefits or disasters for humanity. We have the capacity to manage microclimates for the benefit of ourselves, but we also alter them to the detriment of living things and neighbors. For instance, cutting of forests reduces the amount of rain and alters the process of evapotranspiration and runoff as well as the flow of air. In contrast, irrigation and the creation of windbreaks are representative agricultural practices that influence microclimates (Critchfield, 2003).

Climate, which we live in, affects everyone on earth in one way or another. The changing climate is a challenge for both current and future generations. Thus, reliable climate information is vital in order to make appropriate decisions in all aspects of human involvement. In line with this reality, changes in climate should be given due attention before it is too late for the Earth to recover. Climate change is an alteration in the state of the climate that can be identified by changes in mean and/or the variability of its properties, and that persist for an extended period, typically decades or longer (Lavell et al., 2012). So, anticipating the swings of climate is important for ensuring sustainable and balanced economic growth in these times of increasing pressure on the earth's limited resources.

As the scientific consensus grows that significant climate change, in particular increased temperature and precipitation pattern, is very likely to occur over the last 21st century (Christensen and Hewitson, 2007), economic research has attempted to quantify the possible impacts of climate change on economic growth. Ignoring climate change issue will eventually damage economic growth. The damages from climate change will accelerate as the world gets warmer. Thus, tackling climate change is the pro-growth strategy for the long-term balanced economic growth. The earlier effective action is taken, the less costly it will be. As the same time, taking measures to help people adapt climate change are essential. Likewise, the less mitigation we do now, the greater difficulty of continuing to adapt in the future.

There is no question or it is evident that the continued build up of greenhouse gases will cause the earth to warm (IPCC 2007). However, there is considerable debate about what is the sensible policy response to this problem. Economists, weighing cost and damages, advocate a balanced mitigation and adaptation program that starts slowly and gradually becomes more severe over the century. Scientists and environmentalists, in contrast, advocate more extreme near-term mitigation policies. Which approach is followed will have a large bearing on economic growth. The balanced economic approach to the problem will address climate change with minimal reductions in economic growth.

The more aggressive the near-term mitigation program, however, the greater the risk that climate change will slow long-term economic growth. It should be understood that climate is not a stable unchanging phenomena even when left to natural forces alone. There have been several major glacial or cold periods in

just the last million years. These natural changes have had major impacts on past civilizations causing dramatic adaptations and sometimes wholesale or general migrations. Climate change is not new. Human-induced climate change is simply an added disturbance to this natural variation.

The heart of the debate about climate change comes from a number of warnings from scientists and others that give the impression that human-induced climate change is an immediate threat to society (Stern 2006). Millions of people might be vulnerable to health effects and crop production might fall in the low latitudes, water supplies might decrease, precipitation might fall in arid regions, extreme events will grow exponentially, and between 20-30 percent of species will risk extinction (IPCC 2007; Stern 2006). Even worse, there may be catastrophic events such as the melting of Greenland or Antarctic ice sheets causing severe sea level rise, which would inundate hundreds of millions of people. Proponents or advocates argue that there is no time to waste. Unless greenhouse gases are cut dramatically today, economic growth and well-being may be at risk (Stern, 2006).

Climate change is a real threat to our planet is widely recognized both in the developed and developing countries from social, economic and environmental perspectives. Ever since the wide recognition of the adverse impact of climate changes, there have been a number of related international treaties and conventions in place. Though economic analysis of climate change is comparatively new issue, numerous studies have estimated the impacts of climate change on economic growth-GDP in different regions of the world. In Zambia, for example, 0.4percent loss of growth occurred annually b/n 1977 and 2007 due to climate variability, and the accumulated cost for this period was US\$13.8billion (James et al, 2009).

Though most of such studies are numerical in nature and a bit speculative, they provide a solid baseline for other researches to be carried out in the area. Due to climate change the size and composition of countries' GDP may change. Climate change also affects the long-term growth potential of the country. According to Stern and Others (2006), in the next fifty years world temperature is expected to raise 2-3c°. This increase will have severe consequences on economic development as it will affect water quality, agricultural productivity and human health. It leads to a loss of 5 percent global GDP per annum.

Dell et al (2008) found that due to climate change the growth rate of poor countries would be reduced by 0.6 to 2.9 percentage points. On the other hand according to Fankhauser and Tol (2005), climate change affects capital accumulation and people's propensity to save, which in turn reduces economic growth- real GDP. By using different growth model specifications, it was found that dynamic/indirect effects are relatively larger than that of static/ direct impacts of climate change. As temperature and precipitation are direct inputs in agricultural production, many scholars in the area believe that the largest effects of climate change will be on agriculture. Climate change can affect food systems in various ways, such as imposing direct impact on crop production through changes in rainfall pattern leads to drought or flooding, where as warmer or cooler temperatures will change the length of the growing season. Both of them will have the potential to affect food prices and the economics of supply chain.

Environmental regulations are generally perceived to impose constraints on production, which lead to harmful impacts on economic growth. However, it has been argued that the effects of environmental policy on economic growth vary through the stages of development (Smulders et at, 2011). Such regulations will enhance the prospects for growth when improved quality increases the productivity of inputs. This is because environmental regulation promotes pollution abatement activities, increasing returns to scale and such regulations can also estimate innovations. In line with this reality, Greiner (2004; 2005) has found that an increase in greenhouse gas emissions will negatively affect the aggregate output and the marginal productivity of capital and those higher abatement activities might reduce GHG emissions and lead to higher economic growth. Besides, Tol (2009) has argued that GHG emissions would seriously affect

economic development and called for a higher carbon tax to reduce the emissions at the level where there is no an exaggerated magnitude of economic loss.

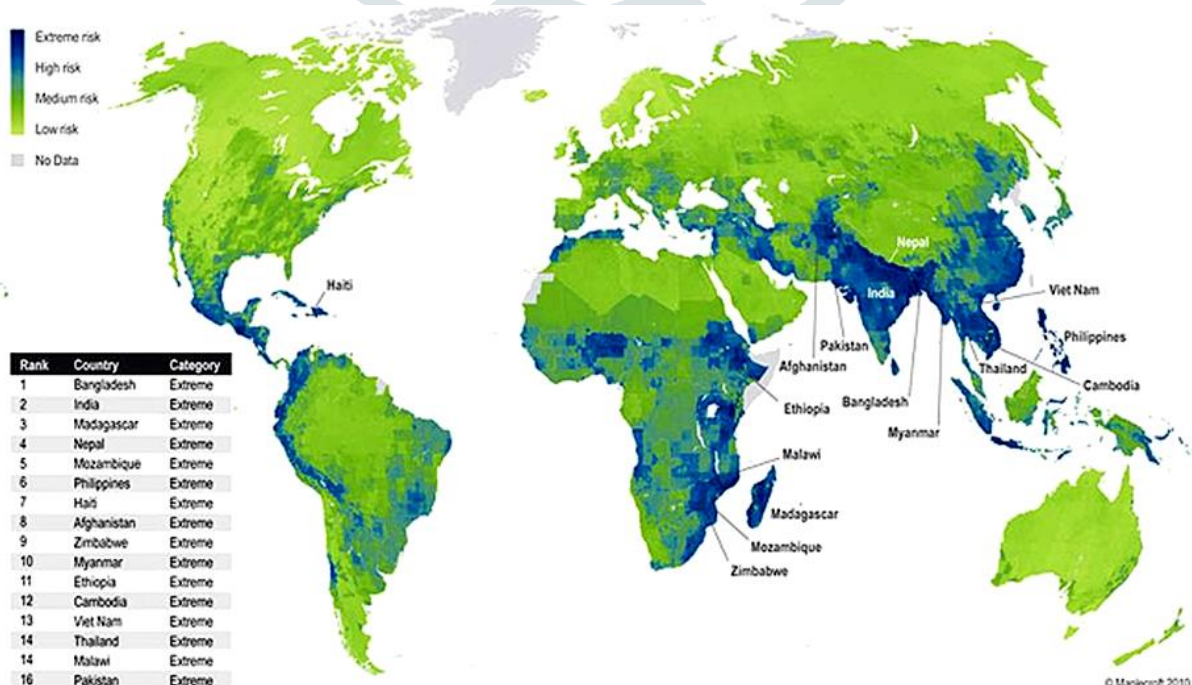
Growth in terms of sustainability refers to increasing or non-decreasing environmental quality and natural resource depletion and continuous growth in per capita income (Brock and Taylor, 2005). Beyond the basic links between economic production and environment, the links between economic growth, environment and climate change are highly complex, multidimensional and dynamic. Simply put, the links are far from straight forward; simple universally valid truths.

In 2010, Maplecroft released a climate change vulnerability index out of 170 countries, 16 countries were identified to be in a condition of extreme risk. The table below provides a list of the vulnerable countries arranged in their respective order of vulnerability to climate change.

Table 1: List of the most vulnerable countries to climate change

SI No.	Country
1	Bangladesh
2	India
3	Madagascar
4	Nepal
5	Mozambique
6	Philippines
7	Haiti
8	Afghanistan
9	Zimbabwe
10	Myanmar
11	Ethiopia
12	Cambodia
13	Vietnam
14	Thailand
15	Malawi
16	Pakistan

Figure 3: World Most Vulnerable Countries in Climate Change



Source: Climate Change Vulnerability Index 2011 Photograph: Maplecroft

That value in the brackets indicates the respective rank of the country to vulnerability. It is worth mentioning here that the variation in climate and geographic features in Bangladesh is among the vulnerable countries to climate change. Such climate change is resulting in the degradation of land, ecosystems, water and air quality. It is further threatening to undermine food security as well as causing health problems and impacting aggregate economic value real GDP.

Concepts and operational definitions that are relevant in climate change issues are the following, which are adapted from the Intergovernmental Panel on Climate Change (IPCC, 2007) and Adaptation Policy Framework (APF, 2005):

- **Weather** - is the instantaneous state of the atmosphere and it is what we experience from day to day.
- **Climate** - refers to the statistical averages of weather elements prevailing over a given place during a long period of time.
- **Climate variability**- is a fluctuation of climatic parameters from the normal or base line values.
- **Climate change** - is a change in the long-term mean value of a particular climatic parameter. It is a persistent long-term change.
- **Vulnerability** - is the degree to which an exposure unit is susceptible to harm or climate change due to lack of ability to cope, recover or fundamentally adapt to it.
- **Resilience**-is the amount of change a system can undergo without changing state.
- **Coping range** - is the range of climate where the outcomes are beneficial or negative but tolerable; thus, beyond this scope the damages or loss are no longer tolerable and the society or system is said to be vulnerable.
- **Climate-related risk**- is the interaction of physically defined hazards with the properties of the exposed system. It can also be considered as the combination of an event, its likelihood, and consequences. Mathematically risk equals the probability of climate hazard multiplied by a given system's vulnerability.
- **Mitigation** - is one of the strategies that countries need to take under the climate change convention. It involves reducing greenhouse gases (GHGs) to meet the objective of the UNFCCC (article 2).
- **Adaptation** - is one of strategies under the convention, which is recognized as a critical response to the impacts of climate change, because current agreements to limit emissions even if implemented will not stabilize atmospheric concentrations of GHGs and climate change. It can reduce present and future losses from climate variability and change. It is neither a one-off intervention nor a stand-alone activity; rather it is a process that needs to be incorporated in the overall development planning, including the design and implementation of projects and programs across the relevant sectors.

INTERNATIONAL RESPONSE TO CLIMATE CHANGE

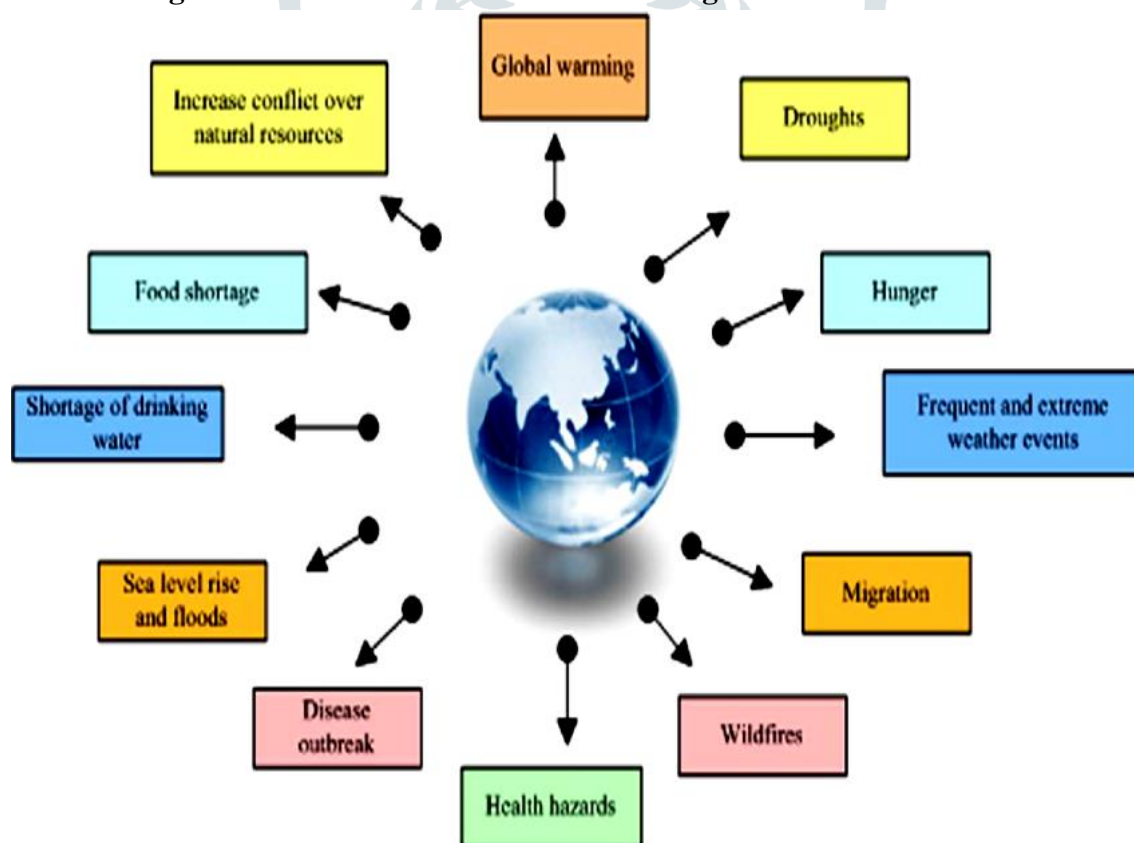
Increasing awareness by international organizations and nation-states of changes in the ecosystems and the destruction of natural resources initiated the attempts to address environmental concerns on a global scale. The 1972 United Nations Conference on Human-Environment resulted in the establishment of the United Nations Environment Programme (UNEP). While the purpose of establishing UNEP was environmental assessment and research and monitoring, it also played a role in placing the link between environment and development on the international agenda. The First World Climate Conference was held on in 1979 in Geneva as one of the first major international meetings on climate change. It focused on climate change in addition to climate research and forecasting (UNFCCC, 2010).

The First World Climate Conference recognized climate change as a serious problem. This scientific conference explored how climate change might affect human activities and issued a declaration calling on the world's governments "to foresee and prevent potential man-made changes in climate that might be adverse to the well-being of humanity". It also endorsed the establishment of the World Climate Programme

(WCP) under the joint responsibility of the World Meteorological Organization (WMO), the UNEP, and the International Council of Scientific Unions (ICSU). A number of international conferences were held in the late 1980s and early 1990s. Together with increasing evidences they helped to raise international concern about the issue of climate change. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the UNEP and the WMO with the mandate to assess the state of existing knowledge about the climate system and climate change. They outlined environmental, economic and social impacts of climate change, and the possible response strategies.

In 1990 the IPCC issued its First Assessment Report, confirming that human-induced climate change was indeed a threat and calling for a global treaty to address the problem. The UN General Assembly responded to these calls in December 1990, formally launching negotiations on a framework convention on climate change by its resolution 45/212. These negotiations were conducted by an Intergovernmental Negotiating Committee (INC), chaired by Jean Ripert (France). Negotiators from 150 countries finalized the convention in 15 months and adopted by consensus the United Nations Framework Convention on Climate Change (UNFCCC) in New York on May 9, 1992. The UNFCCC was signed by 154 states (plus the European Commission, EC) at the UN Conference on Environment and Development (UNCED), otherwise known as the "Earth Summit", held 3–14 June 1992 in Rio de Janeiro. The Earth Summit became the largest ever gathering of Heads of States. Other agreements adopted at Rio were called the Rio Declaration- Biological Diversity and Forest Principles.

Figure 4: Global Effects of Climate Change on the Environment



The UNFCCC is an international environmental treaty and sets an ultimate objective of stabilizing atmospheric concentrations of GHGs at levels that would prevent "dangerous" human interference with the climate system. To achieve this objective, all parties to the convention are subject to an important set of general commitments, which place a fundamental obligation on them to respond to climate change. However, the UNFCCC did not commit states to a specific and binding limitation on GHG emissions because of the sharp disagreements among the big emitters of carbon dioxide, especially the Organization for Economic Cooperation and Development (OECD) countries. Countries with large reserves and a

dependence on oil, such as the United States, resisted the inclusion in the Convention of a timetable and a target for the reduction of CO² emission, which western European countries, with small relative dependence on coal, favored. The Convention, however, established a mechanism for future action to be taken as warranted by scientific evidence.

The conference of parties (COP), held in Kyoto, Japan, on December 1997, adopted the Kyoto Protocol. The Kyoto Protocol is a legally binding agreement under which industrialized countries are committed to reduce their collective emissions of six GHGs by 5.2% from 2008-2012, calculated as average over these five years. It was also agreed that developing country parties would not be required to take on new commitments under these new processes. Agreements on the 5.2% targets and other issues, including the base year, were reached after tense negotiations, each country proposing different indicators as the basis for emission cuts. The only common theme of these indicators was that each proposal suited the interests of the country making the proposal. The complexity of the negotiations, however, meant that considerable "unfinished business" remained even after the Protocol was adopted. At the time of its adoption, the Kyoto Protocol sketched out the basic features of its "mechanisms" and compliance system, but did not develop all important rules on how they would operate.

The Kyoto protocol is praised by some as the first to impose legally binding commitments and emission reduction targets, strongly sought by those who argue that the international community must take immediate steps to stem the rise in global warming (Albert, 2001). However, the negotiations leading to the adoption of the Protocol reflected different interests of those parties with most to gain from their inclusion (Grubb 2003). Developed countries such as the United States and Australia pushed for the inclusion of carbon sinks (e.g., by including forests that absorb CO² from the atmosphere) in the protocol to minimize domestic political difficulties.

The UNFCCC provides for the periodic review of the emission reduction commitments. It was initially suggested in the Kyoto Protocol that negotiations for the post-2012 period would start in 2005. However, the long time it took to have the Protocol ratified meant that this negotiation had to start much later. Post-Kyoto negotiations refer to high level talks attempting to address global warming by limiting greenhouse gas emissions. Generally part of the UNFCCC, these talks concern the period after the first "commitment period" of the Kyoto Protocol.

METHODOLOGY

As the success of any econometric analysis ultimately depends on the availability and accuracy of data, it is paramount to identify about the source and nature of data. The study is conducted using a secondary country level macroeconomic data covering the period from 1980 to 2022. For the study of climate change impact on the economic growth, secondary data with time series pattern is used. The data used in this study is collected from various sources which can be grouped into two main categories as data from government organizations and online data bases.

Accordingly, the first category includes Bangladesh Bank, Bangladesh Bureau of Statistics (BBS), Bangladesh Meteorological Department (BMD) and Ministry of Finance. And the online data sources include United Nations Development Program (UNDP), World Bank (WB) and Organization for Economic Cooperation and Development (OECD).

The complexity of climate-economy relationship is apparent. However, less discussed perhaps critical issue, the ideas or economic philosophy related to development that link productivity to temperature is vital. This paper takes a different approach rather than identifying mechanisms one-by-one and summing-up; it examines the effects of temperature and precipitation on a single aggregate measure of economic growth-

real GDP. This is done by constructing historical temperature and precipitation data at country level and combines this data set with annual economic growth (real GDP) data and other relevant data to be incorporated in the model.

CLIMATE CHANGE AND ITS EFFECTS IN BANGLADESH

The effects of climate change are highly remarkable in Bangladesh. According to the research, compared to recent temperatures, temperature could increase to 2.7°C higher than the current level by 2100, causing high humid summer and warmer winters. The rainfall could increase to 10% at the same time, changing drastically usual rainfall patterns (Ahmed, 2006). The seawater rise would cause more havoc as predicted that by 2100 the level would increase by 85 cm from the present level, submerging an enormous portion of land with saltwater. Frequent and severe floods, frequent storms, several natural disasters may approach which, leads to destroying lives, destroying landscapes, and deforestation.

Table 2: Climate Change outbreak in Bangladesh at a Glance

Crop production and Food availability	Rainfall patterns changed due to climate change - crop yields expected to reduce In gross. Crop production will decrease 30% in 2100. Production of paddy will decrease by 47% within the next 30 years.
Salinity	There are 13% areas are salinity at Magura, Mongla & Sathkhira, the south-western coastal districts of Bangladesh at present which will increase 16% in 2050 and 18% by 2100.
Coral reef	Corals are sensitive to the heat waves. If the Sea surface temperature increases $1-3^{\circ}\text{C}$ then the coral reef will be in threat.
Mangrove Forest	About 75% area of mangrove forest, Sundarbans (60007 Sq. km) will submerge if the sea level will increase 45 cm. If the sea- level rises 1 m, then the islands of the Bay of Bengal and whole Sundarbans will be destroyed, including its nature & wildlife.
Aquatic lives	The death rate of marine lives will increase if the water temperature is more than 32°C (CEGIS). Diseases of fish may increase. Production of crops may decrease due to saline water intrusion in the ponds and open water bodies. Production of sweet water fish will narrow and be extinct if the sea level rises.
Health	Flood water is non- potable water. It increases cholera, diarrhea, typhoid etc. Frequent droughts and decreasing food production. Increasing significant malnutrition. More air pollution. Breathing difficulty. Rise of temperature leads an increase in pest and pathogen that will increase malaria, diarrhea, dengue, etc. Decrease physical mobility and resulting in diabetes, psychosocial stress, and death rate increased. High salinity in water will affect human health including, high blood pressure and kidney malfunction.
Increasing refugee	Every year, many people become homeless due to natural disasters. Those who lost their shelter, they tend to live in slums with unhygienic conditions.
Rise of Sea- level	If the sea level rises, the following dangers will observe: 1. Scarcity of potable water.

	2. Agricultural production will change.
Increase rate of evaporation and heavy precipitation	Global average water evaporation and precipitation projected to increase during the 21st century.
Biodiversity	If the global temperature rises by 2°C, 30% of all land species will be at risk, which resulting in extinction of some species each year.

According to the above discussion, we can save Bangladesh from approaching disasters in both animal and plant kingdom. We should take all the discussed issues in account to reduce the threats.

Table 3: Major natural disaster in Bangladesh and their adverse effects

Year	Affected area	Loss of lives	Speed/ Height of tide
1963	Chittagong, Noakhali, Cox's Bazar	11520	10' -20'
1970	Whole coastal area	5000	Gusty wind with 220 km
1985	Chittagong, Noakhali, Cox's Bazar	11069	10' -15'
1991	Whole coastal area	150000	Gusty wind with 225 km
1997	Chittagong	15000	Gusty wind with 224 km
2008	Coastal areas	12000	3332 Gusty wind with 220 to 230 Km

Bangladesh's coastal region witnessed a dramatic sea-level rise over the last three decades. The ensuing sea-water intrusion is giving rise to salinity in coastal drinking water with severe health consequences for the neighboring populations (Daily Star, 2011b). About 53% of Bangladesh's coastal areas are now affected by salinity. Millions people of Bangladesh is threatened by riverbank erosion and severe droughts (Daily Star, 2011c). During the current century, climate change increases the risk of more recurrent and severe floods through higher river flows, resulting from high and more unpredictable rainfall in the Ganges-Brahmaputra-Meghna system during the monsoon and increased melting of the Himalayan glaciers. International Federation of the Red Cross and Red Crescent Societies in 2000 identified river erosion as the largest concern for Bangladesh (New Age, 2011).

Table 4: Disaster risk period in Bangladesh

Type of calamity	Period
Flood	June to September
Excessive rainfall	July to October
Tornado	March to June
Cyclone	April to May and October to November
Flood with tide	April to May and October to November
Cold wave	December to February
Drought	March to May

FINDINGS OF THE STUDY

Bangladesh is one of the top 10 nations mostly vulnerable to climate change, said German watch Global Climate Risk Index (CRI)-2011 report. By the end of the century, Bangladesh is set to disappear under the waves as mentioned by US government's NASA space agency. The International Panel on Climate Change (IPCC) predicted that by 2050, Bangladesh is on course to lose 17% of its land and 30% of its food production and as a result poverty will increase (Planetizen, 2008; The Independent, 2008). The country has already begun to feel the effects of the climate change as flood periods have become longer and the cyclones, droughts and earth quakes that hit the country cause greater devastation and adversely affecting

the country's agriculture and land, and challenging water resources, occupational dislocations, food, health, energy and urban planning (Chimalaya, 2011).

The Healthy Center for Climate Prediction and Research (HCCPR) estimates that sea level in Bangladesh will rise about 40 cm (15 inches) by 2080 (Streatfield, 2008). Water level rises by at least 5.6 mm a year at Hiron point, 1.4 mm at Cox's Bazar and 2.9 mm at Khepupara, which was cited 2008 data from Bangladesh Water Development Board (ANN, 2010a). The climate models suggest that temperature will increase in Bangladesh during all seasons by approximately 1.0 to 15°C by 2030 (Kafiluddin, 2005). The Prime Minister of Bangladesh referred to the more extreme estimations that a one-metre rise in the sea level would submerge a quarter of Bangladesh's land mass (News Today, 2011).

CONCLUSIONS

This paper has examined the potential impacts of climate change on Bangladeshi economic growth- real GDP using a time series data (1980-2022). Accordingly, the result shows that an increase in temperature has negative impact on economic growth measured by real gross domestic product. On the other hand, since Bangladesh depends on rain-fed agriculture which comprises more share of its GDP (43%), a decline in rain fall reduces an economic growth measured by real GDP. The reduction in economic growth will also result in increasing poverty. Thus, control of climate change is not only important for economic growth issue, but also crucial for poverty alleviation.

The study asserts that if climate change is not controlled, the economic growth will be reduced (an increase in temperature dangers a lot) considerably in the long run. However, Bangladesh alone can do very little with regard to controlling climate change as its share of GHG emissions in comparison to developed countries is small. Although the developing countries like Bangladesh contribute the least to causing climate change, they are the most affected by this phenomenon. This is due to their dependency on agriculture and their unaffordability to pay for the resources necessary to combat climate change via adopting the preventive measures (mitigation) and adaptation techniques.

RECOMMENDATIONS

Since Bangladesh is experiencing the effects of climate change, it requires an active step in managing or controlling climate-related problems. In order to solve this negative externality, the mitigation and adaptation strategies should be in place. Besides the direct effects such as an increase in average temperature or a short run dynamics in rainfall patterns, climate change also presents the necessity and opportunity to change to a new, sustainable development model- a Climate-Resilient Green Economy (CRGE) Strategy to protect the country from the adverse effects of climate change and to build a green economy. Furthermore, Bangladesh should firmly continue with the bargaining and active participation on climate change agreements at global scale so as to be compensated for the risk of GHG emitted from industrialized countries who take historical responsibility for emission.

In response to the severe impacts of climate change on economic growth some possible climate-related strategies or programs and policies should be implemented. Since climate change has already begun in our country, no time to stay and mitigation to reduce its damage should be applied primarily. Then, adaptation should be the second and best method to reduce the adverse impact of climate change since adjustment an important tool for the long-run economic growth. In line with these programs, government should apply policies related to climate change with objectives to minimize the emissions of GHGs by using alternative energy sources such as geothermal energy, hydrothermal energy and solar energy. Furthermore, building a strong Green Economy should be part and parcels of all stakeholders and the general public. This building of Green Economy enables for sinking carbon and in the long-run it promotes carbon market.

REFERENCES

1. Ahmed, A.U. (2006). Bangladesh Climate Change Impacts and Vulnerability: A Synthesis. Dhaka: Climate Change Cell, Bangladesh Department of Environment.
2. AKM Kafiluddin (2005). Human Health, Disease and the Environment. 57/1, Lake Circus, Kalabagan, Dhaka 1205. Bangladesh. Accessed on July 13, 2011
3. Albert, M. (2001). "The Poverty of Africa's Position at the Climate Change Convention Negotiations." UCLA Journal of Environmental Law and Policy.
4. ANN (2010b). Food production in Bangladesh to feel climate heat. Available at: <http://www.asianewsnet.net/home/news.php?id=14822&sec=1>. Accessed on: June 14, 2011.
5. Barro, R., and Sala, X. (2003). Economic Growth, 2nd ed. Cambridge: MIT Press. Brock, W., and Taylor S. (2005). Economic Growth and the Environment: a Review of Theory and Empiricism Handbook of Economic Growth. Philippe Aghion and Steven N. Durlauf, North-Holland.
6. Chimalaya (2011). Adapting agriculture to climate change. Available at: <http://chimalaya.org/2011/01/02/adapting-agriculture-to-climate-change/>. Accessed on: June 14, 2011.
7. Daily Star (2011a). Major disasters and management issues. Available at: <http://www.thedailystar.net/suppliments/2011/anniversary/part6/pg10.htm>. Accessed on: June 14, 2011.
8. Daily Star (2011b). Water salinity and maternal health. Available at: <http://www.thedailystar.net/newDesign/news-details.php?nid=188591>. Accessed on: June 14, 2011.
9. Daily Star (2011c). Climate change: Pressure on urbanization. Available at: <http://www.thedailystar.net/newDesign/news-details.php?nid=193545>. Accessed on July 10, 2011
10. Daily Star (2011d). Contextually effective steps needed. Web site. [On-line]. Available: <http://www.thedailystar.net/newDesign/news-details.php?nid=207464>. Accessed: Oct, 23 2011.
11. Daily Star (2011e). Vulnerable women, children need special attention. [On-line]. Available: <http://www.thedailystar.net/newDesign/news-details.php?nid=208648>. Accessed: Oct, 31, 2011
12. Daily Star, (2009). Urgency of tackling climate change. Available at: <http://www.thedailystar.net/newDesign/news-details.php?nid=103678>. Accessed on: June 19, 2011.
13. Dell, M., B.F. Jones, and B.A. Olken (2008). Climate change and economic growth: evidence from the last half century. Cambridge, MA: National Bureau of Economic Research.
14. Envoinfo (2011). Much crowded planet can best adapt to rising sea levels. Available at: <http://www.envoinfo.com/2011/04/much-crowded-planet-can-best-adapt-to-rising-sea-levels/>. Accessed on: August 25, 2011.
15. Fankhauser, S., and R.S. Tol (2005). On climate change and economic growth. Resource and Energy Economics, vol. 27.
16. FAO (2011). State of forest genetic resources conservation and management in Bangladesh. Available at: <http://www.fao.org/docrep/007/ad870e/ad870e01.htm>. Accessed on: June 14, 2011.
17. Greiner, A. (2004). Anthropogenic climate change in a descriptive growth model. Environment and Development Economics.
18. Grubb, M. (2003). The Kyoto Protocol: An Economic Appraisal. Cambridge University, Faculty of Economy, Carbon Trust, Imperial College Centre for Environmental Policy.
19. Howard J. Critchfield (2003). General Climatology. 4th edition, Western Washington University.
20. IAC (2011). What is the definition of Weather? Available at: <http://uk.ask.com/question/what-is-the-definition-of-weather>. Accessed on: July 24, 2011.
21. ICDDR, B (2011). Our Strategy. Available at: http://www.icddrb.org/what-we-do/publications/cat_view/52-publications/10043-icddrb-documents/10055-annual-report/10056annual-report-2009/10063-our-strategy. Accessed on: June 14, 2011.
22. IPCC. (2007). Managing the risks of extreme events and disasters to advance climate change adaptation. Special Report, Geneva, IPCC Secretariat.
23. James T., Tingiju Z., Xinshen D, (2009). The Impact of Climate Variability and Change on Economic Growth in Zambia.

24. Jen H. Christensen and Bruce Hewiston (2007). *Regional Climate Projections in Climate Change: The physical basis*. Cambridge University Press.
25. Lavell, A., Diop, C., Hess, J. (2012). *Climate change: new dimensions in disaster risk, exposure, vulnerability, and resilience*. Cambridge University Press, Cambridge, UK & USA.
26. New Age (2011). *Resolve common environmental concerns during the September Summit*. Available at: <http://www.newagebd.com/newspaper1/op-ed/31589.html>. Accessed September 4, 2011.
27. News Today (2011). *Hasina vows to pull people out of poverty*. Available at: http://www.newstoday.com.bd/index.php?option=details&news_id=28441&date=2011-05-26. Accessed on: June 14, 2011.
28. Nordhaus, W.D. (1991). *To slow or not to slow: The economics of the greenhouse effect*.
29. Planetizen, (2008). *Bangla-Doomed?* Available at: <http://www.planetizen.com/node/33615>. Accessed on: June 14, 2011.
30. Smulders, S., L. Bretschger, and H. Egli (2011). *Economic growth and the diffusion of clean technologies: Environmental and Resource Economics*.
31. Stem, N., and others (2006). *Stern Review: The Economics of Climate Change*. London. : HM Treasury.
32. Streatfield, K (2008). *Population Challenges for Bangladesh in the Coming Decades*. *J Health Popul Nutr*; 26(3): 261–272.
33. Tol, R.S.J. (2009). *The economic effects of climate change*. *Journal of Economic Perspectives*, vol. 23.
34. Tretwartha TG, Horn HL (1980). *An introduction to climate*. McGraw Hill, Aucland
35. United Nations Framework Convention on Climate Change (UNFCCC). (2010). "Inventories of Anthropogenic Emissions by Sources and Removals by Sinks of GHG. Sixth Compilation and Synthesis of Initial National Communications."

