The London School of Economics and Political Science (LSE)

Climate Change Adaptation and Recovery from Climate Hazards: Micro-econometric Evidence from Rural Bangladesh

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Declaration

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I warrant that this authorisation does not, to the best of my belief, infringe the rights of any third party.

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Statement of publication of work

I confirm that I already published a major part (around 80%) of chapter 2 in the Ecological Economics journal (October 2015) as single author.

Abstract

This thesis addresses two important issues of environmental and resource economics: how agricultural households adapt to climate change (CC) and how the households recover from climate hazards. Chapter 1 attempts to enunciate the perspective of the overall research and the rationale for researching on Bangladesh. It summarizes the global evidences of CC and disaster, their impacts, vulnerabilities in agriculture sector, significance of adaptation and poverty impact of disaster. Chapter 2 examines whether crop choice is affected by CC and the extent to which households switch their crops in response to the CC scenarios. It finds that crop choice is climate-sensitive and a shift in crop choices will take place in Bangladesh in response to CC scenarios. This research also finds that crop choice will be more sensitive to change in temperature than change in rainfall. Chapter 3 examines the effect of CC on crop diversification and the households' response to CC scenarios. It finds that crop diversity is climate sensitive and this diversity in different locations varies with climatic conditions. Effects of rainfall scenarios on crop diversity are much lower compared to the effects of temperature. Chapter 4 investigates the impact of cyclone on consumption and income dynamics in a quasi-experimental setting and finds that low income people are more sensitive of their asset loss to income generation compared to the high income people, and disaster causes income loss, but, people show their resilience in accelerating higher income growth compared to the non-affected areas. Chapter 5 examines poverty group dynamics in the post-shock period and the existence of a poverty trap in the cyclone affected coastal region of Bangladesh. It finds that asset loss or asset holding impacts the dynamism of the poverty groups and poverty traps exists at low levels of income in the disaster affected areas compared to the unaffected areas.

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Chapter 1

Climate Change, Disaster and Adaptation: Relevance of Research on Bangladesh

Abstract

This chapter discusses the overall background of the dissertation and presents the importance of climate change from the perspective of Bangladesh; a South Asian country which is highly vulnerable to climate change. The chapter begins with discussion of the global evidence for climate change, its impact and the importance of adaptation to climate change. Climate change vulnerabilities in the agriculture sector and the significance of adaptation in this sector have been highlighted in this chapter. Different climate change adaptation strategies in the agricultural sector have been discussed, and observed changes in climate that have taken place in the country along with their potential impact on the agricultural sector have also been discussed along with a discussion on the climate change adaptation policies and related institutions of the country. This chapter also discusses the effects of cyclones, their occurrence in Bangladesh and impact on poverty. Different short and long-term coping strategies to deal with cyclones have been presented in this chapter. This chapter presents the overall structure of the research highlighting the research objectives, contribution to literature and rationale behind choosing the specific case studies. The conclusion of this chapter will synthesise the whole chapter focusing the rationale of researching climate change adaptation in the agricultural sector and impact on poverty of cyclones in Bangladesh.

1.1 Climate Change: Evidence, Impacts and Adaptation

For the last several years, climate change has been the centre of the policy and political debate in both national and international arenas. Through a series of international summits including the United Nations Climate Summit, United Nations Conferences on Sustainable Development and the Conference of the Parties (COP), this process continues, echoing the concerns of the nations which are worst effected by climate change and global warming. The issue of climate change and global warming is different from more usual examples of externality as the extent of its cause and effect are not confined to a single country. Stern (2008) has referred to GHG emissions, which is believed to be an important cause of global warming as an externality that is different from usual examples. Stern (2008) also argued that as with the economic analysis of global warming, analysis of climate change should be undertaken in parallel as it is at the core of the economics of risks and uncertainty, the links between ethics and economics, and the role of international economic policy. Climate change has been mentioned as the biggest market failure ever faced, the biggest exercise in applied Bayesian probability theory and the perfect moral storm (Gardiner, 2006; Stern, 2008; Weitzman, 2009) .

In the past two centuries, the world has witnessed the gradual evolution of the scientific discovery of climate change. Until the 1980s, the prediction of climate change was neither convincing nor well accepted. During the 1980s, persuasive calculation methods for climate change led to a consensus that human activity was linked to the process of warming the climate, leading to the foundation of the modern period of global warming science (Hutchins, 2009). IPCC[1] provides a good number of climate change evidences through publishing

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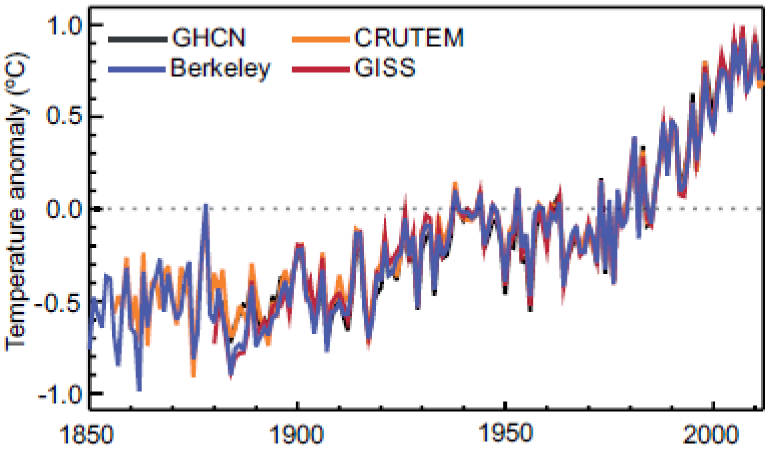
[1] The Intergovernmental Panel on Climate Change (IPCC) which was established by the United Nations Environmental Programme (UNEP) and the World Metrological Orgnization to provide a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts is the leading international scientific body for the assessment of climate change. It reviews and assesses the most recent scientific, technical and

assessment reports and updates at regular intervals highlighting the physical process of climate change, its impact, and the potential significance of adaptation and mitigation. The latest published report of IPCC (2013), a part of the Fifth Assessment Report on climate change reported strong statistical evidence for climate change[2].

IPCC (2013) acknowledged that since the publication of the Fourth Assessment Report (AR4) in 2007, substantial progress took place in the production of revised data sets, more digital data records, and new data set efforts in the development of more scientific and reliable evidence on the increase in global land surface air temperature (LSAT). These modernisations led to a better understanding of data issues and uncertainties and to dependable quantification of variation at regional level. This ultimately enhanced the reliability of the global LSAT trend over time. Figure 1.1 displays the global annual average land-surface air temperature (LSAT) anomalies relative to 1961–1990 climate from the latest versions of four different data sets (Berkeley, CRUTEM, GHCN and GISS). It shows that, the global LSAT has been increasing continuously from 1980 onward.

Figure 1.1: Global annual average land-surface air temperature (LSAT) anomalies in 1850-2012 relative to a 1961–1990 climatology



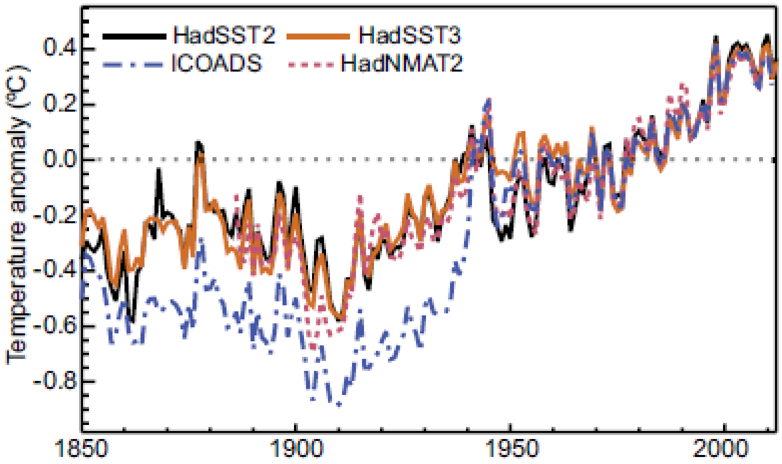
Source: IPCC (2013)

socio-economic information produced worldwide relevant to the understanding of climate change.

[2] AR5 consists of three Working Group (WG) reports and a Synthesis Report (SYR) that provide a clear and up to date view of the current state of scientific knowledge relevant to climate change.

IPCC (2013) also acknowledged that significant progress took place in estimating global annual average sea surface temperature (SST) since AR4. Figure 1.2 shows global annual average SST anomalies relative to a 1961–1990 climatology from gridded data sets of SST observations (HadSST2 and its successor HadSST3), the raw SST measurement archive (ICOADS, v2.5), and night marine air temperatures data set HadNMAT2 (Kent et al., 2013). It shows that in all the four data sets, global annual average SST anomalies maintained a continuously increasing trend since 1980 after exhibiting a steady trend in the 1950-1980. Interestingly, in case of all the four datasets, this anomaly maintained an increasing trend in the period 1900-1950.

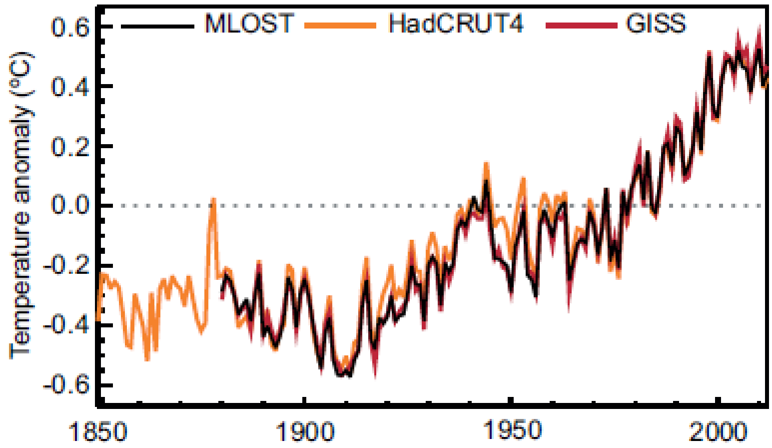
Figure 1.2: Global annual average sea surface temperature (SST) anomaly relative to a 1961–1990 climatology



Source: IPCC (2013)

When we consider LSAT and SST together as global mean surface temperature (GMST), a steady increase in the temperature anomaly has been found as shown in the Figure 1.3. Figure 1.3 depicts annual GMST anomalies relative to a 1961–1990 climatology from the latest version of the three combined LSAT and SST data sets (HadCRUT4, GISS and NCDC MLOST).

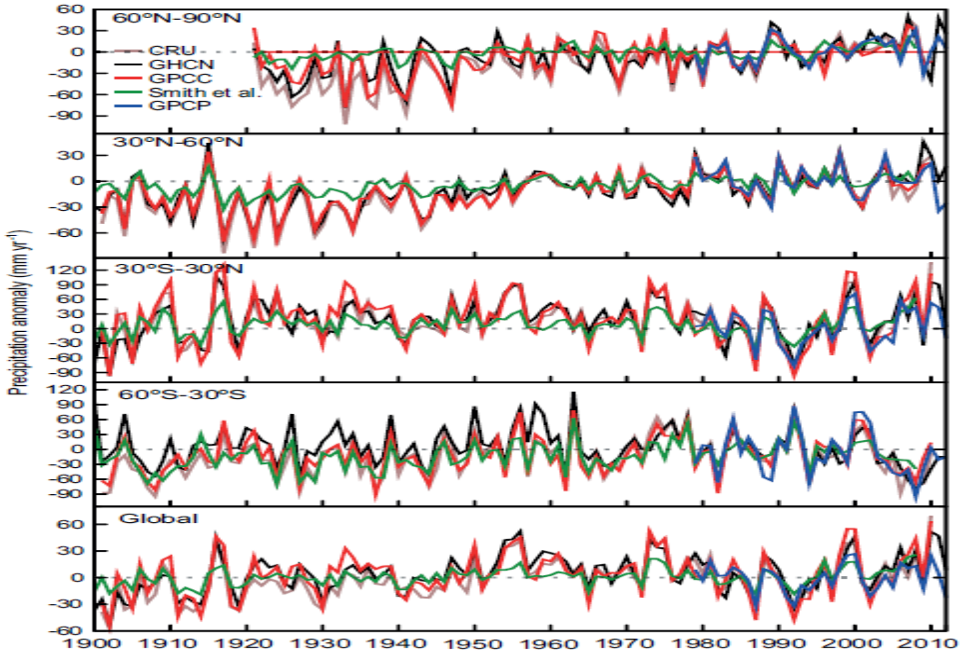
Figure 1.3: Global mean surface temperature (GMST) anomaly relative to a 1961–1990 climatology



Source: IPCC (2013)

IPCC (2013) also shows high confidence in finding the increase in global average precipitation on land areas during the past period of a century. Figure 1.4 which is collected from IPCC (2013) shows annual average precipitation anomalies on land areas for four latitudinal bands and also globally from five global precipitation data sets relative to a 1981–2000 climatology. AR5 found that all datasets show increases in average precipitation at global level for the period of 1901–2008. Three of the four datasets exhibit statistically significant changes in precipitation.

Figure 1.4: annual average precipitation anomalies on land areas relative to a 1981–2000 climatology



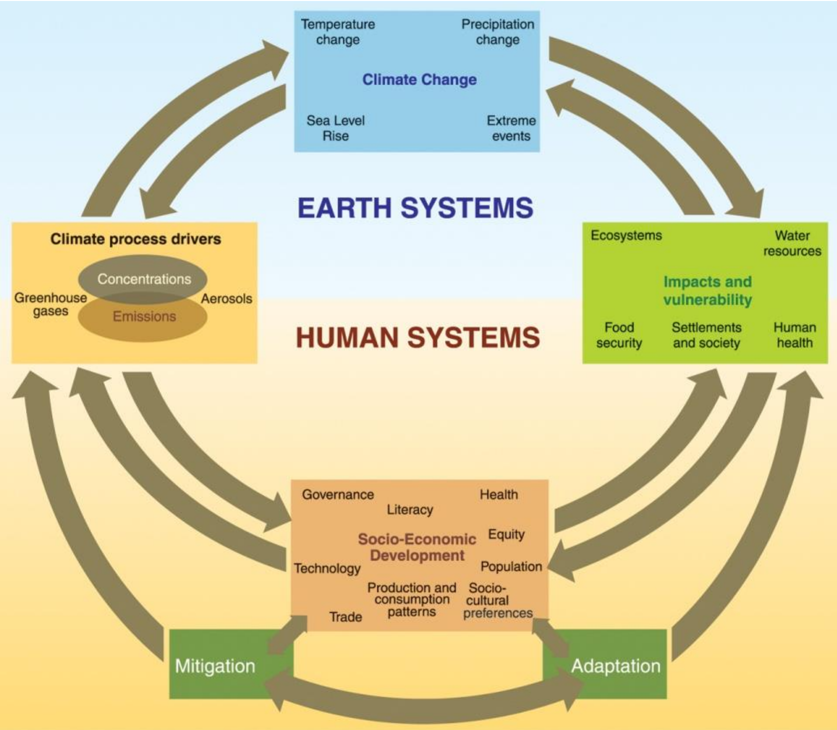
Source: IPCC (2013)

IPCC (2013) does not provide any conclusive trends about the changes in frequency of tropical cyclones over the past century, which was also echoed in IPCC (2007) and the IPCC (2012). However, at the regional level, some robust changes in the intensity and frequency of cyclones have been supported by a number of research papers (Grinsted, Moore, & Jevrejeva, 2012; Kossin & Vimont, 2007).

IPCC (2007b) reports that the world has witnessed cognizable changes in terms of temperature, sea level and snow cover in the northern hemisphere with the following properties: (a) Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850); (b) global average sea level rose at an average rate of 1.8mm (1.3mm to 2.3mm) per year over 1961 to 2003 and at an average rate of about 3.1mm (2.4mm to 3.8mm) per year from 1993 to 2003; and (c) annual average Arctic sea ice extent has shrunk by 2.7% (2.1% to 3.3%) per decade, with larger decreases in summer of 7.4% (5.0% to 9.8%) per decade. AR4 also reports that the temperature increase is widespread over the globe and is greater at higher northern latitudes. Average Arctic temperatures have increased at almost twice the rate of the global average in the past 100 years. Land regions have warmed faster than the oceans. Observations since 1961 show that the average ocean temperature has increased, this has been measured to depths of at least 3000m, and that the ocean has been absorbing over 80% of the heat being added to the climate system. New analyses of balloon-borne and satellite measurements of lower- and mid-tropospheric temperatures show warming rates similar to those observed in surface temperature.

IPCC (2007a) has presented the following diagram (Figure 1.5) linking the earth systems and human systems of climate change. The diagram also delineates that climate change mitigation works through climate process drivers, while adaptation works through impacts and vulnerability to climate change. It also shows that mitigation and adaptation to climate change are mutually reinforced by factors such as governance, literacy, health, population, and technology.

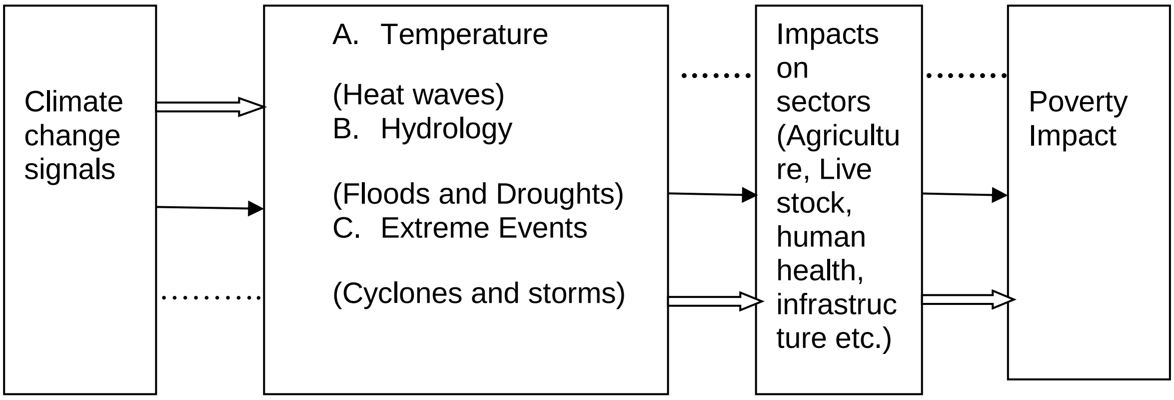
Figure 1.5: Interaction between earth and human systems in climate change



Source: (IPCC, 2007a)

Figure 1.6 presents the strength of the channels of climate signals and their impact on poverty. Here narrow arrows represent weaker relationship while wider arrows show a strong relationship. Figure 1.6 also shows that climate change signals appear more prominently in temperature changes compared to frequency of extreme events like cyclones and storms. But the impacts of extreme events are more compared to temperature effects and these impacts occur in different sectors such as agriculture, livestock, human health, and infrastructure. All these impacts have an implication for poverty.

Figure 1.6: Strength of relationship of climatic signal and their impacts on poverty



Source: (Huq, Reid, & Murray, 2006)

Climate change is an environmental issue which has significant implications for poverty and inequality. The pattern and behaviour of climate, including variability and extreme events, plays a significant role in freshwater availability, agricultural productivity, functions of natural ecosystem and biodiversity, human health and livelihood of the people (General Economic Division, 2009). These characteristics of climate either create a favourable condition for a system to function better, or increase its vulnerability. Therefore, economic growth and the performance of nations and society depend on to a large extent on the behaviour of climate.

A good number of papers (Jacoby, Rabassa, & Skoufias, 2015; Skoufias, Rabassa, & Olivieri, 2011; Thurlow, Zhu, & Diao, 2012) have recognized climate change as one of the emerging issues of pro-poor growth, poverty and inequality. Poor people are generally the most vulnerable to climate change as they tend to live in disaster prone and often remote areas and also have little capacity to adapt to shocks. They are also more dependent on ecosystem services and products for their livelihoods. Any impact that climate change has on a natural system therefore threatens employment, which ultimately affects income generation. Moreover, livelihood, food consumption, health and education are also affected by climate change. Empirical evidence using cross-country data suggests that climate change will slow the pace of global poverty reduction, but the expected poverty impact will be relatively modest and far from reversing the major decline in poverty that is expected to occur over the next 40 years as a result of continued economic growth (Skoufias et al., 2011). A study on Zambia using a dynamic computational general equilibrium model found that if rainfall declines by 15 percent, climate change enhances the negative effects of climate variability by a factor of 1.5 and pushes an additional 30,000 people below the poverty line over a 10-year period (Thurlow, Dorosh, & Yu, 2012). The welfare cost of climate change falls disproportionately on the shoulders of the poor -which is true in urban as well as rural areas (Jacoby et al., 2015).

1.1.1 Adaptation vs Mitigation

Policy makers have two non-mutually exclusive options in formulating climate change related policies. Firstly, they can stop the process of climate change, i.e. mitigation, or, they can accept the change and set the strategy to adapt with climate change, or they can partially do both. Both the processes involve costs. Since climate change is a cross-boundary issue, its mitigation strategy depends on the consensus of nations. But, the chance of such consensus is quite low as multiple agendas on diverse interests are involved. On the other hand, adaptations can be done both privately and publicly. For instance, individuals in a coastal area may change the formation of their dwelling places when they are aware of the sea level rises due to climate change. Such operations involve private costs. Similarly, government may take some operations for adaptation using public resources. Some argue that there is a trade-off between mitigation and adaptation to climate change.

In 'The Perfect Moral Storm', philosopher Stephen Gardiner (2006) blames inaction for environmental crises and considers them an ethical failure. Gardiner explains the moral situation indicating the following issues: (a) the world's most affluent nations are tempted to pass on the cost of climate change to the poorer and weaker citizens of the world; (b) the present generation is tempted to pass the problem on to future generations; and (c) our poor grasp of science, international justice, and the human relationship with nature helps to facilitate inaction. As a result, our wilful self-deception leads the lives of future generations, the world's poor, and even the basic fabric of life on the planet to be at stake. Gardiner (2006) demands more institutions, leaders and all in general to wake up to this profound ethical failure.

There is a long debate linking intergenerational justice with climate change mitigation as it requires a huge investment, the fruits of which will be available for future generations. From the normative point of view on how much a nation ought to save for future generations, Ramsey taking a purely Utilitarian approach, derived the efficient path of consumption over time, which will maximize the present value of utility over an infinite time horizon. But, there exists a problem as future generations are not well represented in the welfare function. There is a strong debate between Nordhaus and Stern in economic analysis of climate change. The debate is between a positive and a normative school of thought on the issue of the selection of the parameters of the SRTP, which characterise the intertemporal social welfare function. Both the schools of thought have some strong arguments. Groom (2010) provides the details of this and the various other ethical questions and approaches that arise from it. This includes a discussion of the role of deontological, rather than con- sequentialist approaches, as well as non-teleological approaches, such as virtue theory. However, the present research will limit its scope to adaptation to climate change as the economic perspective of Bangladesh will not allow the country to go for a huge investment for mitigation, rather, adaptation to climate change is pragmatically favourable.

1.1.2 Definition of Adaptation

The IPCC (2001) defines adaptive capacity as the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. The goal of an adaptation measure should be to increase the capacity of a system to survive external shocks or change.

The also defines adaptation as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

The IFPRI (2007) defines adaptation as the process of improving society's ability to cope with changes in climatic conditions across time scales, from short term (e.g. seasonal to annual) to the long term (e.g. decades to centuries).

1.2 Climate Change, Agriculture and Adaptation

It is widely agreed that the toll of climate change on developing countries is much more than it is on developed countries. The immediate channel through which this cost is likely to be accrued is agriculture and food security. William Cline, whose earlier models of climate change from 1992 were more or less in line with the Stern Review, has undertaken a recent study of the estimated impact of climate change on agriculture by country (Cline, 2007). The findings of this study that have been presented in the book of Cline (2007) are as follows:

- Warming will decrease production by accelerating growth speed and reducing their water consumption;
- Evaporation from topsoil will increase, as will transpiration, again inducing moisture loss, or evapotranspiration;
- This is partially countered by the increase in rainfall anticipated due to climate change;
- On the positive side, CO_2 can help agriculture via carbon fertilization, which aids photosynthesis for so-called C_3 crops (wheat, rice and soy) but not C_4 crops (sugarcane and maize).

Using the output of a number of climate models which estimate the relationship between CO_2 emissions and surface and ocean temperatures into an agronomic model of agricultural production, Cline (2007) has estimated the change in production for 116 regions of the world. Around 5^{o}C temperature increase in the business as usual scenario is predicted in the model. Table 1.1 shows some details of the results of the model, measured by the percentage changes to agriculture that are likely to take place, and the expected cost of climate change on agriculture with and without 'carbon fertilization' (CF).

Table 1.1 shows that the percentage change in the agricultural output potential due to climate change is higher for non-annex I countries.[3] Table 1.1 represents the estimates derived from 'crop models' using data on climate change, land quality, and fertilizer into an agronomic model to predict the changes. Other models statistically infer the value of climate and so on in agriculture and make predictions in the basis of observed relationships. These are the so called 'Ricardian' models which look at the determinants of land rents and yields. In both cases the impact on crop yields is strongly negative, and only partially offset by Carbon Fertilization. Developing countries face 10%-15% reductions overall, compared to around 5% gains in developed countries. Africa, Latin America and South Asia suffer the worst reductions - in the order of 20%. Cline (2007) also finds that equatorial countries suffer the most from climate change, since these areas are projected to increase in temperature more than others. Some areas will gain if carbon fertilization is considered. Those areas which benefit are generally in the upper latitudes. Other countries which benefit have higher elevations, such as the Tibetan plateau. In Africa; Ethiopia and South Africa appear to suffer most (25%+), while Nigeria has lower losses. In South Asia, India appears to be most vulnerable, with 30-40% losses predicted.

[3] United Nations Framework Convention on Climate Change (UNFCCC) lists a number of especially climate change vulnerable countries which are mostly developing with with low-lying coastal areas and those prone to desertification and drought.

Table 1.1: The costs of agriculture as a consequence of climate change

	Land Area	**Farm Area**
	Base Levels	
Temperature	13.15	16.20
Precipitation	2.20	2.44
By 2080s		
Temperature	18.10	20.63
Precipitation	2.33	2.51
	(Percentage change in agriculture output potential)	
	Without CF	With CF
World		
Output-weighted	-16	-3
Population-weighted	-18	-6
Median by Country	-24	-12
Industrial Countries	-6	-8
Developing Countries	-21	-9
Median	-26	-15
Africa	-28	-17
Asia	-19	-7
Middle-east and North America	-21	-9
Latin America	-24	-13

Source: Cline, 2007

Agricultural households use capital and labour for production and maximize utility through consumption subject to asset constraint. Every agricultural household faces a range of risks which can be divided into two parts- systematic risks and unsystematic or idiosyncratic risk. Risk from climate change can be referred as idiosyncratic risk as climate change/extreme events don't follow any pattern of happenings. Through community level mechanisms such as kinship, social network and institutional mechanisms, agricultural households in a community could share risk among each other and achieve Pareto efficient allocation of risk. But the Pareto efficient allocation of risk within a community is almost impossible to achieve under the rationality assumption as marginal utility of aggregate social or communal work for risk pooling will be different for different individuals. Therefore, moral hazard in the community will collapse the risk pooling structure of Pareto program (Carter, 1997; Rosenzweig &

Binswanger, 1993; Ruthenberg, 1971). Since in the agrarian rural economy, poor households cannot successfully prevent the income loss by taking ex post measures because of lack of resources, technical know and effective institutional mechanism, they will apply ex ante measures to overcome income loss. In an agrarian rural economy, those ex ante measures among others are planting multiple crops and rapidly maturing varieties. This establishes the motivation of research on crop switching/diversity as they ensure low risk (less variance) of income from crop production.

Agriculture has been mentioned as a primary means by which the impacts of climate change are transmitted to the poor, and as a sector at the forefront of climate change mitigation efforts in developing countries (Hertel & Rosch, 2010). Different adaptation strategies both at individual and societal level have emerged to tackle the negative effect of climate change on agriculture. Bradshaw, Dolan, and Smit (2004), Seo and Mendelsohn (2008), Wang, Mendelsohn, Dinar, and Huang (2009), Kurukulasuriya and Mendelsohn (2008) and Di Falco, Veronesi, and Yesuf (2011) suggested a number of climate change adaptation strategies which have been listed in the Table 1.2.

Table 1.2: List of adaptation strategies in agriculture

No	Adaptation Strategy in Agriculture
1	Crop switching
2	Crop diversification
3	Using drought-resistant varieties
4	Using high-yield water sensitive crops
5	Changing planting and harvesting dates
6	Floating garden in the flooded area
7	Soil conservation
8	Water conservation
9	Mixed crop livestock farming system
10	Mixed crop fish farming system
11	Cage Fishing
12	Duck rearing in the flooded area

Among all these adaptation strategies in agriculture, this dissertation will focus on the first two adaptation strategies; crop switching, and crop diversification for the following reasons. Firstly, extensive literature survey confirmed that research on crop choice as climate change adaptation and its probable response under different climate scenarios in Bangladesh and even in the south Asian nations is not addressed till now.[4] Secondly, Household income and expenditure survey (HIES), a nationally representative and a big data set of Bangladesh provides the crop choice statistics of the rural households of the country that gives an unique opportunity to work on crop choice as climate change adaptation. Chapter 2 will deal with crop switching while chapter 3 will focus on crop diversification as climate change adaptation in details.

1.3 Disaster, Impacts and Coping Strategies

Natural climate variability that is taking place due to climate change has led to an increase in the frequency, intensity and duration of climatic extremes in the recent past few decades (Cameron, Norrington-Davies, te Velde, & Mitchell, 2012). Evidence shows that climate variability increases volatility in precipitation levels, sea level rises, drought, floods and so on since the 1950s, creating new risks in the development process and creating human crises. The fifth Assessment report of IPCC shows that sustaining the current rate of fossil fuel burning will cross the two degrees Celsius threshold leading to more frequent and longer heatwaves, more precipitation, faster sea level rises etc. Extreme weather and climatic events that claim thousands of lives and cause billions of dollars of damage globally are referred as natural disasters (Hallegatte, 2012). However, all extreme climatic events may not turn into disasters because of their exposure and intensity.

Disaster is a widespread term that refers to any hazardous physical event. Events that cause severe interruption in the normal functioning of livelihood are called disasters. IPCC (2012) defined disasters as severe alterations in the normal

[4] Chapter 2 and chapter 3 will present the recent literature on crop choice as climate change adaptation in details.

functioning of a community or a society due to hazardous physical events. Those events, in association with vulnerable social conditions lead to widespread adverse human, material, economic, or environmental effects. The sources of hazardous physical events may be different. Those may be of natural, socio-natural or purely anthropogenic origins(Smith, 1996). Natural disasters include a wide range of physical events such as earthquakes, volcanoes, tsunamis, and cyclones amongst others. This dissertation will focus on cyclones. The terms 'disaster' and 'extreme events' are often used synonymously, although there are subtle differences. IPCC (2012) stated that extreme events are often but not always associated with disaster, but non-extreme physical events also can and do lead to disasters, where physical or social structures generate such a result. For instance, a large number of disasters included in the disaster database like University of Louvaine EM-DAT database are not statistically extreme events.

Tropical cyclones originate in the tropical oceans. IPCC (2012) reports that about 90 tropical cyclones take place globally every year, and this frequency of occurrence has remained roughly stable since the mid-1970s. Although the global frequency of tropical cyclone has been steady for the last several decades, substantial variability in inter-annual to multi-decadal frequency in individual ocean basins can occur (Webster, Holland, Curry, & Chang, 2005). Because of the occurrence of cyclones in different ocean basins and the heterogeneity in reporting protocols, finding trends in tropical cyclone features such as frequency, intensity, and duration can become a major challenge. However, IPCC (2012) states that global reanalyses of tropical cyclone intensity using a homogenous satellite record suggests a link between observed global tropical cyclone intensity and climate change based on a roughly 30-year period of satellite observations.

Tropical cyclones are usually associated with extreme wind and storm-surges. Storm surges and freshwater flooding from extreme rainfall generally cause the great majority of damage and loss of life and wealth (Rappaport, 2000; Webster, 2008). Tropical cyclones emerge as a major hazard to the populations and infrastructure of coastal areas and their economic activities. Calculating the impacts of cyclones is not straightforward as it involves multiple sectors and time dimensions. The literature on cyclones is unanimously suggestive of their negative impact on economic development in the immediate or short run. But, regarding the long run impact of cyclones, there are two strands of research. One school of thought states that natural disasters are setbacks for economic growth while another is opposite, although overwhelming earlier literature supports the first opinion. However, there is a growing literature that finds natural disasters or climate extremes as a truly potential impediment to economic development with significant poverty impacts.

Disaster impacts multiple sectors and both the demand and supply side of the economy. Therefore, unlike climate change in the agriculture sector, adaptations to disaster are quite complicated. There are some immediate coping strategies while others are in short run or in medium run. Table 1.3 displays the immediate and short/medium run coping strategies in relation to cyclones.

Table 1.3: Immediate and short/medium run coping strategies in cyclone

Serial	Immediate/short run	Serial	Medium run
1	Land sale	1	Flood resistant housing
2	Livestock sale	2	Safe drinking water from raised wells
3	Decrease in consumption	3	From fish farming to integrated farming
4	Decrease in health and education expenditures	4	Adopting new water technologies like PSF and rain water
5	Government relief	5	Limited migration/relocation
6	NGO relief	6	Changing workplace/profession
7	Charity		
8	Loan from informal sources		
9	Spend saving		

Chapter 5, the final chapter of this dissertation will investigate the impact of the coping strategies on asset index which ultimately determine the poverty dynamics. This research considers the influence of the coping strategies in the asset-based livelihood function, which is an improvement over the existing asset index estimation methods. This is a new dimension of research which is not addressed in other similar literature till now.

1.4 Bangladesh: Climate Change and Disaster

This section will present the evidence of climate change and incidences of cyclones in Bangladesh as well as their probable impacts.

1.4.1 Climate Change in Bangladesh

Bangladesh is already vulnerable to many climate change related extreme events and natural disasters. It is expected that climate change will bring changes in the characteristics of the natural hazards that the country faces alongside gradual changes in the physical system. The fourth assessment report of the intergovernmental panel on climate change (IPCC) for South Asia predicts that monsoon rainfall will increase, resulting in higher flows during monsoon season in river systems. It has also predicted that sea level rise will be between 0.8 to 0.9 meters which will lead to salinity intrusion and coastal flooding. Rainfall is predicted to become higher and more erratic. Frequency and intensity of natural disasters are likely to increase especially in the northern and western part of the country. Several evidences of these phenomena and their associated impacts on the agricultural system are already visible in Bangladesh. Erratic rainfall and temperature, the occurrence of extreme weather events and salinity intrusion are a key indication of changes in the climatic system. Impacts of climatic changes on production and human systems are also being noticed in Bangladesh. Among the different production systems agriculture will face significant adverse impacts due to climate change from changes in the hydrological regime. More water during the monsoon causes floods and low water flow and erratic behaviour of rainfall will result in intense and frequent drought.

With a wide spatial and temporal distribution, the average annual rainfall of Bangladesh stands around 2300mm. Different regions of the country experience different levels of annual rainfall. The north-eastern region of the country situated close to Cherapunji and Mawsyriem in India, two of the rainiest places in the world, records the highest amount of annual rainfall, over 5000 mm. The north-western region is the driest area having 1220mm followed by the central part of 1490mm. The coastal area where the survey area of this research is located has 3380mm annual rainfall (Rashid, 1991). Change in duration of rainfall especially in the rainy season has already been visible in the country. Bangladesh National Adaptation Programme of Action (NAPA) reports that the duration of the rainy season has decreased but the total annual rainfall remains more or less same, meaning that heavier rainfall occurs within a shorter period. This change in rainfall duration has a solid impact on agriculture and livelihoods.

Box 1.1: Climate Change Situation in Bangladesh

- Rainfall is predicted to become higher and more erratic
- Coastal people are more vulnerable
- Frequency and intensity of disasters are likely to increase
- 45 cm rise of sea level may inundate 10-15% land by 2050 resulting 35 million climate refugees in coastal districts
- Climate change could affect more than 70 million people of Bangladesh
- Average monsoon maximum and minimum temperature show an increasing trend annually by 0.05 C and 0.03 C annually.
- Average winter season (December, January and February) maximum and minimum temperature show respectively a decreasing and increasing trend annually at 0.001 C and 0.016C.

Bogra: A metrological station

- Overall annual maximum and minimum temperature increasing annually by 0.008C and 0.003C from 1971 to 2002.
- Average monsoon maximum and minimum temperature show an increasing trend annually by 0.033C and 0.014C annually.

Rangpur: A metrological station

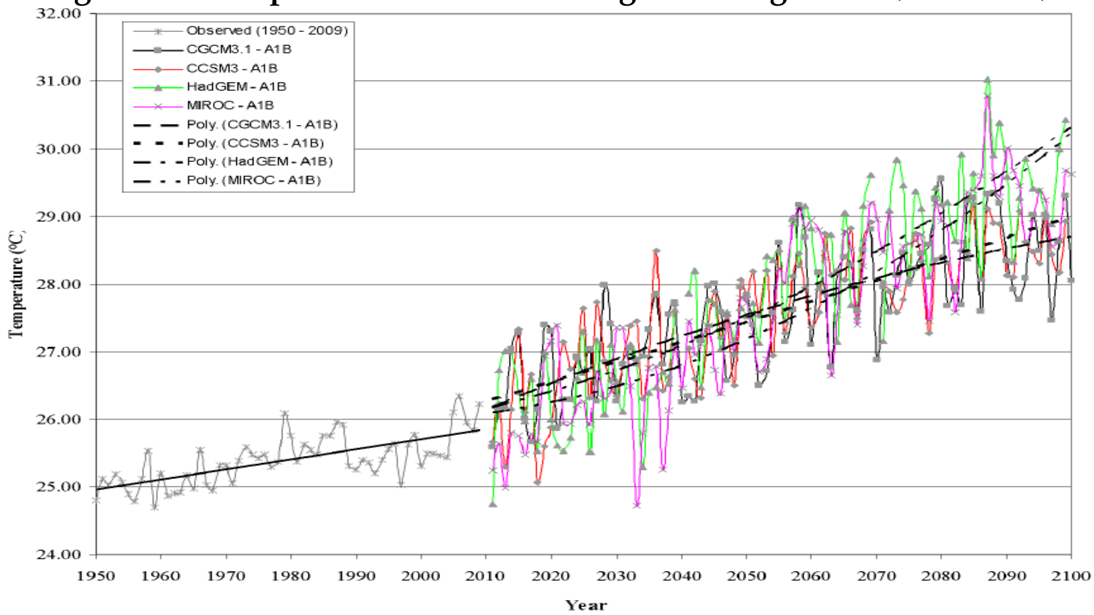
- Overall annual maximum and minimum temperature increasing annually by 0.035C and 0.027C from 1978 to 2002.
- Average monsoon maximum temperature shows an increasing trend annually by 0.02C annually.

Note: Information presented in the box has been taken from (General Economic Division, 2009).

During the period of 1950-2010, average observed temperature has increased by 0.8 ° C which is displayed in Figure 1.7. Figure 1.7 also shows the temperature scenarios up to 2100AD from different climate models. All the climate models show increasing trends in temperature. The average increase in

2100AD ranges from 2.0 ° C to 3.5 ° C. Climate change scenarios will be discussed in detail in Chapter 2 and Chapter 3 of this dissertation.

Figure 1.7: Temperature: observed changes in Bangladesh (1950-2010)



1.4.2 Planned Climate Change Adaptation in Bangladesh

Bangladesh has been regarded as a pioneering country in the climate change adaptation policy framework. Adaptations pioneered by government have been defined as planned adaptations. Planned adaptations include policy framework, institutional set up, and the establishment of funds for climate change adaptation projects.

National Adaptation Programme of Action (NAPA)

Following the broad guiding principles given by the LDC Expert Group (LEG), the Ministry of Environment and Forest (MoEF) prepared NAPA for Bangladesh in 2005. The NAPA was formulated as a response to the decision taken at the UNFCCC's Seventh Session Conference of Parties (COP7). The NAPA aimed to assemble the understanding of the current state of affairs from discussions with appropriate stakeholders from four sub-national workshops and one national workshop (MoEF, 2005). It recognized the immediate and urgent needs of the country in regard to adaptation activities and has listed priority activities (BCAS, 2008). The NAPA was prepared keeping in mind the sustainable development goals and objectives of Bangladesh where the importance of addressing environmental issues and natural resource management with the participation of stakeholders in bargaining over resource use, allocation and distribution was recognized (BCAS, 2008). The suggested future adaptation strategies mentioned in NAPA are across different sectors including water, infrastructure development, broad agriculture sector, capacity development, disaster preparedness and mainstreaming adaptation policies. NAPA has identified areas of actions in climate change adaptations, but, it does not suggest any implementation mechanism.

Bangladesh Climate Change Strategy and Action Plan 2009 (BCCSAP)

Bangladesh Climate Change Strategy and Action Plan (BCCSAP) is the most recent policy document of the government aiming to address both adaptation and mitigation for the decade 2009 to 2018. It was prepared in 2009 focusing on 10 years-worth of action measures to counter the potential challenges and variable conditions. BCCSAP identifies all the climate induced hazards including flood, drought, salinity intrusion, cyclones and storm surges, and variations in temperature and rainfall, and their associated impacts on different sectors. BCCSAP identifies a set of activities/measures under the following six major themes:

i. Food security, social protection and health
ii. Comprehensive Disaster Management
iii. Infrastructure
iv. Research and knowledge management
v. Mitigation and low carbon development and
vi. Capacity building and institutional strengthening

The BCCSAP was developed through a participatory process involving all relevant Ministries and agencies, civil society, research organisations and the business community. Programmes funded under the Action Plan will be implemented by line Ministries and agencies, with participation, as appropriate, from other stakeholder groups, including civil society, professional and research bodies and the private sector. Therefore, the role of the private sector is defined in the implementation of BCCSAP.

Sectoral Adaptation Policies

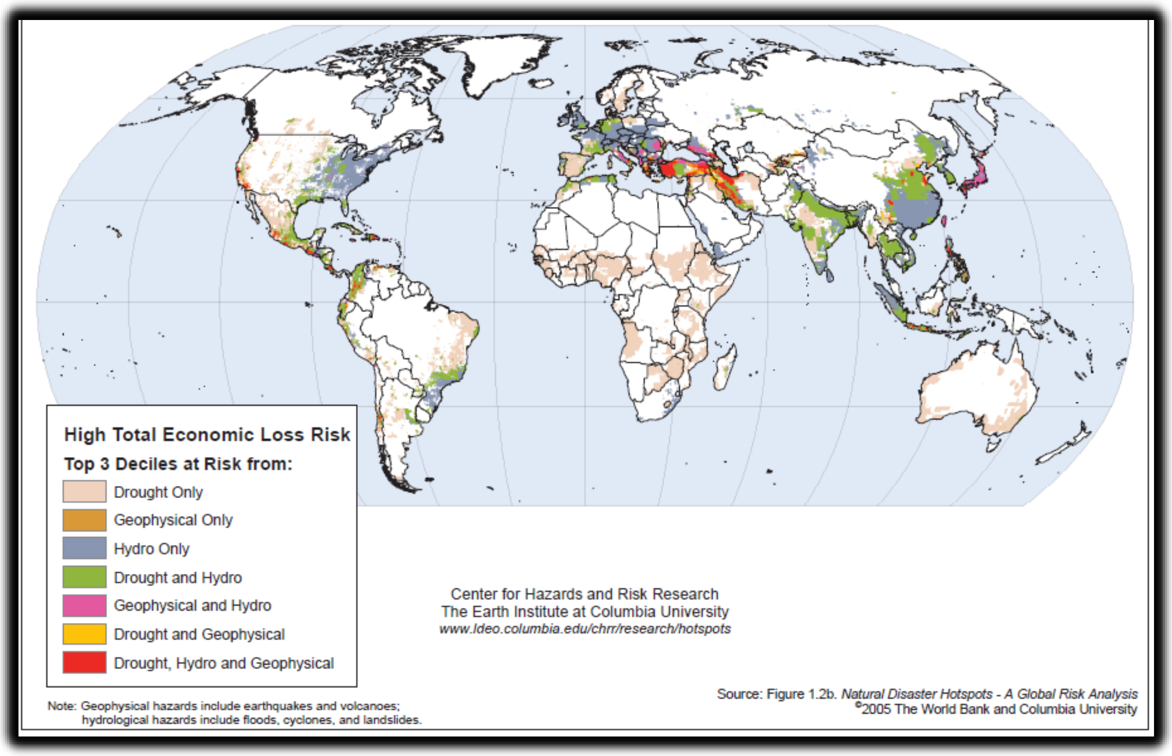
A number of sectoral policies and plans were developed by the Government of Bangladesh since the 1990s. Considering the fact that Bangladesh is highly susceptible to climate change, only one sectoral policy on the Coastal Zone has considered climate change (BCAS, 2010). The National Water Policy (NWP) formulated in 1999, considered short, medium and long-term perspectives for water resources in Bangladesh. The NWP was followed by the National Water Management Plan (NWMP) in 2001. Although there is a huge effect of climate change on water resources in Bangladesh, the NWP does not mention the climate change issue at all. However, the NWMP identifies climate change as one of the future elements affecting supply and demand of water. The National Environmental Management Action Plan (NEMAP), which was published in 1995, does not adress climate change issue. Similar to NEMAP, the National Land Use Policy (NLUP) and the National Forest Policy (NFoP) does not make direct reference to climate change either. Climate change was not also addressed in the Poverty Reduction Strategy (PRS) Papers until recently. The PRS recognizes the threat of climate change and its adverse impacts on the development process. It understands the need for integration and mainstreaming of adaptation measures into other policy areas and the implementation of the adaptation projects identified in the NAPA (BCAS, 2010). Moreover, Bangladesh is pursuing medium term five-year plan and long-term perspective plan where climate change adaptation needs in agriculture needs to be highlighted.

The findings of this dissertation, specially chapter 2 on crop switching as climate change adaptation and chapter 3 on crop diversification as climate change adaptation will produce some policy recommendations that would feed into the NAPA, BCCSAP and other sectoral adaptation policies.

1.4.3 Cyclones and impacts in Bangladesh

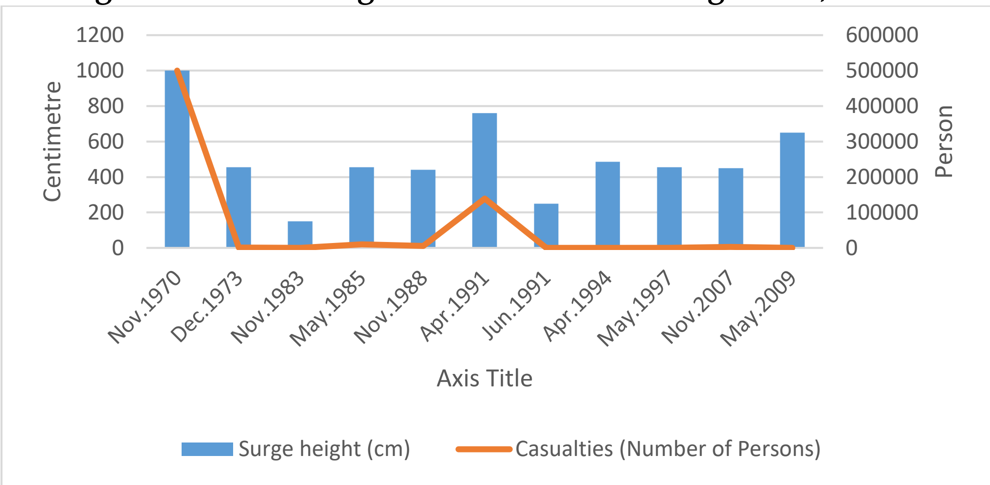
Bangladesh is the safe landing ground of many hydro related natural disasters. In the global perspective, Bangladesh is known as the hydro and drought prone country which is displayed in the Map 1.1(Center for hazards and risk research, 2005). It also shows that Bangladesh is ranked in the top 3 deciles at risk from hydro and drought related disaster.

Map 1.1: Global distribution of highest risk disaster hotspots by hazard type



The Bay of Bengal is regarded as the source of tropical cyclones that hit the coastal area of Bangladesh during pre-monsoon (April and May) and post-monsoon (October and November) seasons. The conical shape of the Bay of Bengal is considered to be significant when assessing the frequency of cyclones landing on the coastal area of the country. Over the last 50 years, 15 mega cyclones with wind speeds from 140 to 225 km/hr have hit the coastal area of Bangladesh. Seven of them hit in pre-monsoon and rest in the post-monsoon season. The coastal area of Bangladesh is more vulnerable to cyclones than other regions in the Bay of Bengal (General Economic Division, 2009). In recent history, the cyclone of 1970 was the deadliest with a 1000 centimeter tidal surge claiming 500,000 lives of the coastal region of the country. Another remarkable cyclone hit in 1991 that claimed 138,000 lives of the south east coastal region of the country. The most recent mega cyclone named Aila hit in 2009 in the southwestern coastal districts of the country, claiming 300 lives. It is worth mentioning that an early warning system, which has been introduced as a part of disaster management in the country, has contributed significantly in reducing the deaths caused by cyclones in the recent years. But the losses from the disaster are still enormous as the assets of households in the coastal areas are physically exposed to the cyclone. Chapter 4 of this dissertation will present a detailed analysis of Cylone Aila and its immediate losses.

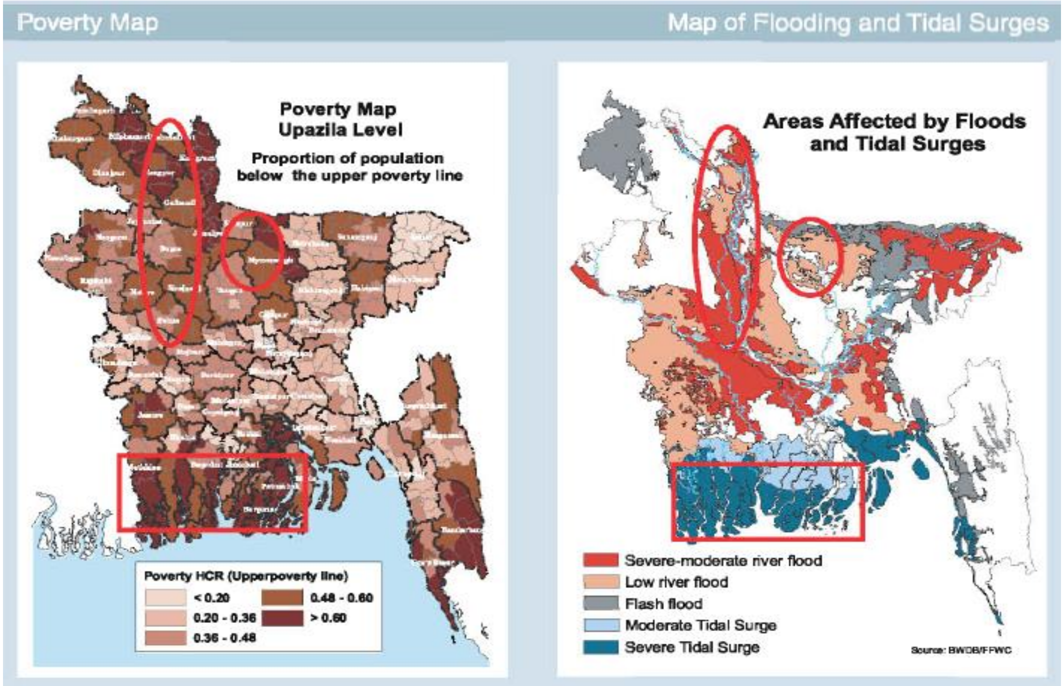
Figure 1.8: Tidal surge and casualties in Bangladesh, 1970-2009



Please note that this figure has been prepared on the basis of the data given by General Economic Division (2009)

Map 1.2 presents a comparison of the areas stricken by climate hazards and the distribution of poverty in Bangladesh. In the left panel, the map shows the poverty prone areas while the right panel map displays the areas affected by floods and tidal surges of the country. It is clearly evidential from the map that areas affected by severe floods and tidal surges are mostly poor compared to the unaffected areas. For instance, the southern coastal areas displayed by the rectangle, are affected by severe tidal surge and have highest incidence of the poverty in terms of head count ratio (HCR). This gives me a foundation of research interest for looking into the poverty impact of the disaster event.

Map 1.2 : Climate hazards and poverty in Bangladesh



Source: (World Bank, 2010)

1.5 Summary of the Structure of the Dissertation

This research is based on the agricultural household model where the households use capital and labour and maximize utility through consumption. They treat the climate change/extreme events as idiosyncratic risk. In addition, they cannot allocate risk efficiently through community level mechanisms. Households from the rural areas across Bangladesh will be the population of this research while agricultural household will be the sample unit of this research. This section presents the overall structure of the research highlighting the research objectives, contribution to literature and rationale behind choosing the specific case studies.

1.5.1 Chapter 2: Crop Choice as Climate Change Adaptation

This research examines crop switching as a means of climate change adaptation. Which crops (crop switching) farmers are likely to choose in response to the climate change scenario (temperature and rainfall) will be examined in this research. From a couple of adaptation strategies in agriculture, this research will focus on crop switching as a means of climate change adaptation because of the existing research gap in the south Asian nations.[5] Moreover, household income and expenditure survey (HIES), a nationally representative big data set of Bangladesh supplies the repeated crop choice statistics of the rural households of the country that provides the opportunity to work on crop choice as climate change adaptation. A sample of 11,389 farmers across the country from the years 2000, 2005, and 2010 provides the scope of looking into the structural stability of the repeated and single year cross sectional models which ultimately refine the crop switching prediction.

This research unravels an improvement over the existing literature as it uses pooled cross section to predict future crop choice probability while the existing literature uses single cross section to do this (Kurukulasuriya & Mendelsohn, 2008; Seo and Mendelsohn, 2008). In addition, it examines the structural stability of the different models to look at the steadiness of the impacts of the climate and other variables on crop choice which is not addressed in the other similar literature. There are two strands of literature on the relation between crop sector and climate change adaptation. The first strand of literature mainly deals with how the climate change adaptation affect yield or crop productivity. This strand of literature mainly attempts to measure the effect of climate change adaptation on yield or productivity of different specific crops. Second strand of literature mainly focus crop choice as climate change adaptation where crop switching is only one dimension of crop choice. This research contributes to the second types of literature focusing crop switching as climate change adaptation strategy.

It is evidential that climate change has a devastating effect on agriculture in low-latitude countries. But, empirical work on crop choice is virtually non-existent in these areas (Wang, Mendelsohn, Dinar, & Huang ,2008). The non-

[5] Chapter 2 will present the recent literature on crop choice as climate change adaptation in details.

existent work of this type of study in South Asia, a region that is highly vulnerable to climate change provides the justification for conducting this research on Bangladesh, a potential worst victim country of climate change from this region (Parry, Intergovernmental Panel on Climate Change. Working Group II., World Meteorological Organization., & United Nations Environment Programme., 2007). Different national and international forums on climate change also recognise Bangladesh and its big agriculture sector[6] as seriously vulnerable to climate change (General Economic Division, 2009, 2011; World Bank, 2010). Therefore, researching on climate change and agriculture in Bangladesh carries enormous importance for Non-annex 1 countries of the world.

1.5.2 Chapter 3: Crop Diversity as Climate Change Adaptation

This research examines crop diversification as a means of climate change adaptation and also looks into quantitatively how farmers would diversify current crop choices in response to future climate scenarios of rainfall and temperature. Like crop switching in chapter 2, this research will pick up another means of climate change adaption in agriculture, i.e. crop diversification. Like the research on crop switching as climate change adaptation in chapter 2, the motivation of the research on crop diversification as climate change adaptation comes from the non-existence of the empirical work on climate change adaptation in agriculture in the low latitudes where climate change is expected to have a devastating effect on it (Wang et al., 2009). Although since 2009 till now, a good number of paper on climate change and crop sector have evolved in the context of the developing countries, those works mainly focus on the link between climate change adaptation and its impact on crop yield. Literature on crop choice in the form of diversification as climate change adaptation is still non-existent in the south Asian countries that provides the motivation for conducting

[6] Please note that agriculture sector employs 45% of labor force of the country.

the research on the crop choice of Bangladeshi households as climate change adaptation.

Crop diversification as climate change adaptation is an under researched area. Moreover, it uses pooled cross section to predict a reliable and refined future crop diversity. In addition, this research depicts the estimated relationship between the crop diversity with confidence interval and climate variables that show the differences in farmers' response from different landscape with different climate conditions. The findings of this research yield some policy suggestions that can be fed in the national adaptation policies and actions in Bangladesh.

1.5.3 Chapter 4: Natural Disaster and Income and Consumption Dynamics

This research will look into how the households recover after asset and income shocks caused by cyclone Aila and whether any divergence or convergence takes place in income growth in the recovery path. It will also investigate how the consumption pattern behaves after asset and income shocks from cyclone Aila and examine whether any divergence or convergence occurs in consumption in the recovery path. This research uses the 'difference in difference' (DID) estimation method to investigate the income loss from cyclone Aila compared to the non-affected similar areas. It also attempts to look at how resilient the households in the treatment areas are in gaining income growth in the recovery period.

The effect of disaster on poverty is context specific as mentioned by Hallegate et al. (2016). Therefore, the current research on the effect of cyclone Aila will provide a new context of the effect of disaster. Moreover, this research compares the effects of disaster between the affected and unaffected areas in a quasi- experiment set up which is not commonly done in the similar literature. In addition, this research is intended to explore the effect of disaster in the medium run while most literature on the effect of disaster considers the immediate or short run effect. This research incorporates the ex ante characteristics of the households and their impacts on the ex post disaster effect which is not done in the similar literature. Finally, this research will set up a new dimension of exploring the link between poverty and disaster focusing income, asset and consumption that can be applied in other developing countries of the world.

Researches on Aila (Kumar, Baten, Masud, Osman, & Rahman , 2011; Akter and Mallick, 2013; Ahsan and Takeuchi, 2015) mainly focus on the immediate impact of the cyclone Aila and its detrimental impacts on the communities. Therefore, there is a research gap to look into the impact of the recovery from the cyclone Aila in the longer period than immediate. Moreover, the present research compares both the poor and non-poor households of the affected areas with those of the less or no affected areas which is a new dimension on the research on Aila. Finally, for three specific reasons, research on the impact of disaster in Bangladesh draws special attention- a) the country is known as safe landing ground of natural disaster, b) it is a potential climate change vulnerable country, and c) incidence of poverty is high in the country.

This chapter sets up the context of the research of the next chapter. After investigating the medium-term impact of Alia in this chapter, the next chapter will examine whether any poverty trap occurs due to Aila in the affected areas.

1.5.4 Chapter 5: Natural Disaster, Poverty Dynamics and Poverty Trap

This research examines poverty dynamics in the wake of cyclone Aila and the effects of different hypothetical asset losses on top of the existing asset loss on the dynamism. It also investigates the existence of a poverty trap in case of households affected by cyclone Aila in the coastal region of Bangladesh. This research examines empirically the effect of different coping strategies on asset growth. Finally, this research will compare the extent of the poverty traps of the affected areas with the unaffected areas.

This poverty trap analysis is based on the empirical evidence of consumption smoothing: sacrificing savings and investments which provides a theoretical foundation of the poverty trap analysis. This research validates the influence of assets on the household's welfare and uses the asset-based approach with empirical data to examine the existence of a poverty trap as a consequence of a natural disaster. Both parametric and non-parametric approaches have been used for affected and un-affected areas to separately capture the impact of shocks: this is unique in the relevant literature. In addition, this research incorporates the coping strategies in the asset-based livelihood function, which is an improvement over the existing estimation procedure of asset indexing. It will also compare the poverty trap situation in the areas affected by the disaster with that of the unaffected areas which is not addressed in the existing literature.

Two strands of research on assets and poverty traps in the developing countries evolve in the recent times. The first strand is based on micro-economic perspective and uses household-level data of assets to examine the existence of a critical threshold, above which asset acceleration happens, and below which asset dynamics move towards a low-level equilibrium, in which households are trapped in poverty (Barrett, Carter, & Little, 2006; Carter & Barrett, 2006; Giesbert & Schindler, 2012). The second type of research is based on macro-economic perspective and investigates the existence of low-level equilibria and the divergence of living standards between regions and countries and to what extent this is linked with 'adverse geography' (Bloom, Canning, & Sevilla, 2003; Bowles, Durlauf, & Hoff, 2006; Kanbur & Venables, 2005). This research follows the first stream.

Few empirical studies in the poverty trap literature (Adato, Carter, & May ,2006; Hoddinott, 2006; Carter et al. 2007; Giesbert & Schindler, 2012; Quisumbing & Baulch ,2013) explicitly consider the role of shocks on asset dynamics and the poverty trap. There is even less evidence of the impact of household shock coping strategies on asset accumulation. Carter et al. (2007) and Giesbert and Schindler (2012) take the coping behaviour into account while investigating the poverty trap. But these papers do not consider the impact of coping behaviour on asset growth while an asset index has been constructed. Moreover, comparing the poverty trap situation in shock affected areas with unaffected areas is a new dimension in this literature. This comparison is very much important in terms of policy implication.

1.6 Conclusion: Rationale of Dissertation

Climate change has been evidential day-by-day through scientific research and the world has accepted this as a potential threat to global economy. Climate change vulnerability of the different regions of the world, especially South Asia, has been brought into focus in the flagship report of the IPCC. Bangladesh, a developing country from this region has been regarded as one of the most vulnerable countries of the world, in terms of the impacts of climate change. Long term increases in temperature, the erratic nature of rainfall, and frequent climate hazards are the evidence of climate change in Bangladesh. Moreover, it is expected that the predicted sea level rise will inundate the coastal districts of Bangladesh, which will dislocate around 10 million people. Since Bangladesh is a highly populated country with a small land area, ensuring food security in the face of climate change is a big challenge. To begin to address this, adaptations to agriculture which may lead to sustaining the food security is a priority for the survival of the majority of the population. Moreover, 85 percent of the crop production is rice. Therefore, this research focuses on rice varieties. Crop switching and crop diversification will be investigated as climate change adaptation strategies in Bangladesh. The findings from the research on crop switching and diversification as climate change adaptation will suggest some policy recommendations that would feed into the NAPA, BCCSAP and other sectoral adaptation policies.

In the development planning of Bangladesh, adaptation mechanisms need to be well defined. In the subsequent five-year plan and long term perspective plan, adaptation deficit and implementation mechanisms need to be incorporated. Moreover, more research on climate change adaptation strategies and their implementation mechanisms needs to be done in both public and private sector.

Incidence of poverty is a longstanding challenge in Bangladesh. Although HCR decreased to 23.2% in 2015 from 39.1% in 2005, climate hazards like cyclone in the coastal districts evidentially put a setback on the poverty reduction momentum. Therefore, looking into the poverty impact of climate hazards is a very timely issue for the country. Moreover, internationally there is scant research on the poverty impact of cyclones, which gives motivation for this research. Finally, research on cyclone Aila will provide a new context that will be valuable to the other disaster prone developing countries of the world.

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Chapter 2

Crop Choice as Climate Change Adaptation: Evidence from Bangladesh

Abstract

This paper examines whether crop choice is affected by climate change. I have used a sample of 11389 farmers across Bangladesh from the years 2000, 2005 and 2010 and 30 years moving average of rainfall and temperature against each year. Using multinomial logit model, I regress climate variables and other household level socio-economic factors on crop choice. This regression result implies that crop choice is climate-sensitive. Households in the high rainfall areas choose rain-fed Aman rice as their dominant crop while farmers of low rainfall areas select irrigation based Boro rice. Using the estimated results, I simulate the impact of different climate change scenarios on crop choice and find that a shift in crop choices will take place in Bangladesh. Especially, temperature increase will upset rainfed Aman rice crop choice and make the farmers to choose irrigation based Boro, Aus and other crops. Unlike temperature, rainfall scenarios are not damaging for rain-fed rice crop choice. This paper also unveils a shortcoming of structural stability between different single cross-sectional models to simulate the effect of climate change scenarios on crop choice. Changes in future rice cropping pattern in Bangladesh come up as findings of this research, which indicate important policy implications for climate vulnerable developing countries.

2.1 Introduction

This paper examines crop switching as climate change adaptations. This research uses repeated cross-sectional evidence to explore how farmers would adapt to exogenous environmental factors such as temperature and rainfall. By comparing choices of farmers who face different environmental conditions across the landscape, I examine empirically how farmers would adjust their current choices in response to future climate. In this paper, I apply structural Ricardian technique[7] to study how climate affects the choice of crops by Bangladesh farmers. I quantify which crops (crop switching) and how many crops (crop diversity) farmers are likely to choose in response to the climate change scenario. As estimation methods, crop switching uses multinomial regression technique while crop diversity uses negative binomial count model. A sample of 11,389 farmers across the country from the years 2000, 2005, and 2010 provides the scope of looking into the structural stability of the repeated and single year cross sectional models which ultimately refine the crop switching and crop diversity prediction.

To investigate crop switching as climate change adaptation, at first, I estimate a pooled cross-sectional model and find that major crops are climate sensitive and crop characteristics determine sensitivity of climate variables to a particular crop. For instance, Aman, a rain fed rice variety shows its sensitivity to rain fall (coefficient -0.03 as log odds) in its production period. Some of the agricultural inputs like irrigation and socio-economic indicators like house space are important to determine the crop choice. From the estimated relationship between crop choice probability and climate variables, I find that probabilities of the major crops across the farmers in the lower and higher rainfall (temperature) areas compared to the mean rainfall (temperature) areas were more sensitive to rainfall (temperature) levels, as their corresponding 95-percent confidence intervals become wider. This paper also unveils a shortcoming of structural

[7] Kurukulasuriya and Mendelsohn (2008) improves the structural Ricardian model that I use in this paper.

stability in single cross-sectional data as the differences among the estimated results from different cohorts of cross-section at different time periods were significantly different. Therefore, I use the estimated results from the pooled cross section to simulate the crop choice probability in response to the different climate scenarios and find that a shift in major crop choices, especially from rainfed Aman rice towards irrigation based Boro rice and non-rice varieties, will take place in Bangladesh. This finding has an important policy implication in agriculture, fertilizer, seed, subsidy and above all food security of the country.

This research registers an improvement over the existing literature in the following ways: a) this paper uses pooled cross section to predict future crop choice probability while the existing literature uses single cross section to do this; b) it gets better estimates of the coefficients; c) it evaluate the dynamic aspects of crop choice; d) it examines the structural stability of the different models to look at the steadiness of the impacts of the climate and other variables on crop choice and diversity, and finally e) this research depicts the estimated relationship between the probability of choosing the crops (number of crops) with confidence interval and climate variables. So, this paper can show the difference in response of the farmers from different landscape with different climate factors.

There is one strand of literature that focuses on the impact of adaptation on farm productivity outcomes (Di Falco et al.,2011; Di Falco & Veronesi, 2014; Gorst, Groom & Dehlavi, 2015). There is another strand of recent literature that explores how farmers change their crop choice varieties as a way of climate change adaptation(Kurukulasuriya & Mendelsohn, 2008; Seo & Mendelsohn, 2008; Wang, Mendelsohn, Dinar, & Huang, 2009). The present research belongs to the second strand of recent literature. Primarily, non-existence of the research on crop switching as climate change adaptation in the lower latitude countries provides the motivation to conduct this research. Moreover, existing literature uses single cross section data at a small scale while the present research uses national level pooled cross section data. This research is the first to study how farmers change their crop choices under different climate change scenarios in

Bangladesh at the country level. Extensive literature survey also confirmed that there is a research gap on crop switching as climate change adaptation in the south Asian countries that is representative at country level.

The rest of the paper is structured as follows. Literature review is done in Section 2.2. while sections 2.3 presents data description. Section 2.4 discusses theoretical framework and empirical methods. Then, section 2.5 discusses estimation results and section 2.6 presents the simulated results under different climate change scenarios using the estimation results used to analyze farmers' crop choice in the presence of climate change. Finally, Section 2.7 ends the paper with conclusions and policy implications.

2.2 Literature Review

2.2.1 Risk in Agriculture

Agriculture sector has undergone a lot of risks. The major risks are production risks, financial risks, policy or institutional risks etc. (Just, 1975a) has mentioned three sources of risk and uncertainty in agricultural problems: risk associated with environmental (and technological) factors such as weather, diseases, pests, and improved crop varieties and livestock breeds; risk associated with market factors such as supply in other exporting countries, export demand, input supply, and competing demand for inputs; and uncertainty with respect to policy changes such as the form of government programs, the level of supports, and the regulation of pesticides and wastes. Which type of risks between price and production risks is more important for the farmers depends on whether the farmers are expected profit maximize or utility maximize. If any farm household maximizes its profit, then all price risk terms can be disregarded in supply response estimation and only production risks are to be considered Just (1975b).

Just (1974) has shown an empirical investigation of the importance of risk in farmers' decisions. This paper using the acreages harvested of the important field crops as the dependent variables and subjective variance of returns for wheat, allotment, price support and so on as the dependent variables has shown that well over 90 percent acreage variation in the San Joaquin Valley, the most important district of the research area, is explained when risk variables are included in the analysis. In case of the crops for which government has strong regulated programs, risk could not be shown to be of importance. One of the major goals of the government is stabilization of farm prices and income. This claim has been substantiated in the paper of Just (1974) showing that 'Feed grain programs' have been successful in achieving stability for grain sorghum, barely and corn returns. How environmental variables effect the production risk is relatively a new dimension of research. A paper (Edeh, Eboh, & Mbam, 2011) taking the case of a Nigeria shows that the feature of rainfall intensity and duration greatly effects the variability of rice yield in the study area.

2.2.2 Climate Change Adaptation in Agriculture

Among different production systems, agriculture faces significant adverse effects of climate change.[8] Among others, Bradshaw, Dolan, and Smit (2004) and Di Falco, Veronesi, and Yesuf (2011) suggested various means to climate change adaptation such as crop diversification, mixed crop-livestock farming systems, changing planting and harvesting dates, using drought-resistant varieties and high-yield water-sensitive crops.

There is one strand of literature that focuses on the impact of adaptation on farm productivity outcomes. Di Falco et al. (2011) have examined the impact of adaptation on farm households' food productivity in the Nile basin of Ethiopia. They investigate how farm households' decision to adapt, through implementing a set of strategies (e.g., changing crop varieties, adoption of soil and water conservation strategies) in response to long run changes in key climatic variables such as temperature and rainfall, affects food crop productivity in Ethiopia. The major findings of this research are- (a) there are significant and non-negligible differences in food productivity between the farm households that adapted and those that did not adapt to climate change, (b) adaptation to climate change increases food productivity, (c) the impact of adaptation on productivity is smaller for the farm households that actually did adapt than for the farm

[8] See W. R. Cline (2007) for a detailed description of the adverse effects of climate change on agriculture.

households that did not adapt in the counterfactual case that they adapted. They also analyzed the drivers behind adaptation. Econometric results show that information on both farming practices (irrespective of its source) and climate change is crucial in affecting the probability of adaptation. It is found that farm households with access to credit are more likely to undertake strategies to tackle climate change. Di Falco and Veronesi (2014) investigates whether the set of strategies (e.g., change crops, soil and water conservation) implemented in the field by farm households in response to long-term changes in environmental conditions (e.g., temperature and rainfall) affect production risk exposure which is based on the survey undertaken in the Nile basin area of Ethiopia in 2005. The major findings of the research are- (a) climate change adaptation *reduces* downside risk exposure i.e. farm households that implemented climate change adaptation strategies get benefits in terms of a decrease in the risk of crop failure, (b) farm households that did not adapt would benefit the most in terms of reduction in downside risk exposure from adaptation; there are significant differences in downside risk exposure between farm households that did and those that did not adapt to climate change, and (d) provision of information through radio, farmer-to-farmer extension, and extension officers is a key driver of adaptation. The analysis also shows that the quasi-option value, that is the value of waiting to gather more information, plays a significant role in farm households' decision on whether to adapt to climate change. Farmers that are better informed may value less the option to wait to adapt, and so are more likely to adapt than other farmers. Gorst, Groom and Dehlavi (2015) found that there are significant positive productive benefits from adaption for most of the farmers in case of wheat and cotton production in Pakistan.

There is another strand of recent literature that explores how farmers change their crop choice varieties as a way of climate change adaptation. Some studies – such as (Kurukulasuriya & Mendelsohn, 2008; Seo & Mendelsohn, 2008; Wang, Mendelsohn, Dinar, & Huang, 2009) - examine crop choices as adaptation strategies in agriculture mainly in Latin America, Africa, and China. Although climate change has a devastating effect on agriculture in low-latitude countries, Wang, Mendelsohn, Dinar, and Huang (2008) stated that empirical work on crop choice is virtually non-existent in these areas. The non-existent work of this type of study in South Asia, a region that is highly vulnerable to climate change provides the justification for conducting this research on Bangladesh, a potential worst victim country of climate change from this region (Parry, Intergovernmental Panel on Climate Change. Working Group II., World Meteorological Organization., & United Nations Environment Programme., 2007). Different national and international forums on climate change also recognise Bangladesh and its big agriculture sector[9] as seriously vulnerable to climate change (General Economic Division, 2009, 2011; World Bank, 2010). Therefore, researching on climate change and agriculture in Bangladesh carries enormous importance for Non-annex 1 countries[10] of the world.

Existing literature of crop switching as climate change adaptation mainly uses single cross-sectional data. For instance, Seo and Mendelsohn (2008), taking 2,000 farmers from eight Latin American countries, finds that Latin American farmers adapt to climate change by changing crops. They also show that both temperature and precipitation affect the crop choice of Latin American farmers and predictions on the impact of climate change must reflect not only changes in yields or net revenues, but also crop switching. Wang, Mendelsohn, Dinar, and Huang (2008) show that Chinese farmers also adapt to climate change by switching crops. From a cross sectional data of 8,405 farmers in 28 provinces in China, they find that Chinese farmers are more likely to irrigate in case of lower temperatures and less precipitation. Oil crops, maize, cotton, and wheat are the chosen crops of farmers in warmer regions and they choose to produce vegetables, potatoes, sugar, and, to a lesser extent, rice and soybeans. Farmers in wetter regions tend to choose soybeans, oil crops, sugar, vegetables, cotton, and rice, while they produce less potatoes, wheat, and maize. The paper also shows that future climate scenarios will cause farmers in China to reduce irrigation and shift toward oil crops, wheat, and cotton, moving away from potatoes, rice,

[9] Please note that agriculture sector employs 45% of labor force of the country.

[10] United Nations Framework Convention on Climate Change (UNFCCC) lists a number of especially climate change vulnerable countries which are mostly developing with low-lying coastal areas and those prone to desertification and drought.

vegetables, and soybeans. From a cross-country analysis of a sample of over 5,000 farmers across 11 countries in Africa, Kurukulasuriya and Mendelsohn (2008) finds that farmers shift the crops to match the change in climate. Arumugam et al. (2014) shows that there is a linkage between climatic variables and crop choice in Tamil Nadu India using a small sample of 60 households. But, they didn't show the dynamism of the crop choice under different climate change scenarios.

2.2.3 Climate Change and Adaptation in Agriculture of Bangladesh

Different national and international forums on climate change have referred Bangladesh as one of the most vulnerable countries in the world to climate risks (General Economic Division, 2009, 2011; World Bank, 2010). Bangladesh is vulnerable to river and rainwater flooding, mainly during the monsoon season. Two-thirds of the country is situated less than five meters above sea level. Once in every three to five years, up to two-thirds of Bangladesh is inundated by floods that cause substantial damage to infrastructure, housing, agriculture, and livelihoods. Low-lying coastal areas are also at risk from tidal floods and severe cyclones. On average, once every three years, a severe cyclone hits the coastal area of Bangladesh, either before or after a monsoon. Cyclones sometimes cause storm surges in excess of 10 meters. Crops and the livelihoods of the rural poor in low-lying coastal areas are also devastated by saline water intrusion into aquifers and groundwater and land submergence. Moreover, seasonal droughts irregularly hit the north western region of the country (General Economic Division, 2009, 2011; World Bank, 2010).

Agriculture is a key economic sector in Bangladesh, accounting for nearly 20 percent of GDP and 65 percent of the labor force. The achievement of food self-sufficiency remains a key development agenda for the country and is the first of six pillars in the Bangladesh Climate Strategy 2009 (General Economic Division, 2009). Climate change events and natural catastrophes cause great havoc in the crop production of Bangladesh. According to the Bangladesh Agricultural Year Book 2010, 113,465 metric tons of Aman rice and 369,591 metric tons of boro rice are lost due to flood, excessive rainfall, and flash flood in the years 2008-09 and 2009-10, respectively (Bangladesh Bureau of Statistics, 2010b). Being a highly-populous country, ensuring food security has been a long-standing challenge for Bangladesh. IPCC estimates that by 2050, rice production in Bangladesh could decline by 8 percent and wheat production could decline by 32 percent. The combined effects of rising temperatures, higher precipitation, CO_2 fertilization, severe flooding, occasional seasonal droughts, and loss of arable land in coastal areas resulting from climate change are expected to result in declines in rice production by 3.9 percent each year, or a cumulative total of 80 million tons over the years 2005–2050 (World Bank, 2010). Therefore, researching climate change adaptation in the agriculture sector of Bangladesh has important policy implications for the agriculture sector of the country and, ultimately, for ensuring food security for 3.5 percent of the people of the world.

A number of literature evolved in the recent years focus on the crop sector and climate change in Bangladesh. One strand of literature focuses on the impact of climate change on the yields of the crops in Bangladesh. Hoque & Haque (2016) found that people of the coastal area of Bangladesh who are exposed to different climatic vulnerabilities have been suffering from lower crop productivity and less cropping intensity. Based on the data from 240 households of Satkhira sadar upazila of Satkhira district and Kalapara of Patuakhali district of Bangladesh and long term climate data (1950-2010), they found that average yield level of Boro rice, Aman rice, vegetables and oil seeds underwent reduction by considerable amount due to erratic rainfall, increased intensity and frequency of drought, salinity, floods, cyclone, use of local varieties, increased incidences of pests and diseases etc. in the context of climate change. To examine the climate change impacts on agriculture, Banerjee et al. (2015) used a dynamic computable general equilibrium model linked with food security and found that impacts of climate change on agricultural sector were severe that led to reduce output by -1.23% and to reduce total caloric consumption by 17%. James and Winston (2011) find that climate change alters the temporal distribution of damages and slows Bangladesh's long-run adaptation into winter season rice production. To evaluate the impact of climate change on agriculture in Bangladesh by 2050.

Thomas et al. (2013) using climate data from four general circulation models (GCMs) found that using cultivars better suited for climate change and adjusting planting dates can lessen the impacts of climate change on yields, especially for rice, and in some cases actually result in higher yields. There is another strand of literature that focus on the agricultural inputs and climate change in Bangladesh. Using the data from 1800 Bangladeshi farm-households in eight drought-prone and groundwater-depleted districts of three climatic zones, Mohammad et al. (2014) found that farmers adopt science-driven and environmental resource-depleting adaptation strategies to alleviate adverse effects of climate change. Khan (2011) finds that, climatic change is likely to impact significantly upon surface and groundwater availability in Bangladesh and in other countries. This research also suggests the utilization of irrigation water from surface water sources to maximize the expected net social return from rice production. Extensive literature survey confirmed that crop choice under different climate scenarios in Bangladesh is not addressed till now that is a motivation of the current research.

2.3 Data Description

This research required the data of crop choices, temperature and rainfall, agricultural inputs, and household endowments. Other than temperature and rainfall, all data were collected from Household Income and Expenditure Surveys (HIES), an internationally-reputed and widely-used data set for evaluating the poverty situation and the standard of living of the people of Bangladesh conducted by the Bangladesh Bureau of Statistics with five-year intervals.

2.3.1 Household Information

The consistency of the data with the need of the present research constrained the researcher to using the HIES data of 2000, 2005, and 2010. A two-stage stratified random sampling technique was followed in drawing a sample of HIES under the framework of an Integrated Multipurpose Sample (IMPS) design developed on the basis of the sampling frame based on the Population and Housing Census 2001. According to the sample design, the survey was accomplished in one complete year (February 1, 2010 to January 31, 2011). In HIES-2010, 12,240 households were selected, with 7,840 from rural areas and 4,400 from urban areas. The number of households covered in the HIES increased from 7,440 in 2000 to 10,080 in 2005. Household information of crop choice, irrigation adoption, agricultural inputs, and household characteristics such as access to mobile phone and electricity from the HIES 2000, 2005, and 2010 constituted the repeated cross-sectional data, which are presented in Table 2.1. Agricultural households that produced crops either as landowners or tenants were considered as sample elements in this research.

Table 2.1: Household information of the HIES 2000, 2005, and 2010

Variables	HIES2000	HIES2005	HIES2010
Total number of households	7,440	10,080	12,240
Crop producing agricultural households	2,671	3,314	5,404
Mean Family Size	5.18	4.85	4.50
Mean Crop Choice	3.44	3.88	4.55
Inputs (% households)			
Irrigation	64.51	69.34	76.35
Fertilizer	88.02	90.10	96.26
Insecticides	61.70	59.14	78.08
Wage Labor	66.45	69.70	77.44
Electricity	22.76	35.40	47.11
Mobile phone	0.34	7.09	63.48

Source: (Bangladesh Bureau of Statistics, 2001, 2011)

Agricultural households adopting irrigation were on the rise over the period 2000-2010. In 2000, 64.51 percent of households adopted irrigation, which increased to 76.35 percent in 2010. Fertilizer use was widespread and increased over time. In 2000, 88.02 percent of households used fertilizer in their farms, which increased to 96.26 percent in 2010; 61.70 percent of households applied insecticides on their farms in 2000 and it increased to 78.08 percent in 2010. Dependency of agricultural households on wage labor increased over time. Wage labor was employed in 66.45 percent, 69.70 percent, and 77.44 percent in 2000, 2005, and 2010, respectively. Uses of electricity in the agricultural farming were becoming widespread in the country. Use of electricity in irrigation pumps and husking machines were cost-effective and time-efficient in the country. In 2000, 22.76 percent of households had access to electricity and then it more than doubled to 47.11 percent in 2010. Agricultural households in Bangladesh very quickly became connected with mobile phones. In 2000, only 0.34 percent of the sample used a mobile phone and then shot up to 63.04 percent in 2010.

2.3.2 Crops of Bangladesh

Rice is the major crop of Bangladesh. In 2009-2010, rice was cultivated in 78.2 percent of the agricultural land of the country, followed by wheat at 2.53 percent (Bangladesh Bureau of Statistics, 2010a). Three major varieties of rice - Aman, Boro, and Aus – were produced in the country. Table 1 presents the crop choice scenario and their dispersion over time. Mean crop choice of 2000 was reported as 3.44 and then increased to 4.55 in 2010. Standard deviation of the crop choice increasingly became wider over the period, indicating an increase in diversity in crop choice. According to HIESs, households with small farm size (up to 0.49 acre) dominated the agriculture sector of Bangladesh.

Figure 2.1: Percent of households producing different number of crops in 2000, 2005 and 2010.

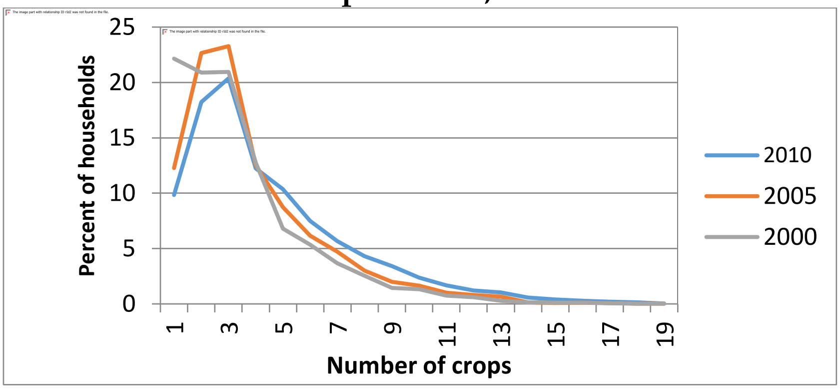


Table 2.2 summarizes the climatic characteristics of the six major crops in Bangladesh. Both Aman and Aus are rainfed rice crops, while Boro is irrigation-based crops. Both Aman and Aus require high temperatures for growing, whereas Boro and Wheat need moderately-low temperatures and irrigation for growing. Jute requires high temperatures and rainfall. Sugarcane is a perennial

crop, requiring high temperatures (12-30 C), high rainfall in growing, and low rainfall in maturity.

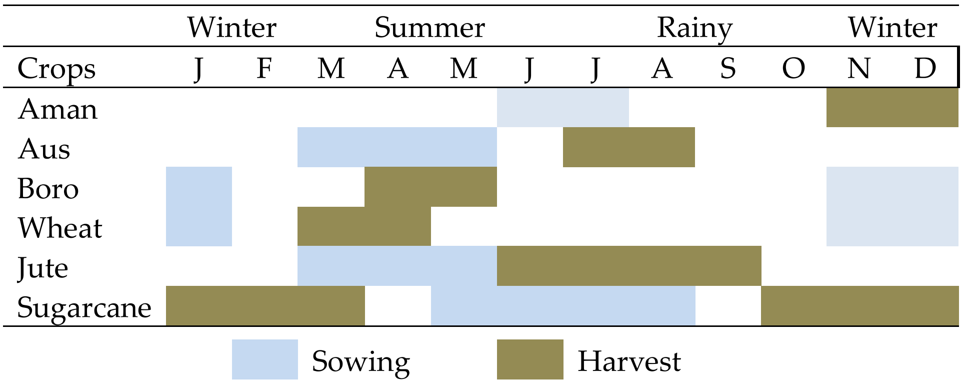
Table 2.2: Climatic characteristics of the six major crops in Bangladesh

Crop	Characteristics
Aman	Monsoon rainfed, deep water, low land
Aus	Rainfed, low land, high temperature
Boro	Irrigation, heavy soil, low land, low temperature
Wheat	Irrigation, lighter soil, low temperature
Jute	Wide variation in climate, wet land
Sugarcane	Perennial, high temperature (12-30), high rainfall in growing, low rainfall in maturity

Note: Crop characteristics are a summary from Bangladesh Agricultural Research Council (BARC) website

Figure 2.2 provides the sowing and harvesting period of the six major crops of the country. It shows that Aman is planted in the rainy season and harvested in winter, whereas Aus and jute are planted in the summer season and harvested in the rainy season. Boro and wheat are usually planted in winter and harvested in summer, whereas sugarcane is a perennial crop.

Figure 2.2 : Cropping pattern in Bangladesh



Note: Letters in the second row denote the first letter of the twelve months of the year beginning from January and the cropping patterns in Bangladesh are from Bangladesh Agricultural Research Council (BARC) website

2.3.3 Pattern of Land Ownership

Table 2.3 presents the percentage of household by land size (both owned and operated) in the rural area of Bangladesh. In the case of owned land, 60.5 percent of households belonged to the group of 0.01-0.49 acre land size in the HIES 2010, which was 47.6 percent in 1991. In the case of operated land, this number was 55.4 percent, but was 48.5 percent in 1991. The number of landless in both owned and operated land in 2010 was less than 5.0 percent in 2010. It is also worth mentioning that the percentage of households having land owned one acre or more decreased to 23.6 percent in 2010 from 33.2 percent in 1995 and 35.5 percent in 1991. On the other hand, the percentage of households having less than one acre of land owned (0.01-0.99) increased to 72.1 percent in 2010 from 61.3 percent in 1995 and 59.1 percent in 1991. The number of households with 7.5+ acre owned land represented 3.1 percent of households in 1991 and then decreased to 1.1 percent in 2010, showing a declining trend in the past two decades. These indicate that households with small farm size dominated the agriculture sector of Bangladesh.

Table 2.3: Rural household by size of land percent (owned and operated)

Land Size (in acre)	HIES-2010	HIES-2005	HIES-2000
	Owned Land		
Landless	4.6	5.3	5.6
0.01-0.49	60.5	55.2	60.0
0.50-0.99	11.6	12.4	9.5
1.00-2.49	14.6	17.6	15.4
2.50-7.49	7.6	8.7	8.1
7.50+	1.1	1.6	1.3
Total	100	100	100
	Operated land		
Landless	3.6	4.1	4.9
0.01-0.49	55.4	52.9	54.0
0.50-0.99	14.2	14.2	11.9
1.00-2.49	18.3	19.1	18.8
2.50-7.49	7.8	8.6	8.8
7.50+	0.7	0.9	1.6
Total	100	100	100

Source: : (Bangladesh Bureau of Statistics, 2001, 2011)

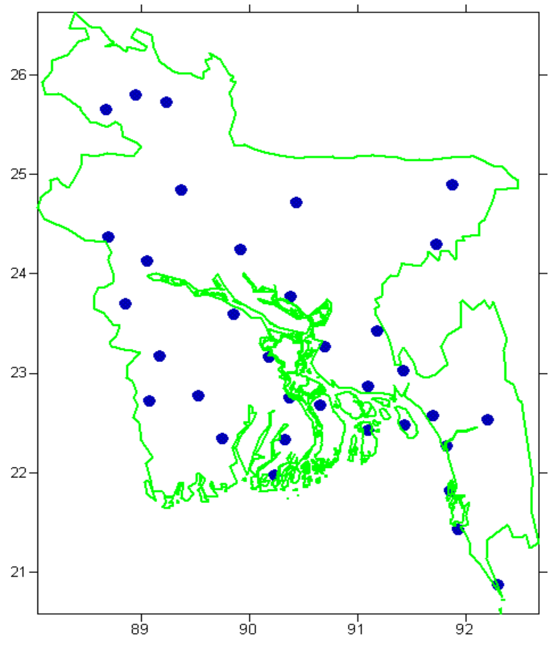
2.3.4 Environmental Data

Bangladesh possesses a subtropical monsoon climate marked by seasonal variations in rainfall, high temperatures, and humidity. Although there are six seasons in a year (summer, rainy, autumn, dry, winter, and spring) in Bangladesh, it is generally difficult to differentiate all the six seasons because of the overlapping and similarity among them. Conversely, there are three distinct seasons in Bangladesh, including a hot and humid summer from March to June; a rainy monsoon season from June to October; and a cool, dry winter from October to March. Generally, maximum summer temperatures vary between

30°C and 40°C in Bangladesh. April is reported as the warmest month in most parts of the country, while January is the coldest month, with temperatures around 10°C. Most areas of the country receive at least 2000 mm of rainfall per year, with the exception of the relatively dry western region of Rajshahi, where the annual rainfall is about 1600 mm. Because of its location just south of the foothills of the Himalayas, where monsoon winds turn west and northwest, the regions in north eastern Bangladesh receive the greatest average precipitation, sometimes over 4000 mm per year (Weather Online, 2015).

Environmental data used in this research are limited to temperature and rainfall. Bangladesh metrological department has 33 stations all over the country which are reporting the environmental data. Monthly data has been converted into seasonal data. Mean rainfall and temperature are calculated for the period 1996-2000, 2001-05 and 2006-10 and are used against the crop choice data of HIES2000, HIES2005 and HIES2010 respectively in the econometric model. Same environmental data have been assigned for all the households living in the metrological station areas.

Figure 2.3: Weather station maps of Bangladesh



Note: This map is taken from Bangladesh Metrological Office website. It indicates the locations of the metrological stations in the country

Moving average of annual temperature and all three seasonal temperature along with their dispersion for all three periods- 1971-2000, 1976-2005 and 1981-2010 increase gradually. Table 2.4 shows also shows that in case of rainfall and its dispersion, any clear trend is absent over the period.

Table 2.4: Mean annual temperature and rainfall in Bangladesh

	Temperature(Celsius)				Rainfall(mm/month)			
	Annual	Summer	Rainy	Winter	Annual	Summer	Rainy	Winter
1971-2000	25.61 (0.42)	27.64 (0.68)	28.32 (0.25)	20.86 (0.77)	176.55 (39.55)	202.57 (59.42)	309.31 (65.18)	17.79 (6.09)
1976-2005	25.67 (0.44)	27.72 (0.73)	28.42 (0.26)	20.86 (0.79)	180.56 (42.07)	207.57 (60.64)	317.64 (70.79)	16.45 (5.53)
1981-2010	25.80 (0.45)	27.87 (0.78)	28.52 (.0.27)	21.01 (0.83)	178.83 (39.78)	203.31 (56.77)	316.33 (67.43)	16.87 (5.52)

Note: Temperature and rainfall data are collected from Bangladesh Agricultural Research Council (BARC) database while standard deviations are author's own calculation (Bangladesh Agriculture Research Council, 2015)

This research considers the full year as a composition of three distinct seasons: summer (March to June), rainy (July to October), and winter (November to February).

2.4 Theoretical Motivation and Empirical Methods

An overwhelming number of studies (Amthor, 2001; W. Cline, 1992; W. Cline, 2010; Fuhrer, 2003; Rosenzweig & Parry, 1994; Tol, 2002) have contributed to the assessment of climate change impacts in agriculture. Those studies mainly looked into how temperature, carbon emission, sea level rise, and such climatic variables impacted the crop yields. Mainly agronomic models have been used in these studies by establishing a direct relationship between climatic variables and crop yields. Since these studies assumed that farmers make no change in crop choice, the predicted net revenue losses in the crop yield caused by the climatic variables were large.

There are four research approaches into the economic impacts of climate change on agriculture: agronomic, agro-economic, panel data and Ricardian.

Agronomic model: The objective of the Agronomic model is to optimise consumer and producer welfare, subject to the constraint of climatic and other factors imposed in the model. This model is based on detailed experiments to find the response of specific crops and crop varieties to different climatic and other conditions. Economic impacts - changes in acreage, supply by crop and region etc. are estimated by incorporating yield estimation results from crop simulation models e.g. from General Circulation Model (GCM) forecasts into economic models of the agricultural sector (Adams, 1999). The agronomic literature predicts large and dire yield losses (Rosenzweig & Parry, 1994), especially in many areas of Africa (Deressa, Hassan, & Poonyth, 2005; Gbetibouo & Hassan, 2005). In this model, if the economist fails to correctly predict the probable adjustments and adaptations, the estimates might be biased (Adams, 1999). Another disadvantage of agronomic models is that they have historically ignored the adoption of new technologies and most of them impose climate change scenarios on current agricultural systems (Mendelsohn, 2000). Agronomic models are usually associated with very high cost implications (Mendelsohn, 2000; Adams, 1999). Therefore, it is difficult to implement this model in poor and developing countries.

Agro-Economic Model: Agro-Economic model, another scientific method to assess the impact of climate on agriculture, is a combination of controlled experiments on specific crops, agronomic modelling, and economic modelling to determine climate change impacts (Adams and McCarl, 2001). The changes in yields derived from the agronomic model are embedded into an economic model, which determines crop choice, production, and market prices. Agro-Economic Model is difficult to apply to developing countries as it underestimates climate change adaptive measures (Mendelsohn and Neumann, 1999). Moreover, most developing countries do not have sufficient experiments to determine agronomic responses. Finally, economic models of developing country agriculture are poorly calibrated (Seo et al., 2005).

Panel data model: Panel data approach, using presumably random year-to-year fluctuations in realized weather across counties to estimate the effect of weather on agricultural output and profits (Deschenes & Greenstone, 2007). This approach controls time-invariant district-level unobservables such as farmer quality or unobservable aspects of soil quality. Moreover, this method uses data on actual field outcomes, rather than outcomes in a controlled experiment. Estimates from panel data will show intra-year adjustments by farmers, such as changes in inputs or cultivation techniques. However, by measuring the effects of annual fluctuations, the panel data approach does not reflect the possibility of longer-term adaptations, such as crop switching or exit from farming (Guiteras, 2009).

Ricardian Model: This model has been introduced by Mendelsohn et al. (1994) to estimate the impact of climate change on agriculture. The Ricardian model does not focus the relation between crop and yield. It is a cross-sectional technique that estimates the empirical relationship between land values and climate. In this model, land value is dependent variable while climate, soil, geographic characteristics and other socio-economic variables are used as independent variable. This method is based on the assumption that long-term land productivity is reflected in the land prices (Ricardo,1817). It incorporates different the agricultural activities of farms and controls for adaptation. This model assumes that the adjustments done by the farmers in response to current climate is reflected in the current land values. Thus, the model captures the efficient climate change adaptations adopted by the farmers. It also assumes that farmers will be aware of local climate (Van Passel et al., 2014). The Ricardian model captures the adaptations that farmers make and measures the final net impact (Mendelsohn & Dinar, 2003; Mendelsohn, Nordhaus, & Shaw, 1994). But, Ricardian model is not suitable to the developing country situation where land market does not function properly. Moreover, farmers are not always able to adopt autonomous adaptation strategies due to market constraints. Therefore, the problem with the traditional Ricardian approach is that it is a 'black box' as the actual adaptations by farmers are not revealed.

To overcome the shortcomings of the overstated four types of models Kurukulasuriya and Mendelsohn (2008) developed a structural Ricardian model. This paper will employ the developed structural Ricardian model with the following assumptions: i) farmers maximize their profits; ii) farmers choose the desired species to yield the highest net profit; iii) the probability that a crop is chosen depends on the profitability of that crop; and iv) farmers select multiple crops.

Consider that all inputs are classified into two types: X and Y. Further, we assume that X represents all those inputs which are not tenable to climatic conditions, while Y represents the opposite. In a one product and two inputs from the profit maximization framework, profit function will be as follows:

$$\pi\left(P_{Q,}P_{X,}P_{y};z\right) = \max_{X\,Y} P_{Q} f(X,Y) - P_{X}X - P_{y}Y \quad (1)$$

where z represents a combination of climate and all other inputs.

Every crop production associated with a particular level of threshold climatic variables results in the highest amount of production. IPCC uses the term “climate threshold” to define climate extreme. If C* is the threshold climatic condition and if C is the existing climatic condition, then C* - C is the climate shortage (excess). When climate shortage happens to a particular crop, the production process needs some complimentary inputs. For instance, a particular crop needs a specific amount of rainfall, or a level of temperature during its growing period, but if rainfall or temperature is not enough (excess) to support crop growth, some complimentary inputs like irrigation need to be adjusted by adding more costs to production. Therefore, how many inputs will be used also depends on the climatic condition.

If the farmers get optimal climatic conditions, the profit function can be rewritten as:

$$\pi^{*}\left(P_{Q,}P_{X,}P_{y};z\right) = \max_{X\,Y*} P_{Q} f(X,Y^{*}) - P_{X}X - P_{y}Y^{*} \quad (2)$$

Where Y* and π^{*} are the optimal inputs and optimal profit associated with a threshold climatic condition, respectively. Therefore, any deviation from the threshold climatic condition will make:

$$\pi^*(P_Q, P_X, P_y; z) \;\geq\; \pi(P_Q, P_X, P_y; z) \qquad (3)$$

Equations 2 and 3 imply that if climate unpredictability generates negative perception or uncertainty in the profitability of a crop, the farmer will attempt to switch to a new climate-resilient variety of crops to maximize his profit. Assume that ε represents the uncertainty in the profitability of the crop which originates from climate variability.

$$\pi^*(P_Q, P_X, P_y; z) - \pi(P_Q, P_X, P_y; z) \geq \varepsilon\,(P_Q, P_X, P_y; z) \qquad (4)$$

or, the profit function can be rewritten as follows:

$$\pi^*(P_Q, P_X, P_y; z) \geq \pi(P_Q, P_X, P_y; z) + \varepsilon\,(P_Q, P_X, P_y; z) \qquad (5)$$

Equations 1 to 5 deal with one crop problem.

Let me consider that every farmer has a chosen set of crops, m that ensures profit maximizing level of production subject to some constraints. It is also assumed that any other set of crops, n ($\forall\, m \neq n$) cannot ensure profit maximizing level of output.

In this setting, the farmer will prefer crop m to n if -

$$\pi_m^*(.) > \pi_n^*(.)\; for\; \forall\, m \neq n \qquad (6)$$

which can be rewritten as:

$$\varepsilon_n(.) - \varepsilon_m(.) < \pi_m(.) - \pi_n(.)\;\; for\; \forall\, m \neq n \qquad (7)$$

But farmers usually have to grow a range of crops. So, a farmer's maximization problem will be:

$$\max_m[\pi_1\,(.), \pi_1\,(.), \dots\dots\dots\dots\,.\, \pi_m\,(.)] \qquad (8)$$

The probability (P_m) of choosing crop m will be:

$$P_m \;= [\varepsilon_n(.) - \varepsilon_m(.) < \pi_m(.) - \pi_n(.)]\; for\; \forall\, m \neq n \qquad (9)$$

Assuming error term ε as independently Gumbel distributed and linearity in the parameters of profit function, probability function of choosing a particular crop from a set of crops will follow the multinomial logit model (Hausman & Mcfadden, 1984). So, the probability of choosing a particular crop j from a set of m crops by a farmer i will be:

$$P_{ij} = \frac{Exp(\beta' Z_{ij})}{\sum_{k=1}^{m} Exp(\beta' Z_{ik})} \qquad (10)$$

where the vector β gives the vector of effects of climatic and other input variables. The parameters can be estimated by the Maximum Likelihood Method, using an iterative nonlinear optimization technique such as the Newton–Raphson Method. These estimates are CAN (Consistent and Asymptotically Normal) under standard regularity conditions (McFadden, 1999).

On the basis of above theoretical foundations, this research intends to answer the following research questions:

1) Whether crop choice is affected by climate change (long-tern rainfall and temperature) in Bangladesh?
2) What is the relationship between crop diversity and temperature?
3) What is the relationship between crop diversity and rainfall?
4) What is the marginal effects of rainfall and temperature on crop diversity?
5) How the households change their crop choice in response to different scenarios of rainfall and temperature?

2.4.1 Empirical Methods

In order to answer those questions, this research intends to employ the following empirical strategy. For every farmer, the crop choice is defined as the single crop with the highest revenue. This research assumes that both profit and revenue are highly correlated or related by one-to-one. Farmers are choosing a range of crops as their top crops in terms of profit, which is giving the rationale for using multinomial logit model in this structural Recardian profit-maximization framework. When estimating the multinomial logit regression model, profit is the latent variable as it is implicit in the model. Around 85 percent of farmers cultivate three major rice crops (Aman, Aus and Boro) as their top crops in terms of revenue. Defining other crops as a single crop, we have used four crop choices as dependent variable in the model. Rainfall and temperature of three seasons (summer, rainy, and winter) in Bangladesh have been considered as explanatory variables. Other explanatory variables of the model are agricultural land owned by farmers, family size, agricultural inputs like irrigation, fertilizer, insecticides, wage labour, space of house, mobile phone, and electricity. Values of agricultural input variables are continuous between 0 and 1 and based on mauza (a smallest unit of land administration structure). The crops of the model are produced on various times of the year. Both planting and growing season's environmental characteristics are expected to impact the production of crops. Therefore, statistical significance of planting and growing a season's environmental characteristics implies special meaning in terms of environmental variables' effects on the particular crop's production.

Three cohorts of HIES 2000, 2005, and 2010 constituted the repeated cross-sectional data in this paper. The advantages of using the repeated cross-sectional data are to- a) get better estimates of the coefficients; b) evaluate the dynamic aspects of crop choice; c) make predictions regarding which control for the general trend in crop choices is happening, irrespective of temperature and precipitation. Four econometric models (three of which are from the three cohorts, respectively, and one from the amalgamated) will come up from the repeated cross-sectional data. This will give the researcher for this study the opportunity to look at whether the coefficients among the models were different or similar over time. If the models are different in terms of the values of the coefficients and the time trend is statistically significant, then the repeated cross-sectional model from big data set will give more reliable coefficients among the models. In that case, the estimated crop choice probability from the multinomial logit model of repeated cross-section data will be used for predicting the future trend of crop choice probability under different assumptions of climate change scenarios.

2.5 Estimated Results

In the estimation results, estimation of crop choice econometric models will be presented. In the first part, a comprehensive model of crop choice using all three cross sections of households will be estimated using the multinomial logit (MNL) regression method. Then the model will be repeated for each cross-section to look at how the crop choice is moving over time. This part will also present the existing sensitivity of crop choice to rainfall and temperature by presenting the crop choice probabilities against the environmental variables. This analysis will also be extended for irrigated and non-irrigated groups of the sample.

2.5.1 Results of MNL Regression

Table 2.5 presents the multinomial logit regression results. Boro rice was treated as a base case and so is omitted in the results. Rainfall and temperature of three seasons (summer, rainy, and winter) in Bangladesh are included in the model. Other explanatory variables of the model included agricultural land owned by farmers, family size, wage labor, space of house, mobile phone, and electricity. Table 2.5 presents the multinomial logit regression results. As we know from discussion of introduction section, the three crops of the model are produced at various times of the year and so the probable impact of both planting and growing seasons' environmental characteristics on the production decision of the crops can be identified by statistical significance of planting and growing seasons' environmental characteristics. A time trend and its square are included in the model. The coefficients of each explanatory variable indicated the log of odds which means the log of the probability of success as defined as the ratio of the probability of success over the probability of failure. Very high log of odds produces very high probability - close to 1 and vice versa. For example, log of odds 9.21 and -6.90 have probabilities of 0.99 and 0.001, respectively.

The rainy season in Bangladesh, which is characterized by the high rainfall due to the effect of a monsoon, is an important time period for all the three crops considered in the model in terms of their planting, growing, and harvesting. Accordingly, the estimation results show that coefficients of the rainy season are statistically significant for Aman and Aus crops compared to Boro rice. Even the previous season of rainy season has statistically significant coefficient for Aman rice as in Bangladesh, summer rainfall is not too less in amount compared to that of the rainy season. Average monthly rainfall of the summer season for the period 1981-2010 was 203.31 mm, which was 316.33 mm for rainy season. Rainfall in the winter season used to be a much-lower amount (16.87 mm/month)- compared to the rainy and summer seasons and so its coefficients are not statistically significant for all three types of crops. The cropping pattern of Bangladesh shows that Aman crop production period spans from summer to winter. The estimation results also show that both summer and rainy seasons' temperatures are sensitive to Aman crop production. Summer season temperature has statistically significant co-efficients for Aus rice as it grows in that season. Only the rainy season temperature is sensitive to other crops. Since 'other crops' include a wide range of crops, its sensitivity to temperature may not be straightforward.

Table 2.5: Multinomial logit regression of crop choice

Variables	Aman	Aus	Other crops
Summer rain	-0.02***	-0.01	-0.01
Summer rainsq	0.00***	0.00	0.00*
Rainy rain	0.02**	-00.04***	-0.00
Rainy rainsq	-0.00*	0.00***	0.00
Winter rain	-0.13**	0.03	-0.10
Winter rainsq	0.00***	-0.00	0.00
Summer	-11.40***	-12.88*	-8.29
Summer	0.21***	0.26*	0.17
Rainy temperature	126.47***	47.35	246.12***
Rainy temperaturesq	-2.26***	-0.93	-4.35***
Winter temperature	-2.43	-3.63	0.82
Winter	0.05	0.11	-0.02
Agriculture land	0.00	-0.00	0.01***
Operating land	0.00	0.00***	-0.03***
Crop production	-0.00***	-0.00***	0.00***
Wage labor	-0.27*	-0.85***	-2.89***
Family size	-0.02	0.03	-0.04*
House space	0.00***	0.00*	0.00***
Electricity	-0.60***	-0.26	-0.24
Mobile	0.28	0.00	0.16
Trend	-2.69***	-3.66***	-5.58***
Trendsq	0.86***	1.16***	1.97***
Constant	-	-394.00	-3385.14***

Note: 1) Boro rice is omitted as base crop. 2) Number of observations: 11389, Log likelihood ratio X^2: 6131.60 and PseudoR^2: 0.22. 3) *, ** and *** indicates 1, 5, and 10% level of significance, respectively.

The probability of choosing other crops compared to Boro is statistically significant for farmers who use wage labor in their farming. Family size, which is supposed to be a source of labor, was sensitive to only other crop production. Probability of choosing Aman over Boro is statistically significant for households connected with electricity. House space, which is a proxy for household endowments, is statistically significant for all three crops, although the value of the coefficient is close to zero. A mobile phone, which is supposed to be a source of agricultural extension services, was not statistically significant in this analysis which is counter intuitive. The effects of time trend and its nonlinear effect on all three crops are statistically significant, which has an important implication for future crop choice prediction.

The overall effect of climatic variables and other explanatory variables on crop choice was examined by two tests- the Wald test and likelihood ratio test. Wald test result shows that the parameters of all explanatory variables in together are statistically significant in explaining crop choice (Chi2=4078.73 and Prob=0.00). While I group the variables into environmental variables (Chi2=1077.35 and Prob=0.00) and other control variables (Chi2=3024.36 and Prob=0.00), their parameters separately are also statistically significant in explaining crop choice. The likelihood ratio test from the nesting model of only environmental variables into the model of environmental and other control variables shows that the parameters are statistically significant at 0% level of significance (LR Chi2=2211.78 and Prob=0.00). Table 2.6 shows that in both tests, environmental and other variables are statistically significant in explaining crop choice probabilities.

Table 2.6: Wald and likelihood ratio tests results

Wald Test		
Variables	Chi2	Probability
All Variables	4078.73	0.00
Environmental Variables	1077.35	0.00
Other Variables- Control	3024.36	0.00
Likelihood ratio test		
Model B** nested in Model A*	2211.78	0.00

*Model A includes all environmental and other control variables
** Model B includes all environmental variables only

2.5.2 Comparison among the Four Models: Structural Stability

Crop choice of three cross-sections in three time points gives the scope of comparing estimation results of the three models from three cross-sections. Due to space constraint, this research doesn't present the estimation results from those regression models. Structural stability compares the parameters of the different models and explores that whether they change over time. Chow type structural stability tests for three models- 2000, 2005 and 2010 show that for all three types of crops except base crop, difference in coefficients for each crop among the four models are statistically significant at 1% level of significance. This indicates that the coefficients from four models are different from each other in terms of their values. Differences among the models in terms of coefficient values encourage to use pooled cross section model by combining the three models for simulating crop choice probabilities on different climate scenarios.

Table 2.7: Structural Stability tests among the four models

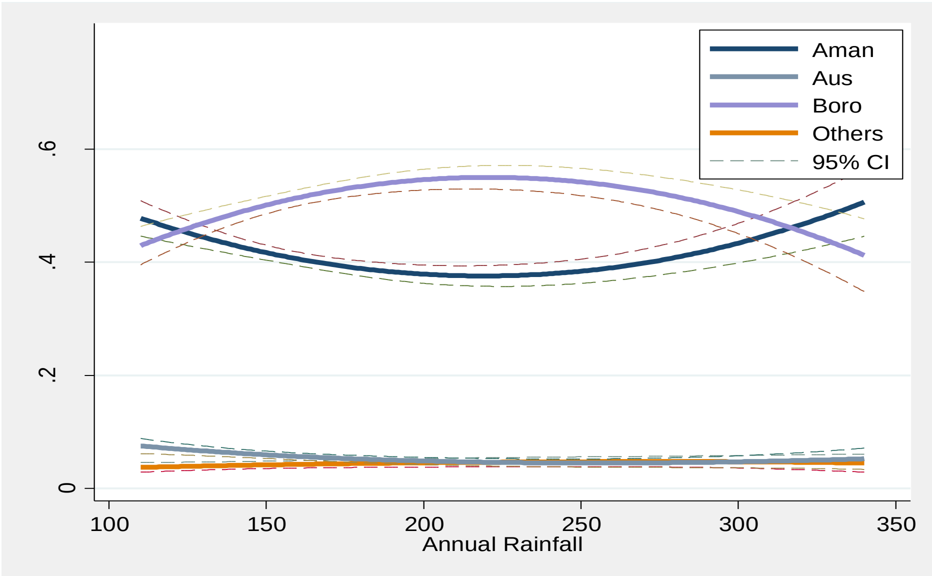
		2000 and 2005	
	Aman	Aus	Others
Chi2	175.70	118.80	118.04
Probability	0.00	0.00	0.00
		2005 and 2010	
Chi2	540.39	218.63	225.76
Probability	0.00	0.00	0.00
		2000 and 2010	
Chi2	487.45	130.35	227.65
Probability	0.00	0.00	0.00
		2000-10 and 2000	
Chi2	386.50	168.76	339.26
Probability	0.00	0.00	0.00
		2000-10 and 2005	
Chi2	435.20	165.33	318.57
Probability	0.00	0.00	0.00
		2000-10 and 2005	
Chi2	669.04	250.80	637.84
Probability	0.00	0.00	0.00

Note: Crop 2, Boro rice is the base crop in the MNL regression model and so omitted from the test.

2.5.3 Crop Choice and Rainfall

Figure 2.4 shows the estimated relationship between the probability of choosing four crops by the farmers with a 95-percent confidence interval and the annual mean rainfall measured in mm/month. Both Aman and Boro rice crops were sensitive to rainfall. As rainfall increases from its mean, farmers in the high rainfall areas choose more of Aman and less of Boro. Crop choice probabilities by the farmers in the lower and higher rainfall areas compared to the mean rainfall areas were sensitive to the rainfall, as their corresponding 95-percent confidence intervals were wider. To obtain a more accurate picture of the relationships between crop choices and rainfall, the behaviour of agricultural households needs to be analyzed by irrigated and non-irrigated groups.

Figure 2.4 - Estimated probabilities of crop choice with confidence interval over rainfall.

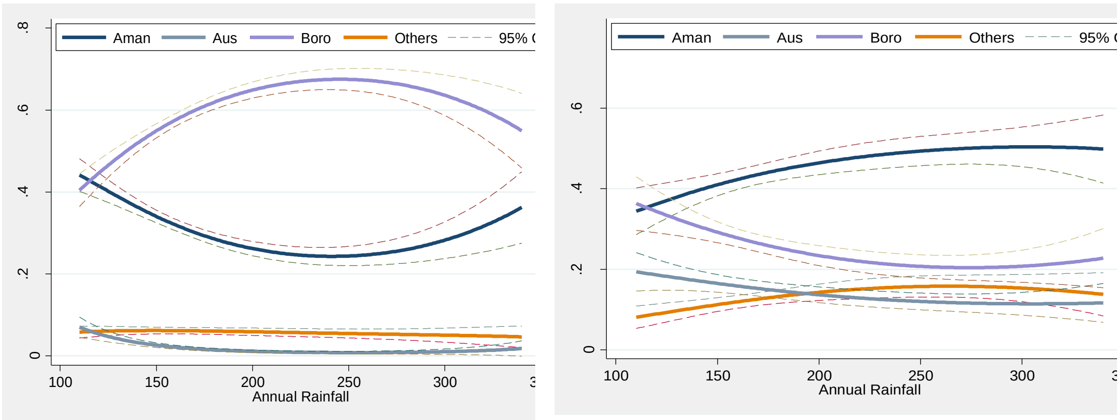


Note: 1) horizontal axis represents annual rainfall measured by millimetre per month. 2) Upper and lower dotted lines around each solid crop choice probability line indicate the upper and lower bound of 95% confidence interval.

In the pooled repeated cross-sectional data, 70.98 percent adopted irrigation while the rest (29.02 percent) did not. It was evident that the adoption of irrigation was increasing over the years. In the year 2000, 64.51 percent of households adopted irrigation, which increased to 76.35 percent in 2010. Two postulations can be made from the rise of irrigation adoptions: first, households adopt more irrigation as rainfall becomes inadequate or erratic, and second, crop varieties less dependent on rainfall are chosen more and more. Figure 2.5a depicts the estimated relationship between the probability of choosing four crops with a 95-percent confidence interval and the annual mean rainfall measured in mm/month in the case of irrigated farmers. Both Aman and Boro rice crops were are sensitive to rainfall. As rainfall increased from its mean, farmers in high rainfall areas chose more of Aman and less of Boro. Crop choice probabilities of Boro, Aus, and Aman by the farmers in the lower and higher rainfall areas compared to the mean rainfall areas were sensitive to the rainfall, as their corresponding 95-percent confidence intervals grew wider. Compared to the non-irrigated farmers (see Figure2.5b), irrigated farmers grew more of Boro, which is basically an irrigation-dependent variety. Because of the dependency of non-irrigated farmers on rainfall, they grow more of Aman, a rain-fed variety, as rainfall increases from its average. Compared to the irrigated farmers, 95 percent confidence intervals were wider in the case of non-irrigated farmers. This means non-irrigated households were more sensitive to rainfall.

Figure 2.5: Estimated probabilities of crop choice with confidence interval over rainfall

a) irrigated Farmers b) non-irrigated farmers

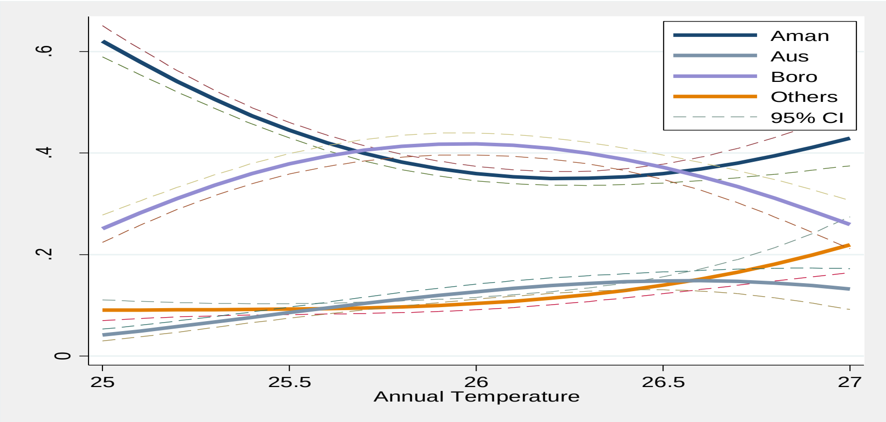


Note: 1) horizontal axis represents annual rainfall measured by millimetre per month. 2) Upper and lower dotted lines around each solid crop choice probability line indicate the upper and lower bound of 95% confidence interval.

2.5.4 Crop Choice and Temperature

Temperature plays an important role in crop choice. Any sort of deviation from the trend or expected temperature, for example, a heat wave, may affect a farmer's crop choice. All the varieties of crops have a tolerable temperature level. Any deviation from this level may impede their growth. Figure 2.6 shows the estimated relationship between crop choice probabilities and annual mean temperature measured in Celsius. Farmers in low temperature areas chose more of Aman and less of Aus, but as the average temperature increased toward the middle, Boro surpassed Aman and at the same time, Aus increased significantly. Other crops were are also sensitive to temperature level. Crop choice probabilities of all four crops by the farmers in the lower and higher rainfall areas compared to the mean rainfall areas were more sensitive to the rainfall, as their corresponding 95-percent confidence interval became wider. Temperature was correlated with irrigation. A high temperature may increase the need for irrigation. Therefore, to obtain a more accurate picture of the relationships between crop choice probabilities and temperature, researchers need to analyse the behavior of agricultural households in terms of irrigation adoption.

Figure 2.6 : Estimated probabilities of crop choice with confidence intervals over temperature.

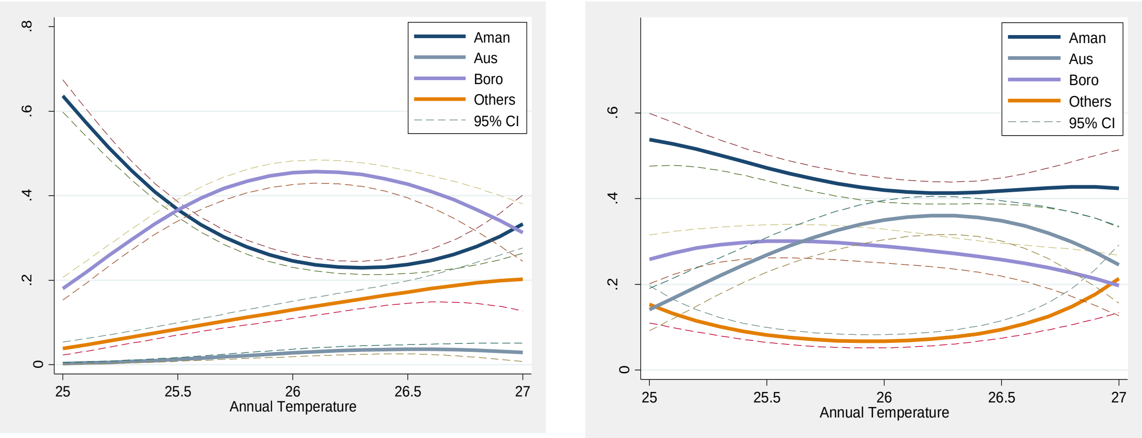


Note: Upper and lower dotted lines around each solid crop choice probability line indicate the upper and lower bound of 95% confidence interval.

Figures 2.7a and 2.7b illustrate the estimated relationship between the probability of the farmers choosing from among four crops and the annual mean temperature measured in celsius for irrigated and non-irrigated groups with confidence intervals, respectively. The graphs show that irrigated farmers in low temperature areas chose Aman the most and chose Aus the least, but in high temperature areas, Boro was the top crop. One explanation may be that Boro requires irrigation and the irrigated farmers of the high temperature areas can afford its cultivation, but in case of non-irrigators, the picture is completely different. Boro was not the top crop choice for the non-irrigators, as shown in figure 2.7b. Compared to the irrigators, non-irrigating farmers are more sensitive to temperature. That means that in any deviation from normal temperature, non-irrigated farmers were more vulnerable in crop production compared to irrigators, as the 95-percent confidence intervals grew wider in the case of non-irrigators compared to irrigators.

Figure 2.7 - Estimated probabilities of crop choice with confidence interval over temperature.

a) Irrigated farmers b) Non-irrigated farmers



Note: Upper and lower dotted lines around each solid crop choice probability line indicate the upper and lower bound of 95% confidence interval.

2.6 Climate Change Scenarios and Crop Switching in Bangladesh

This section will present the forecasting scenarios of both rainfall and temperature derived from different methods like General circular model (GCM) and Providing Regional Calamities for Impact Studies (PRECIS). Then it will look at how the crop choice will move over time with the changes in rainfall and temperature scenarios using the parameters estimated in the repeated cross-sectional model.

2.6.1 Climate Change Scenarios

GCM is a global scale and PRECIS is a regional scale model to provide the future climate change scenario. GCM predicts an average temperature increase of 1.0C by 2030, 1.4 C by 2050, and 2.4 C by 2100, while PRECIS predicts average increases of 1.4 C by 2030, 2.5 C by 2050, and 3.4 C by 2070. GCM predicts average rainfall increase of 3.8 percent by 2030, 5.6 percent by 2050, and 9.7 percent by 2100, while and PRECIS predicts average rainfall increase of 4.0 percent by 2030, 2.3 percent by 2050, and 6.7 percent by 2070. Table 8 summarizes all these predictions. The climate change scenarios presented here are all annual, though the increase will not be equally spread among all seasons. For instance, more than 80 percent of the 2,300 mm of annual precipitation that falls in Bangladesh comes during the Monsoon period (Smith, Rahman, & Mirza, 1998), but for the simplicity of the simulation, only annual scenarios were considered in this research.

Table 2.8: Different climate change scenarios of Bangladesh

Model	2030	2050	2100
	Temperature (C)		
GCM	+1.0	+1.4	+2.4
PRECIS	+1.4	+2.5	+3.4*
	Rainfall (percent change)		
GCM	+3.8	+5.6	+9.7
PRECIS	+4.0	+2.3	+6.7*

Source: (Ministry of Environment and Forests, 2005)
Note: * corresponds to year 2070.

2.6.2 Simulation of Crop Choice under Rainfall Scenarios

How the probability of crop choice will change over time in response to rainfall scenarios will be estimated here. Simulation of crop choice under rainfall scenarios has been done using the following methods - (a) parameters of the pooled cross section model has been used for the simulation, b) when rainfall scenario is considered, all other parameters are assumed to be constant at mean level, and c) simulation effects on crop choice probability for annual rainfall are based on the parameters of the pooled model which uses annual climatic variables instead of seasonal.

Table 2.9 presents the effects of rainfall scenarios under GCM and PRECIS on crop choice. As rainfall increases, keeping temperature and all other variables at mean levels, crop choices of Aman and 'others' decreased, while Boro and Aus increased. The increases and decreases from the baseline probabilities in three varieties, except Aus, were statistically significant at the 1 percent level. Increases in the crop choice probabilities in the Aus crop from the baseline were not statistically significant. One important message from this simulation is that farmers of Bangladesh will shift to Boro crop, a major irrigated rice variety of the country from Aman and Aus due to increases in rainfall under different scenarios.

Table 2.9 : Effect of rainfall scenario on crop choice in Bangladesh

	Aman (%)	Aus (%)	Boro (%)	Others(%)
Baseline	37.17	6.93	46.78	9.11
2030				
GCM	34.16*	7.05	51.67*	7.11*
PRECIS	32.12*	7.04	51.73*	7.09*
2050				
GCM	33.91*	7.05	52.07*	6.95*
PRECIS	34.37*	7.04	51.31*	7.27*
2100				
GCM	33.45*	7.07	52.85*	6.63*
PRECIS**	33.78*	7.06	52.31*	6.86*

Note: * indicates probability change from baseline statistically significant at 1% level and ** implies corresponding to year 2070.

2.6.3 Simulation of Crop Choice under Temperature Scenarios

How the probability of crop choice will change over time in response to temperature scenarios will be estimated here. Simulation of crop choice under temperature scenarios has been done using the following methods - (a) parameters of the pooled cross section model has been used for the simulation, b) when temperature scenario is considered, all other parameters are assumed to be constant at mean level, and c) simulation effects on crop choice probability for annual temperature are based on the parameters of the pooled model which uses annual climatic variables instead of seasonal.

Table 2.10 presents the effects of temperature scenarios under GCM and PRECIS on crop choice. As the temperature increased, keeping rainfall and all other variables at mean level, crop choice of Aman decreased drastically, while all the other three crop choices increased significantly. The increases and decreases from the baseline probabilities in four varieties were statistically significant at the 1 percent level. The increase in 'others' categories experienced the highest increase, followed by Aus crop. The decrease in crop choice probabilities in the Aman crop was also very large, indicating that increases in temperature, farmers tended to diversify their crops instead of concentrating on rice production.

Table 2.10: Effect of temperature scenarios on crop choice in Bangladesh

	Aman (%)	Aus (%)	Boro (%)	Others (%)
Baseline	37.17	6.93	46.78	9.11
		2030		
GCM	24.05*	9.40*	49.60*	16.95*
PRECIS	19.63*	10.53*	48.72*	21.11*
		2050		
GCM	19.63*	10.53*	48.72*	21.11*
PRECIS	8.94*	12.47*	43.09*	35.48*
		2100		
GCM	9.65*	12.31*	43.96*	34.07*
PRECIS**	4.20*	13.44*	33.89*	48.45*

Note: * indicates probability change from baseline statistically significant at 1% level and ** implies corresponding to year 2070.

Comparison between the effects of rainfall and temperature scenarios on crop choice indicates a big difference which needs to be explored. One explanation may be that in Bangladesh, farmers will not be able to control the increase in temperature, due to their poor endowments and resources. Building greenhouses is beyond their means and technical know-how, but they can control the erratic nature or increase in rainfall by adopting small-scale irrigation technology, which is widespread in Bangladesh.

Simulation results indicate that farmers of Bangladesh will shift from rainfed Aman rice to irrigation based Boro, Aus and other crops under different climate change scenario. These results are in line with the results of the other relevant papers. For instance, Seo and Mendelsohn (2008) finds that Latin American farmers adapt to climate change by changing crops. Wang, Mendelsohn, Dinar, and Huang (2008) show that Chinese farmers also adapt to climate change by switching crops. Kurukulasuriya and Mendelsohn (2008) finds that farmers of 11 African countries shift the crops to match the change in climate. But all those literature of crop switching as climate change adaptation mainly use single cross-sectional data while the current research uses repeated cross-sectional data that has produced more refined estimation results.

2.7 Conclusion and Policy Implication

This research shows that the farmers of Bangladesh change their crop choices in the face of climate change. Examining the four major crops of the country, the paper found that a shift in major crop choices, especially in rice varieties, will happen in Bangladesh if the climate change scenario is predicted properly. The strength of the research is that the crop choices were repeated cross-sectional data from the years 2000, 2005, and 2010, and the environment data against each crop choice was the average of the last five years. So, the research included the past effect of climate change on crop choice, but the environment data used in this paper are from 33 metrological stations of the country implying that households located in the area of the same metrological station faced the same environmental situation, but, in practice, even inside the areas under the same metrological station, different households may face slightly different environmental situations. This research presents the country level findings on crop switching under different climate change scenarios. In the regional level, the sample was not representative that was a constraint of this research. However, this constraint leaves the scope of further improvement of this research at regional level. Nevertheless, the findings of the research indicated a future cropping pattern in Bangladesh, which has policy implications in the agrarian economies. Therefore, this research provides the background for how the government will undertake agricultural policy toward different major crop varieties.

This research found that the probability of choosing different crops will change with the changing temperature and rainfall in Bangladesh in future time periods. This implies that farmers will be more willing to cultivate climate change tolerant or insensitive crop varieties in future. This trend has already been seen in Bangladesh in the recent years to some extent. For instance, in the case of rice production, farmers gradually changed their position from the cultivation of the traditional rainfed 'Aman' variety to the irrigation-dependent 'Boro' rice.

Considering this changing trend, the government of Bangladesh needs to take measures to determine the climate sensitive crops. It will help the farmers to choose the crop variety more confidently and to generate more revenue from crop production. The crop production policy in the existing National Agricultural Policy (NAP) emphasized crop diversification in favour of cash crops and crops suitable in the coastal and hilly areas. Among the different aspects, NAP has also addressed the issues of environmental protection in agriculture, emphasizing a crop rotation and salt tolerant seed varieties. This research intends to focus, and along with environmental protection, NAP should address climate change adaptation issues in agriculture. Adaptation strategies taken by the households cannot be effective without policy measures. For instance, supply of climate resilient seed variety needs policy intervention from the government that can be highlighted in the NAP along with other policy measures on climate resilient agricultural inputs. Therefore, NAP should be developed from this point of view, so that farmers can be fewer victims of aberrant behaviour of climate change events in the future. Finally, this paper reveals a shortcoming of the single cohort of cross-sectional data in simulating crop choices and diversity in response to the climate change scenarios. This indicates that repeated cross-section data have an advantage over single cross-section data in terms of estimating the regression parameters and simulating for the future. Household specific climate variables might improve the paper in terms of accurate climate parameters.

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2.9 Appendices

2.9.1 Multinomial Logit Regression of Crop Choice for Different Years

Table 2.11: Multinomial Logit Regression of Crop Choice of 2000, 2005, 2010 and 2000-10

Dependent Variable: Crop Choice Base crop= Boro Rice

Variable	2000	2005	2010	2000-10
Aman crop				
Summer rain	-0.008	-0.019	-0.019***	0.017***
Summer rainsq	0	0.000**	0	-0.000***
Rainy rain	0.015*	0.093***	-0.045***	-0.030***
Rainy rainsq	0	-0.000***	0.000***	0.000***
Winter rain	-0.214***	-0.436***	-0.162***	-0.070***
Winter rainsq	0.005***	0.019***	0.004**	0.002***
Summer temperature	-31.118***	10.55	-49.543***	-11.933***
Summer temperaturesq	0.592***	-0.162	0.848***	0.221***
Rainy temperature	-4.651***	-1.723***	0.144	-0.771***
Winter temperature	-16.217**	1.851	23.122***	-4.998**
winter temperaturesq	0.382**	-0.07	-0.542***	0.105**
Agriland	0.138***	0.080*	0	0.001
Operating land	-0.011	0.277***	0.005***	0.001
Crop production	-0.000**	-0.000***	-0.000***	-0.000***
Irrigation	-3.055***	-2.539***	-0.484	-2.620***
Fertilizer	1.429***	1.520**	-0.08	0.638**
Insecticides	0.525*	-0.896**	-0.803**	0.187
Wage Labour	0.624*	-0.719*	0.601*	0.09
Family Size	-0.028	-0.044	-0.033	-0.02
House space	0	0	0.000**	0.000***
Electricity	-1.081***	-0.672**	0.439*	-0.517***
Mobile	0.384	0.537	-0.188	-0.065
Trend				-2.803***
Trendsq				0.877***
Constant	711.388***	-140.138	482.829***	247.257***
Aus Crop				
Summer rain	0.037**	0.002	0.009	0.026***
Summer rainsq	-0.000*	0	-0.000**	-0.000***
Rainy rain	-0.013	0.048*	-0.077***	-0.041***
Rainy rainsq	0	-0.000**	0.000***	0.000***
Winter rain	-0.007	-0.352*	-0.105	0.063*
Winter rainsq	0	0.018**	0.004*	-0.001

Variable	2000	2005	2010	2000-10
Summer temperature	-41.630**	37.766*	-27.425**	-7.434
Summer temperaturesq	0.784**	-0.656*	0.508**	0.168*
Rainy temperature	-3.194***	-1.28	-3.261***	-2.898***
Winter temperature	-22.734*	-5.536	44.196***	-0.772
winter temperaturesq	0.527*	0.127	-1.070***	-0.008
Agriland	0.244***	0.096	0	0
Operating land	-0.016	0.395***	0.006***	0.003***
Crop production	-0.001***	-0.001***	-0.001***	-0.000***
Irrigation	-3.410***	-1.378*	-2.179***	-3.182***
Fertilizer	-0.328	1.454	1.724**	0.539
Insecticides	0.6	-0.482	-0.523	0.623**
Wage Labour	0.175	-0.568	-0.874*	-0.415
Family Size	0.042	-0.009	0.035	0.046**
House space	0	0	0.000**	0.000**
Electricity	-0.146	1.293**	0.663**	0.218
Mobile	-0.711	-0.7	-0.443	-0.351
Trend				-3.013***
Trendsq				0.941***
Constant	884.677***	-456.012	18.207	183.769**
Other crops				
Summer rain	-0.050**	0.083	-0.003	0.006
Summer rainsq	0	-0.000*	0	0
Rainy rain	0.043*	-0.237***	-0.026**	-0.025***
Rainy rainsq	0	0.000***	0.000***	0.000***
Winter rain	0.710**	0.344	-0.110*	0.131***
Winter rainsq	-0.019**	-0.007	0.002	-0.004***
Summer temperature	-70.749***	-71.563***	-28.597***	9.890*
Summer temperaturesq	1.238***	1.243***	0.514***	-0.153
Rainy temperature	1.241	1.797	-0.796*	-0.696**
Winter temperature	-8.393	24.135	16.000**	-4.25
winter temperaturesq	0.205	-0.526	-0.387**	0.082
Agriland	-0.210**	0.003	0.005***	0.006***
Operating land	0	-0.610***	-0.024***	-0.026***
Crop production	0.000***	0.000***	0.000*	0.000***
Irrigation	-2.384***	-3.596***	-2.522***	-3.268***
Fertilizer	-0.34	1.174	-0.233	-0.093
Insecticides	0.746	0.051	-2.032***	-0.377
Wage Labour	1.120*	2.937***	-1.415***	-0.798***
Family Size	-0.056	0.029	-0.052*	-0.048**
House space	-0.001	0	0.001***	0.000**
Electricity	-0.107	-0.684	0.469*	-0.049
Mobile	0.484	0.825	-0.444	-0.071
Trend				-6.240***

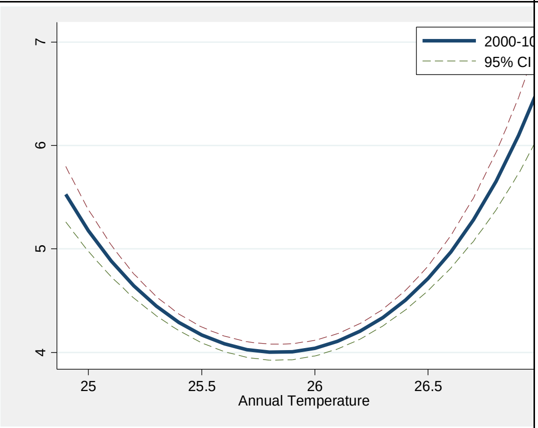
Variable	2000	2005	2010	2000-10
Trendsq				2.098***
Constant	1051.383***	732.352*	265.176*	-77.659
Observation	3114	3318	5404	11836
LRchi2	1335.99	1411.73	3770.04	6935.05
PseudoR2	0.22	0.23	0.26	0.24

(*)(**) and (***) indicates 1, 5 and 10 percent level of significance respectively

2.9.2 Crop Diversity and Irrigation

Figure A.1 : Estimated crop diversity with confidence interval over temperature

a) irrigated Farmers



b) non-irrigated farmers

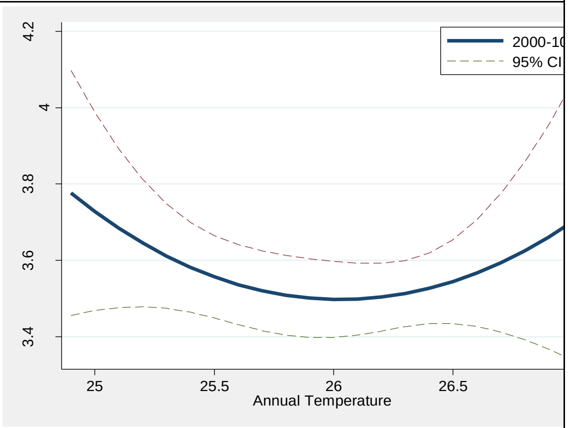
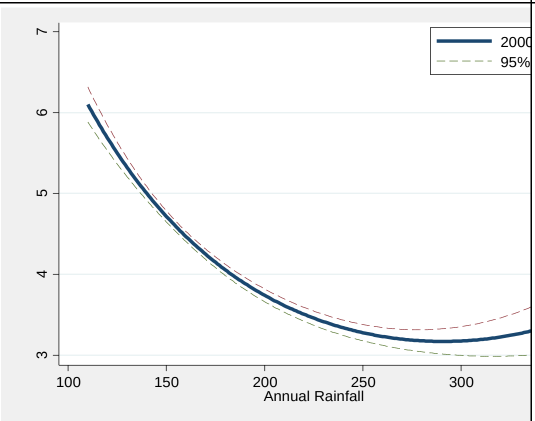
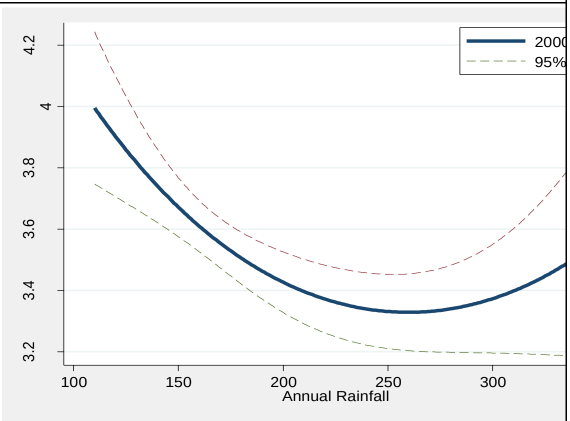


Figure A.2 : Estimated crop diversity with confidence interval over rainfall

a) irrigated Farmers



b) non-irrigated farmers



Chapter 3

Crop Diversity as Climate Change Adaptation

Abstract

This research is based on the theoretical framework of risk in rural agricultural economy where farmers consider climate change as idiosyncratic risk of production. Under inter-temporal agricultural household consumption smoothing model, this paper considers crop diversification as an ex ante measure to tackle permanent income shock from climate change. This paper examines empirically whether crop diversity is affected by climate change and how this diversity will respond to different climate scenarios. Negative binomial regression models are estimated from a nationally representative sample of 11389 farmers across Bangladesh and 30 years average of seasonal climatic variables to find the effects of climatic variables on crop diversity. This paper finds that crop diversity is climate sensitive and this diversity in different locations varies with climatic conditions. This research unveils structural instability between different single cross-sectional models to simulate the effects of climatic variables on crop diversity. It also finds that increases in mean annual temperature by 1 Celsius by 2030 and 2.4 Celsius by 2100 have resulted in 26.40 percent and 149.83 percent increase in crop diversity compared to its baseline of 2010 respectively. The effects of rainfall scenarios on crop diversity are much lower compared to the effects of temperature.

3.1 Introduction

This research examines crop diversification as a means of climate change adaptation. This research uses repeated cross-sectional evidence of 11,389 farmers across Bangladesh from the years 2000, 2005, and 2010 to explore how farmers would adapt to exogenous climate variables such as temperature and rainfall. Considering crop diversity of farmers who face different climatic conditions across the landscape and 30 years moving average of temperature and rainfall, I examine quantitatively how farmers would diversify current crop choices in response to future climate scenarios of rainfall and temperature. Agricultural household model provides the theoretical foundation of this research and negative binomial count regression is used as estimation method. Repeated cross-sectional sample provides the scope to examine the structural stability between the single cross-sectional models. Regression model from pooled cross section data gives the opportunity to have more refined simulation effect of climatic scenarios on crop diversity.

This research registers an improvement over the existing literature in the following ways: a) this paper uses pooled cross section to predict future crop diversity while the existing literature mostly uses single cross section to do this; b) it evaluates the dynamic aspects of crop diversity; c) it examines the structural stability of the different models to look at the steadiness of the impacts of the climate and other variables on crop diversity; d) this research depicts the estimated relationship between the crop diversity with confidence interval and climate variables. So, this paper can show the differences in farmers' response from different landscape with different climate conditions; and finally e) literature on climate change adaptation in agriculture mainly deals with the effect of climate change on crop yield while this research focuses on crop choice diversification as climate change adaptation strategy which is a new dimension in this research area.

There are two strands of literature on the relation between crop sector and climate change adaptation. The first strand of literature mainly deals with how the climate change adaptation affect yield or crop productivity. This strand of literature mainly attempts to measure the effect of climate change adaptation on yield or productivity of different specific crops (Di Falco & Chavas, 2008, 2009; Di Falco & Perrings, 2005; Hoque & Haque, 2016; Banerjee et al 2015; Mohammad et al. 2014). Second strand of literature mainly focus crop choice as climate change adaptation. There are two distinct types of literature under this second strand. The first type of literature focus on crop switching as a climate change adaptation strategy in agriculture (Kurukulasuriya & Mendelsohn, 2008; Seo & Mendelsohn, 2008; Wang, Mendelsohn, Dinar, & Huang, 2009) while the second type of research mainly deals with crop diversification as a climate change adaption strategy (Bradshaw et al., 2004).[11] This research contributes to the second types of literature focusing crop diversification as climate change adaptation strategy. However, this research differs significantly with other research in terms of methods and Bangladesh context.

The rest of the paper is organised as follows. Section 3.2 presents the literature on crop diversity and climate change adaption while sector 3.3 provides data description. Section 3.4 embodies the theoretical motivation and empirical method used in this study. Section 3.5 presents the estimated results for both pooled and single cohort cross section and section 3.6 highlights the simulated results under different climate change scenarios using the estimation results. Finally, section 3.7 ends the paper with conclusions.

3.2 Crop Diversity and Climate Change Adaptation[12]

Literature on agriculture usually reports weather as one of the major sources of production risks. Relatively newly growing literature acknowledges climate

[11] Literature on crop switching as climate change adaptation has been discussed in the chapter 2 of this dissertation in details.

[12] This section shares some similar literature with chapter 2 as the crop switching and crop diversification are two closely related dimensions of crop choice.

change as an important risk factor in agricultural production (Bradshaw, Dolan, & Smit, 2004; Di Falco, Veronesi, & Yesuf, 2011; Seo & Mendelsohn, 2008; Wang, Mendelsohn, Dinar, & Huang, 2009). Moreover, developing countries generally lose more from the effects of global warming on agriculture than the industrial countries that posits a clear importance on the research on climate change adaptation in agriculture of the developing countries (Cline, 2007). But the empirical work on climate change adaptation in agriculture is virtually non-existent in the low latitudes where climate change is expected to have a devastating effect on it (Wang et al., 2009;). After that time, a good number of paper on climate change and crop sector have come up in the context of the developing countries although those works mainly focus on the link between climate change adaptation and its impact on crop yield. Literature on crop choice in the form of diversity as climate change adaptation is still non-existent in the south Asian countries that provides the motivation for conducting the research on the crop choice of Bangladeshi households as climate change adaptation.

Among different production systems, agriculture faces significant adverse effects of climate change. Among others, Bradshaw et al. (2004) and Di Falco and Veronesi (2014) suggested various means to climate change adaptation such as crop diversification, mixed crop-livestock farming systems, changing planting and harvesting dates, using drought-resistant varieties and high-yield water-sensitive crops. Theoretical knowledge of diversified agro-ecosystems suggests that climate change will affect both biotic (pest, pathogens) and abiotic (solar radiation, water, temperature) factors in crop systems which threaten crop sustainability and production. More diverse agro-ecosystems with a broader range of traits and functions will be better able to perform under changing environmental conditions (Altieri, 1999; Matson, Parton, Power, & Swift, 1997).

There is a growing body of literature on quantitative research suggesting that agro-biodiversity contributes to the increase in agricultural crop yield, and to production risk reduction (Bradshaw et al., 2004; Di Falco & Chavas, 2008, 2009; Di Falco & Perrings, 2005; Smale, Hartell, Heisey, & Senauer, 1998). A positive correlation between crop genetic diversity and the mean yield, and a negative correlation between the same diversity and the variance of the yield were found while researching wheat production in Punjab of Pakistan (Smale et al., 1998). Employing a moment-based approach to estimate the mean, variance, and skewness of a stochastic crop production function, Di Falco and Chavas (2008) found that agro-biodiversity increases farm-level productivity and reduces the risk of crop failure in Tigray. Based on 15,000 farms in Canadian prairie agriculture for the period 1994–2002, Bradshaw et al. (2004) found that the adoption of crop diversification reduces risk, but cannot confirm the increase in productivity.

Different national and international forums on climate change also recognise Bangladesh and its big agriculture sector as seriously vulnerable to climate change (General Economic Division, 2009, 2011; World Bank, 2010). Agriculture sector of Bangladesh accounts for 20% of its GDP and employs 65% of labor force of the country (Bangladesh Bureau of Statistics, 2010b). Being a highly populous country, ensuring food security has been a long-standing challenge of Bangladesh. International Panel for Climate Change (IPCC) estimates that by 2050, rice production in Bangladesh could decline by 8 percent and wheat by 32 percent. The combined effects of rising temperatures, higher precipitation, CO2 fertilization, severe flooding, occasional seasonal droughts, and loss of arable land in coastal areas resulting from climate change are expected to result in declines in rice production of 3.9 percent each year, or a cumulative total of 80 million tons over 2005–50 (World Bank, 2010). Therefore, researching on climate change and agriculture in Bangladesh also carries enormous importance for other climate change vulnerable developing countries which have large agriculture sector.

A number of literature evolved in the recent years focus on the crop sector and climate change in Bangladesh. One strand of literature focus on the impact of climate change on the yields of the crops in Bangladesh (Hoque & Haque, 2016;

Banerjee et al.,2015; James & Winston, 2011; Thomas et al. 2013).[13] However, extensive literature survey confirmed that crop choice diversity as a potential climate change adaptation strategy under different climate scenarios in Bangladesh and in the South Asia is not addressed till now that provides the motivation of the current research.

3.3 Data Description[14]

3.3.1 Household Information

3.3.2 Crops of Bangladesh

3.3.3 Environmental Data

3.4 Theoretical Motivation and Empirical Method

Theoretical motivation will present different economic rationale behind crop diversity and the inter-temporal agricultural household consumption smoothing model. Empirical method discusses the estimation of crop diversity using production function approach and the regression model specification.

3.4.1 Theoretical Motivation

Agriculture system is always subject to risk. Several influential papers in the 1970s highlight the importance and impacts of risk in agriculture production (Just, 1975a, 1975b; Just & Pope, 1979). Recently growing literature on agriculture mention climate change as a potential source of agriculture production risk. From different economic points of view, the general motivation behind the crop diversity to tackle climate change risk are follows: First, the very common rationale is the theory of portfolio management, which states that "diversification reduces risk." In a country like Bangladesh, where climate-change events are looming day by day, farmers simply produce several crops in order to hedge the production risk. Second, different crops have different levels of climate resilience,

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[13] Detailed review of these literature has been mentioned in the subsection '2.2.3 Climate Change and Adaptation in Agriculture of Bangladesh'. Therefore, those are not repeated here.

[14] Data description shares the similar data presented in the section '2.3 Data Description' of the chapter 2. That's why the details of household information, crop and environmental data are not repeated here.

which are unknown to farmers. This asymmetry also motivates the farmers to grow multiple crops. Third, another rationale behind growing multiple crops is decreasing returns to scale. Existence of fixed factors of production, like land, farmer time, land quality, and distance from markets, lead the farmer to decreasing marginal productivity of those factors for production in a single crop. Fourth, another important rationale behind crop diversity is missing or imperfect commodity or labor market (Dusen & Taylor, 2005). In developing countries like Bangladesh, the commodity market especially for agricultural production has high transaction costs. This is a disincentive for the farmers of Bangladesh to market their agricultural product. Fifth, in Bangladesh, insurance market for agriculture is non-existent (Climate Cell, 2008). Risk or uncertainty, in the absence of a perfect insurance market, may also lead the household to plant a portfolio of varieties instead of specializing.

Theoretical motivation of this chapter comes from risk behaviour of the households in the rural agricultural economy where the individual household lives in a community. Every household faces a range of risks which can be divided into two parts- systematic risks and unsystematic or idiosyncratic risk. Risk from climate change can be referred as idiosyncratic risk as climate change doesn't follow any pattern of happenings. Let me consider a type of community where community level mechanisms such as kinship, social network and institutional mechanisms do not exist to allocate risk efficiently. Through these community level mechanisms, households in the community could share risk among each other and achieve Pareto efficient allocation of risk. But the Pareto efficient allocation of risk within a community is almost impossible to achieve under the rationality assumption as marginal utility of aggregate social or communal work for risk pooling will be different for different individuals. Therefore, moral hazard in the community will collapse the risk pooling structure of Pareto program (Carter, 1997; Rosenzweig & Binswanger, 1993; Ruthenberg, 1971).

Theoretical framework of this chapter is taken from the chapter 8 (Risk and Insurance in an Agricultural Economy) of the book of 'Development Microeconomics' (Bardhan & Udry, 2000) focusing the consumption behaviour of the household. Under certain conditions, a utility maximizer household faces the following consumption function:

$$c_t = \frac{r}{1+r}\left(A_t + E_t \sum_{\tau=1}^{\infty} (1+r)^{-(\tau-t)} y_t\right) \quad (1)$$

Equation (1) implies the permanent income hypothesis which states that current consumption is the annuity value of current assets plus the present value of the expected stream of future income.

Now, let me consider that climate change events do not follow any systemic pattern of happenings, but happen more or less in a particular interval. In such situation, income shock from climate change can be treated as permanent. Because of the absence of risk pooling structure of Pareto program, permanent income shock from climate change events and imperfect credit market, household consumption declines drastically as current consumption depends on only current income and asset. So, the consumption equation will be:

$$c_t = A_t + Y_t \quad (2)$$

In such situation, because of the consumption smoothing motive, households will apply some ex post measures to tackle their income loss in agriculture. But, in the agrarian rural economy, poor households cannot successfully prevent the income loss by taking ex post measures because of lack of resources, technical know and effective institutional mechanism (Rosenzweig & Binswanger, 1993). When ex post measures will fail to prevent income loss, households will apply ex ante measures to overcome income loss. In an agrarian rural economy, those ex ante measures among others are planting multiple crops and rapidly maturing varieties. This establishes the motivation of crop diversity as it ensures low risk (less variance) of income from crop production.

Now let me consider that there are two farmers- i and j who grow n and k types of crops respectively. Farmer i grows n types of crops as ex ante measure to tackle income loss from climate change risk while farmer j does not diversify crops, and so n>k. Crop diversity will make the farmers better off if the following two condition holds:

a. If the mean income from more diversified crops (Ỹn) are greater than or equal to that of the less diversified crops (Ỹk) i.e. Ỹn≥Ỹk.
b. [If the expected values are equal] If the variance of Yn is less than or equal to the variance of Yk, that is Var(Yn)≤ Var(Yk).

In rain-fed agriculture, there is evidence of high covariance among the farmers income which supports the overstated condition, b (Rosenzweig & Binswanger, 1993; Ruthenberg, 1971).

On the basis of above theoretical foundations, this research intends to answer the following research questions:

1) Whether crop diversity is affected by climate change (long-tern rainfall and temperature) in Bangladesh?
2) What is the existing relationship between crop diversity and temperature?
3) What is the existing relationship between crop diversity and rainfall?
4) What is the marginal effects of rainfall and temperature on crop diversity?
5) How this diversity will respond to different scenarios of rainfall and temperature?

In order to answer those questions, this research uses the following empirical methods.

3.4.2 Empirical Method

Di Falco and Chavas (2008) considered agro-diversity as an input variable in the agricultural production function. Let me consider that farmer i will select the variety of crops to generate the highest revenue. Let me also consider the following production function where the vector C represents climate, soils, and price variable; S includes the socio-economic characteristics and D implies number of crops as an indicator of crop diversity.

$$Q = Q(C, S, D) \qquad (2)$$

Then the econometric representation of production function would be:

$$Q = F(C, S, D) + \varepsilon(C, S, D) \quad (3)$$

where F represents observable components and ε error term. Now, consider vector C and S together as X and then the Poisson regression model assumes that D_i given X_i is Poisson distributed if the density function is:

$$f(D_i/X_i) = \frac{e^{-\lambda_i}\lambda_i^{D_i}}{D_i}, \quad D_i = 0,1,2, \ldots \quad (4)$$

Mean parameter: $E[D_i|X_i] = \lambda_i = \exp(X_i\beta)$ (5)

Then the Poisson model is to be estimated as:

$$D_i = e^{X_i\beta} + \varepsilon_i = e^{(\beta_0+\beta_1 X_{1i}+\beta_2 X_{2i}+\cdots+\beta_m X_{mi})} + \varepsilon_i \quad (6)$$

Poisson regression has several extensions. If the data do not fit in the Poisson regression, a negative binomial regression model will be used in that case. It is worth mentioning here that negative binomial regression can be used for over-dispersed count data, which means that the conditional variance exceeds the conditional mean. It can be considered as a generalization of the Poisson regression, as it has the same mean structure as a Poisson regression and it has an extra parameter to model the over-dispersion. If the conditional distribution of the outcome variable is over-dispersed, the confidence intervals for negative binomial regression are likely to be narrower, as compared to those from a Poisson regression (Institute for Digital Research and Education 2015)

Crop diversity is the dependent variable while climate variables and some input variables will be explanatory variables in the regression model. Households who produce single crop has been considered as 'no crop diversity' household. Therefore, single crop has been called as 'Zero' crop diversity in this research. For the households producing more than one crops, crop diversity has been determined by deducting 1 from number of crops. Three seasonal (summer, rainy and winter) rainfall and temperature for the period 1971-2000, 1976-2005 and 1981-2010 provide six climate variables in the models. Family size in number, house space measured in 100 square feet and house price in 1000 BDT are the household characteristics included as explanatory variables of the models. Electricity, mobile, and wage labour which are measured by the adoption rate in the Mauza (0 to 1) are included as explanatory variables in the model[15].

3.5 Results and Discussion

This section presents the estimated results from negative binomial regression models and results of their goodness of fit and stability tests. Graphical presentation has been done to depict the estimated crop diversities at different values of climate variables. The parameters estimated from the pooled cross section model has been used for simulating the effects of climate scenarios on crop diversity.

3.5.1 Estimation results: Negative Binomial Regression

Table 3.1 presents the estimated results of negative binomial regression models of crop diversity. Models 1, 2 and 3 are from cross sections-2000, 2005 and 2010 respectively while model 4 represents the pooled cross sections of the three time points. At first, Poisson regressions are estimated and goodness of fit chi2 tests from Poisson regression results show that all these datasets are over-dispersed which are not appropriate for Poisson regression. Then the extension of the Poisson regression i.e. negative binomial regression method is employed for the estimation of the models. The coefficients of the explanatory variables are log counts of crop diversity in response to a one-unit increase in the explanatory variables.

[15] Mauza is the smallest land management unit set up by the government. Usually, it is synonymous with village.

Table 3.1: Estimation results of negative binomial regression models of crop diversification

Variables	Model 1 2000	Model 2 2005	Model 3 2010	Model 4 2000-10
Summer temperature	0.277***	0.101	-0.082	0.114***
Rainy temperature	-0.472**	0.560***	0.630***	0.308***
Winter temperature	-0.204***	-0.321***	-0.351***	-0.285***
Summer rainfall	0.003***	-0.003***	-0.003***	-0.001*
Rainy rainfall	-0.002**	0.001*	0.002***	0.001***
Winter rainfall	-0.020**	0.021***	0.054***	0.018***
Agri land	0.102***	0.113***	0.002***	0.002***
Mortgaged in	0.007*	0.078***	0.001***	0.001***
Mortgaged out	-0.060***	-0.113***	-0.002***	-0.002***
House space	-0.001	0.012**	0.025***	0.023***
House price	-0.000	-0.000	-0.000**	-0.000**
Family size	0.046***	0.021**	0.012*	0.034***
Access to mobile	0.037	-0.123	0.144*	0.031
Access to electricity	-0.464***	-0.288***	-0.317***	-0.356***
Wage labour	-0.096	0.117	0.133*	0.090*
Year 2005				0.105***
Year 2010				0.101***
Constant	11.023**	-11.347***	-8.620***	-5.720***
lnalpha constant	-1.321***	-1.793***	-1.213***	-1.230***
PseudoR2	10821.9	13388.9	24184.2	48990.2
Observation	2671	3314	5404	11389

Note: *, ** and *** indicates 10%, 5%, and 1% level of significance, respectively.

In the single cross section model of 2000, all the six climatic variables are statistically significant in explaining the crop diversity. For one Celsius increase in summer temperature, log count of crop diversity will increase by 0.277. One Celsius increase in rainy and winter temperature will decrease log count of crop diversity by 0.472 and 0.204 respectively. Summer rainfall contributes to crop diversity positively while rainy and winter rainfall negatively. In the models-2005 and 2010, except summer temperature, all other climatic variables are statistically significant in explaining crop diversity. But the values of the coefficients of the climate variables are unstable across the three models. For instance, in model 1, one Celsius increase in rainy temperature will lead to change the log counts of crop diversity by -0.472 while those are +0.560 and +0.630

for models - 2 and 3 respectively. Similar type of instability has been found in other climatic variables as well. This instability causes problem in simulation of crop diversity in response to different scenarios of the explanatory variables as different models at different time point will lead to have different simulation results. Therefore, using the single cross section data for the simulation of future crop diversity in response to climate scenarios cannot produce credible results due to this instability problem. In order to address this instability problem, model 4 containing all the three cross sections has been estimated as shown in the Table 3.1. In this model, all the six coefficients of climate variables are statistically significant. Except winter temperature and summer rainfall, all other climate variables are positively contributing towards crop diversity. Another issue needs to be mentioned here is that the absolute effects of temperature on crop diversity are much higher compared to those of rainfall on diversity. One explanation is that one Celsius temperature change has a lot of implications on agriculture compared to one millimetre change in rainfall. Except access to mobile, all other land endowments and other household characteristics are statistically significant in explaining crop diversity. Number of family members has a positive impact on crop diversity. Households using wage labour in agriculture, that means, large agro-farms are diversifying their crops compared to non-wage labour using farms. Year dummy, Yr2010 shows that households cultivate more crops by log count of 0.101 in 2010 compared to the average crop diversity of 2000 and 2005.

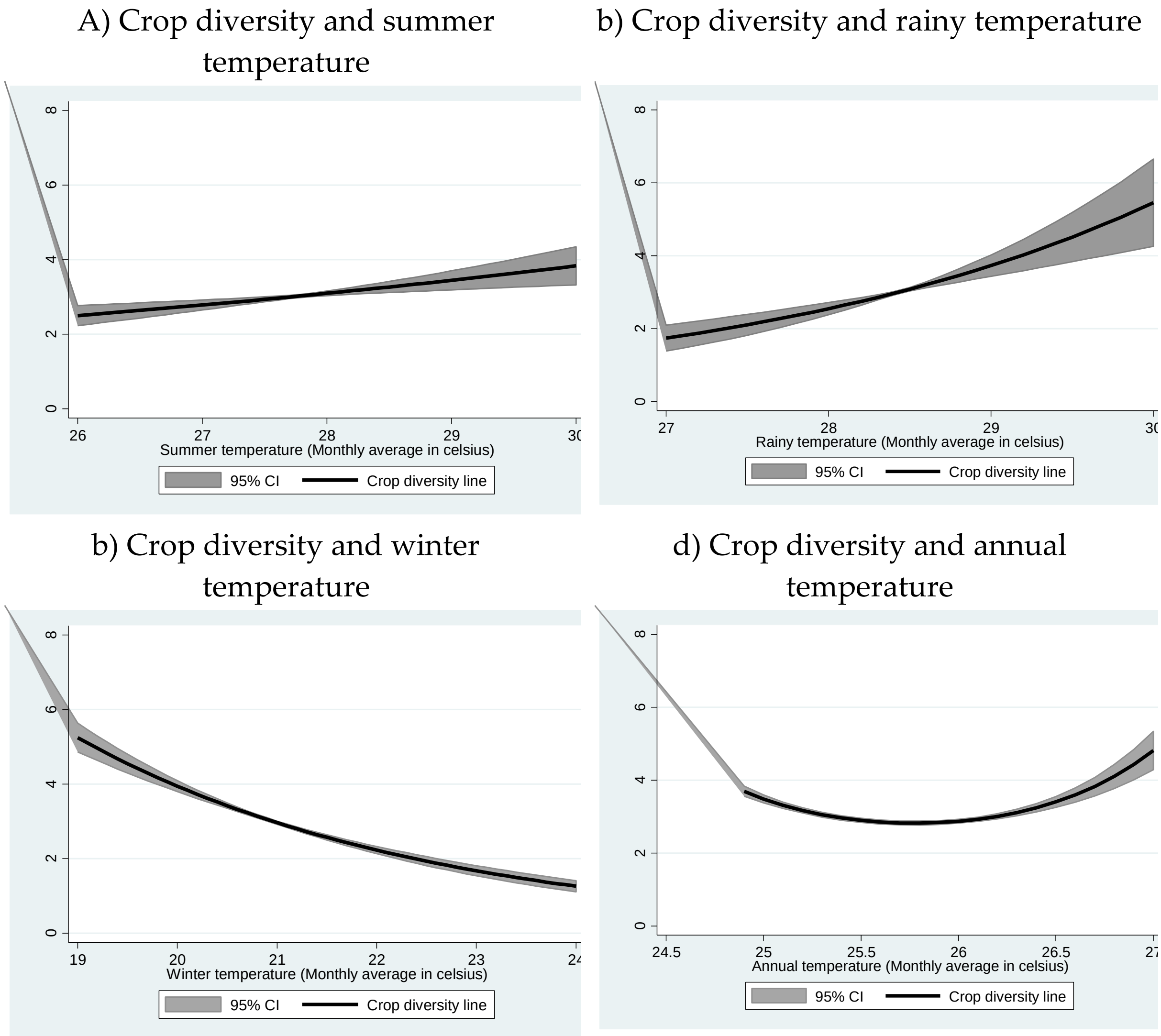
3.5.1.1 Goodness of Fit and Structural Stability

In case of all the four regression models, dispersion parameter, alphas are non-zero at 1% level of significance, suggesting that negative binomial model is more appropriate than the Poisson model for this data set. Effects of climate and other explanatory variables on crop diversity are examined by the Wald test. Wald test results show that the coefficients of all explanatory variables in together are statistically significant in explaining crop diversity in all the four regression models. While I group the variables into climate and other control variables, their coefficients separately are also statistically significant in explaining crop diversity. Structural stability compares the parameters of the different models and explores that whether they change in different models. Results of Chow type structural stability tests for three models- 2000, 2005 and 2010 show that difference in coefficients among the three models are statistically significant at 1% level of significance. This indicates that the coefficients of the same climate variables across those three models are different from each other in terms of their values. Differences among the models in terms of coefficient values inspire to use pooled cross section model by combining the three cross sections for simulating the effects of climate scenarios on crop diversity.

3.5.1.2 Crop Diversity and Temperature

Farmers in the high temperature areas cultivate more crops compared to the low and medium temperature areas. Figure 3.1 shows the relation between estimated crop diversity and temperature for all the three seasons and for the annual average rainfall and 95 percent confidence interval area of upper and lower bound. In the summer season, farmers of high temperature areas cultivate more crops compared to low temperature areas. The upper and lower bound confidence interval areas indicate that farmers of both high and low summer temperature areas are more sensitive to crop diversity in comparison with those of the medium summer temperature areas. Temperatures in both summer and rainy seasons are similar in terms of patterns of crop diversity and confidence intervals. Here it is worth mentioning that ranges of both summer and rainy season temperatures are similar in Bangladesh. The pattern of crop diversity in response to temperature in winter are opposite of summer and rainy seasons. Panel (d) of figure 3.1 shows the crop diversity in various annual temperature levels. It shows that farmers in lower temperature areas cultivate diverse crops while farmers in the higher temperature areas produce highest diverse crops. But as the annual temperature falls from low to the medium, crop diversity reaches to minimum. Panel 3.1(d) also shows that farmers in the higher temperature areas are more sensitive to crop diversity.

Figure 3.1: Estimated crop diversity and temperature



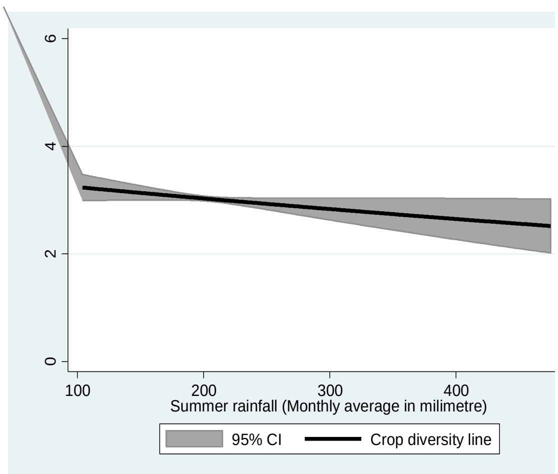
Note: Shaded areas above and below the crop diversity line indicate the upper and lower bound of 95% confidence interval.

3.5.1.3 Crop Diversity and Rainfall

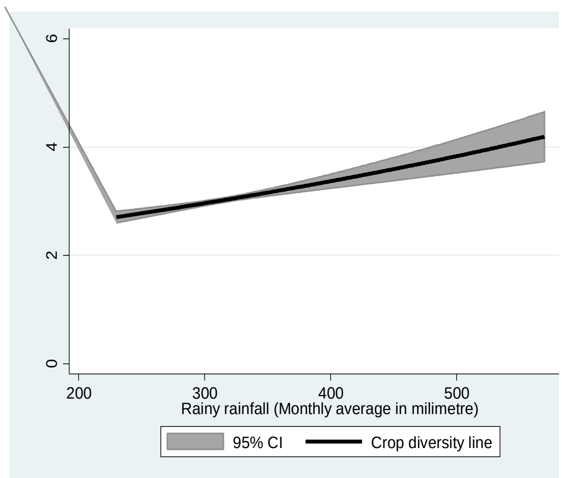
Households located in diverse regions of the country with different rainfall conditions have chosen different crop diversity. Figure 3.2 shows the relation between estimated crop diversity and rainfall for all the three seasons and for annual average rainfall along with 95 percent confidence interval areas of upper and lower bound. In case of summer rainfall, farmers of high rainfall areas cultivate less number of crops compared to low rainfall areas. But, the upper and lower bound confidence interval areas indicate that farmers of high rainfall areas are more sensitive to summer rainfall in terms of crop diversity compared to the farmers of the low rainfall areas. Conversely, in case of rainfall in rainy season, farmers of high rainfall areas cultivate more crops compared to low rainfall areas and high rainfall is more sensitive to crop diversity as indicated by the wider spread between two CI lines. The rainfalls in the winter and rainy seasons have same pattern of crop diversity. Panel (d) of figure 3.2 shows crop diversity in different annual rainfall levels. It shows that farmers in lower rainfall areas cultivate highest diverse crops. But crop diversity reaches to minimum in the medium rainfall areas. Finally, when annual rainfall increases to the highest, crop diversity again goes up. Panel 3.2(d) also shows that farmers in the high rainfall areas are more sensitive to crop diversity.

Figure 3.2: Estimated crop diversity and rainfall

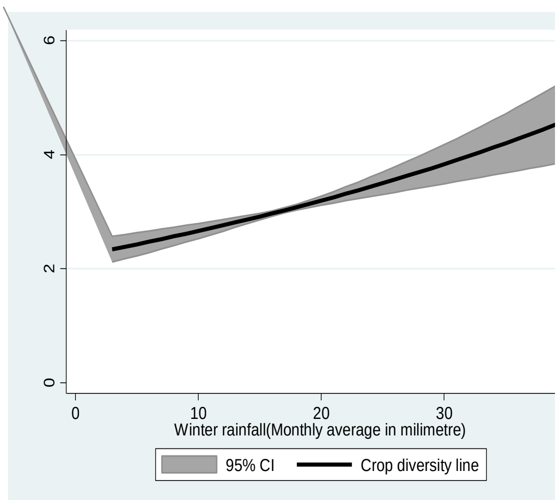
a) Summer rainfall and crop diversity



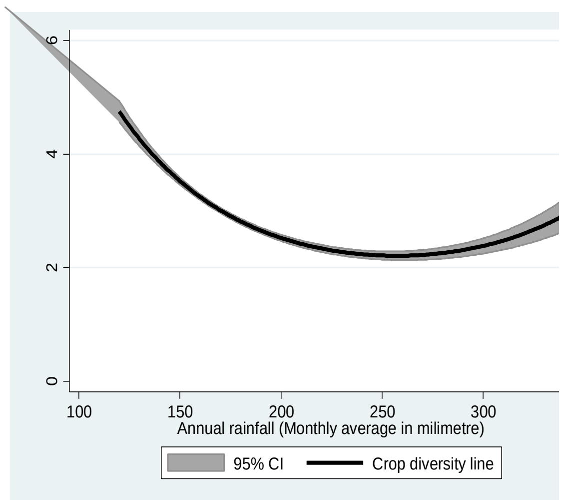
b) Rainy rainfall and crop diversity



c) Winter rainfall and crop diversity



d) Annual rainfall and crop diversity



Note: Shaded areas above and below the crop diversity line indicate the upper and lower bound of 95% confidence interval respectively.

3.5.1.4 Marginal Effects and Incidence Rate Ratio

Marginal effects of temperature in different seasons on crop diversity are larger in amount compared to those of rainfall in those seasons. Similarly, in case of incidence rate ratio (IRR), temperatures in different seasons are more sensitive to crop diversity than rainfall. Table 3.2 presents the marginal effects and IRR derived from negative binomial regression model of pooled cross section (2000, 2005 and 2010). All climate variables have positive marginal effects on crop diversity except summer temperature and summer rainfall. In case of three land related variables (agri land, mortgaged in and mortgaged out), marginal effect on crop diversity is very negligible. Marginal effects of house space, house price and access to mobile on crop diversity are positive while those of family size, wage labour, and access to electricity are negative on crop diversity.

IRR represents the percentage change in crop diversity that is determined by the amount the IRR is either above or below 1. The value of IRR is important as it shows the change in the incidence rate of crop diversity for every unit change in the explanatory variables. In other words, IRR shows how changes in explanatory variables affect the rate at which the dependent count variables occur.

Table 3.2 also shows that one Celsius increase in summer temperature leads to decrease crop diversity by 12.6 percent while that increase in rainy and winter temperatures results in increase in crop diversity by 39.3 and 2.5 percent respectively. Rainfall in summer, rainy and winter seasons are insensitive to crop diversity as their IRRs take values very close to 1. Among other control variables, households using wage labour are sensitive to crop diversity negatively while mobile using households are sensitive to crop diversity negatively.

Table 3.2: Marginal effects and incidence rate ratio of negative binomial regression models of crop diversification

Variable	Marginal effects	Incidence rate ratio
Summer temperature	-0.370	0.874
Rainy temperature	0.913	1.393
Winter temperature	0.068	1.025
Summer rain	-0.003	.998
Rainy rain	0.001	1.000
Winter rain	0.042	1.015
Agri land	-0.000	0.999
Mortgaged in	-0.001	0.999
Mortgaged out	0.0002	1.000
House space	0.012	1.004
House price	0.0001	1.000
Family size	-0.030	0.989
Mobile	0.240	1.091
Electricity	-0.021	0.992
Wage labour	-0.144	0.948

3.6 Climate Change Scenarios and Crop Diversification

Climate change scenarios of Bangladesh estimated in Agrawala, Ota, and Ahmed (2003) by General circulation model (GCM) which were run with the IPCC (Intergovernmental Panel on Climate Change) B2 SRES emission scenario are used in this research to simulate the effects of climate scenarios (rainfall and temperature) on crop diversity. Table 3.3 presents annual and seasonal temperature and rainfall scenarios of Bangladesh. GCM predicts an annual average temperature increase of 1.0 Celsius by 2030, 1.4 Celsius by 2050, and 2.4 Celsius by 2100 and annual average rainfall increase of 3.8 percent by 2030, 5.6 percent by 2050, and 9.7 percent by 2100. Among all the three seasons, winter shows the highest increase in temperature while rainy season shows the lowest. Both summer and winter temperature scenarios are higher than the annual average in all the three time points. More than 80 percent of the 2,300 mm of annual precipitation that falls in Bangladesh comes during the rainy season (Smith et al., 1998). In all the three scenarios, rainfalls in the rainy season record much higher increase compared to the other two seasons. Conversely, winter season rainfall shows a decrease in all the three scenarios.

Table 3.3: Different climate change scenarios of Bangladesh

	2030				***2050***				***2100***			
Climate Variable	An	Su	Ra	Wi	An	Su	Ra	Wi	An	Su	Ra	Wi
Temperature(C)	1.0	1.1	0.8	1.1	1.4	1.5	1.1	1.6	2.4	2.6	1.9	2.7
Rainfall (%)	3.8	2.8	4.7	-1.2	5.6	4.3	6.8	-1.7	9.7	7.5	11.8	-3.0

Note: a) Annual, rainy and winter season scenarios are collected from Agrawala et al. (2003) while summer season scenarios are calculated from annual and other two seasons' scenarios, and b) Ann=annual, Su=summer, Ra=rainy and Wi=winter.

3.6.1 Simulation of Crop Diversity under Temperature Scenarios

Here I estimate how crop diversity will change over time in response to temperature scenarios of 2030, 2050 and 2100. This has been done by simulation of crop diversity under temperature scenarios employing the following methods: (a) parameters of the pooled cross section model has been used for the simulation, b) when temperature scenario is considered, all other parameters are assumed to be constant at mean level, and c) simulation effects on crop diversity for annual temperature are based on the parameters of the pooled model which uses annual climatic variables instead of seasonal. Stata techniques have been used in this simulation exercise. Table 3.4 presents the effects of temperature scenarios on crop diversity. As the temperature increases, keeping rainfall and all other variables at their mean levels, number of crops to be produced by farmers increase by different amounts. Rainy season temperature is highly sensitive to crop diversity. In base line scenario, crop diversity is 3.03 which will be 6.75 under 1.9 degree Celsius increase in 2100. In response to summer temperature scenarios, crop diversity will be 4.35 in 2100 against the same baseline (3.03). Increase in winter temperature under climate scenarios squeezes the crop diversity. Since temperature scenarios in different seasons exhibit different trends of crop diversity, we need to look at the effect of annual temperature scenarios on crop diversity. Table 3.6 shows that effect of annual temperature scenarios leads to increase the crop diversity by large amount. Crop diversity will be 5.26 in 2050 and 7.57 in 2100. This large increase has happened as the nonlinear effect of annual temperature has been added in the model by including the square of the annual temperature.

Table 3.4: Effect of temperature scenario on crop diversity in Bangladesh

Scenarios	Annual	Summer	Rainy	Winter
Baseline	3.03	3.03	3.03	3.03
2030	3.83	3.71	4.44	2.45
	(26.40)	(22.44)	(46.53)	(-19.14)
2050	5.26	3.87	4.98	2.12
	(73.59)	(27.72)	(64.36)	(-30.03)
2100	7.57	4.35	6.75	1.55
	(149.83)	(43.56)	(122.77)	(-48.84)

Note: a) Number in the parenthesis shows the change in crop diversity from the baseline, b) The estimated results of this model is presented in the appendix of this research.

3.6.2 Simulation of Crop Diversity under Rainfall Scenarios

How crop diversity will change over time in response to rainfall scenarios of 2030, 2050 and 2100 will be estimated here. This will be done by simulation of crop diversity under rainfall scenarios that follows the following methods: (a) parameters of the pooled cross section model has been used for the simulation; b) when rainfall scenario is considered, all other parameters are assumed to be constant at mean level; and c) simulation effects on crop diversity for annual temperature are based on the parameters of the pooled model which uses annual climatic variables instead of seasonal.

Simulation of crop diversity under different rainfall scenarios shows that as the rainfall increases keeping temperature and all other variables at their mean levels, number of crops to be produced by the farmers will increase by negligible amounts. Table 3.5 presents the effects of rainfall scenarios on crop diversity. All the rainfall scenarios in three seasons resulted in small increases in crop diversity in the three time points. In case of annual rainfall scenarios, even after controlling the nonlinear effect by including the square of annual temperature in the regression model, crop diversity at first increases to 3.21 in 2030 from 3.03 in baseline and then it starts decreasing slightly and reaches 3.09 in 2100.

Table 3.5: Effect of rainfall scenario on crop diversity in Bangladesh

Scenarios	Annual	Summer	Rainy	Winter
Baseline	3.03	3.03	3.03	3.03
2030	3.21	3.28	3.40	3.33
	(5.94)	(8.25)	(12.21)	(9.90)
2050	3.17	3.27	3.43	3.32
	(4.62)	(7.92)	(13.20)	(9.57)
2100	3.09	3.26	3.50	3.31
	(1.98)	(7.59)	(15.51)	(9.24)

Note: a) Number in the parenthesis shows the change in crop diversity from the baseline, b) Simulation effects on crop diversity for annual rainfall are based on the parameters of the pooled model which uses annual climatic variables instead of seasonal. The estimated results of this model are presented in the appendix of this research.

This research shows that the farmers of Bangladesh will diversify their crops to face climate change, especially temperature, but the rainfall scenarios will diversify the crops by only negligible amounts. Comparison between the effects of rainfall and temperature scenarios on crop diversification indicates a clear difference which needs to be explained. One argument may be like this-increase in temperature cannot be controlled by the farmers of Bangladesh. So, they will look for high temperature tolerant varieties to adjust with high temperature. But they can control erratic nature or increase in rainfall partially by adopting irrigation strategy which may tempt them to fix with the existing varieties.

As we know that there is a growing body of literature on quantitative research suggesting that agro-biodiversity contributes to the increase in agricultural crop yield, and to production risk reduction (Bradshaw et al., 2004; Di Falco & Chavas, 2008, 2009; Di Falco & Perrings, 2005). But those papers didn't focus the crop diversity as climate change adaptation. Moreover, a number of literature (Hoque & Haque, 2016; Banerjee et al 2015; Mohammad et al. 2014) evolved in the recent years focus on the crop sector and climate change in Bangladesh. But those papers didn't consider crop diversification as climate change adaptation. Therefore, this research is not only new in method and Bangladesh context, it also found a research gap which is not addressed earlier.

3.7 Conclusion

This research shows that the farmers of Bangladesh will diversify their crop choices to face climate change, especially change in temperature. But, the rainfall scenarios will increase crop diversity by negligible amount. This research finds structural instability among the regression models of the single cross section over time. Therefore, regression model from pooled cross section data of 2000, 2005 and 2010 has been used in this research to find the crop diversity under different climate scenarios which is strength of this paper. Another strength of this research is that environmental data against each crop diversity is average of the last thirty years. So, the research includes past effect of climate on crop diversity. Environmental data used in this paper are from 33 meteorological stations of the country implying that households located in the area of the same meteorological station face the same environmental situation. But, in practice, even inside the areas under same meteorological stations, different households may face slightly different environmental situation. Therefore, household specific climate variables might improve the paper in terms of accuracy in climate parameters. This research presents the country level findings on crop diversity under different climate change scenarios. In the regional level, the sample was not representative that was a constraint of this research. However, this constraint leaves the scope of further improvement of this research at regional level. It is a fact that regional level research on crop diversity can provide more specific findings on crop diversity under climate change scenarios. Nevertheless, the findings of the research indicate a future cropping pattern of the country which has important policy implication. Therefore, this research provides the background of how the government will undertake climate change adaption and agricultural policy towards different crop varieties. The findings of this research suggest to incorporate the issue of future cropping pattern of the country in the national climate change adaptation plans and actions (NAPA and BCCSAP) and also in the specific sectoral policies like fertilizer, seed and agricultural subsidy policies of the country. National agriculture policy incorporates the following issues-quality seeds, efficient irrigation management, use of balanced *fertilizers* and availability of credit in time and crop diversification has a direct implication in those issues. Therefore, the effect of crop diversification as a potential climate change adaptation strategy at the household level needs to be considered in the national agriculture policy of the country. Since Bangladesh has large agriculture sector and a large chunk of population lives directly or indirectly on agriculture, government has to provide support both in the form of cash/price and kinds for the farmers of the country. For instance, at present government is providing price support for diesel used for irrigation of the agriculture sector. This diesel subsidy policy of agriculture is related with crop diversity which needs to be considered while framing this policy. Adopting crop diversification as a potential climate change adaption strategy has a direct implication in the national seed policy of the country. As this policy influences the production and distribution of the seeds of the different crops, crop diversification as a potential climate change adaption strategy needs to be taken care of while framing this policy. But, this research cannot indicate the specific crop pattern under diversification. Therefore, this research should be complementary with the research on crop switching as a way of climate change adaptation in Bangladesh.

3.8 References

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3.9 Appendix

Table 3.8: Negative binomial regression of crop diversity on Annual temperature, rainfall and other explanatory variables from pooled cross sections

Variables	Coefficient	Std Err	z	P>z	[95% Conf.	Interval]
Annual tem	-18.301	1.620	-11.290	0.000	-21.477	-15.125
Annual temsq	0.355	0.032	11.240	0.000	0.293	0.417
Annual rain	-0.021	0.001	-18.070	0.000	-0.023	-0.019
Annual rainsq	0.000	0.000	15.090	0.000	0.000	0.000
Agri land	0.002	0.000	24.390	0.000	0.002	0.002
Mortgaged in	0.002	0.000	12.030	0.000	0.001	0.002
Mortgaged out	-0.002	0.000	-13.760	0.000	-0.002	-0.002
House space	0.025	0.002	10.160	0.000	0.020	0.029
House price	0.000	0.000	-2.740	0.006	0.000	0.000
Family size	0.028	0.003	8.260	0.000	0.022	0.035
Mobile	0.171	0.040	4.250	0.000	0.092	0.250
Electricity	-0.383	0.035	-11.070	0.000	-0.451	-0.315
Wage labour	0.087	0.039	2.240	0.025	0.011	0.163
Constant	238.947	20.785	11.500	0.000	198.209	279.685
lnalpha	-1.194	0.027			-1.248	-1.141
alpha	0.303	0.008			0.287	0.320

Chapter 4

Natural Disaster and Income and Consumption Dynamics: A Study of Cyclone Aila in Bangladesh

Abstract

This research applies the consumption-income dynamic theoretical model and investigates three research hypotheses empirically. Firstly, how, after experiencing asset and income shocks from cyclone Aila, households accelerate their income in the post cyclone period. Secondly, how the consumption pattern behaves in the post cyclone period. Thirdly, whether the cyclone causes income loss and the households show resilience in income growth in the recovery period. The data used in this research is based on a household survey conducted in the area affected by cyclone Aila in southern Bangladesh. This research puts forward a number of key findings which are; a) asset losses of low income people are more sensitive to income generation compared to the high income people; b) people in the recovery period don’t sacrifice their consumption in proportion with their income loss; c) income losses from the disaster are almost equally sensitive to consumption for different income groups; d) the speed of convergence in income generation is much higher than that of consumption in the recovery period; e) the disaster causes income loss, but people show their resilience by accelerating higher income growth compared to the non-affected areas; and f) people on a low income show more resilience in income generation compared to people on a high income in the post cyclone recovery period.

4.1 Introduction

This research will investigate income and consumption trajectories of the cyclone Aila affected households in the coastal region of Bangladesh. It applies the household level consumption-income theoretical framework in empirical models of both income and consumption growth determination to investigate households' sensitivity to income and asset shocks from climatic extremes. These empirical models will also include a set of control variables such as households' characteristics, access to different institutions, and village-specific variables in order to get a better estimation of households' sensitivity to asset and income shocks. Finally, this research will examine the impact of cyclone Aila in terms of income generation compared to a non- affected area. The data used in this research is based on a survey conducted by the authors in the cyclone Aila affected area of southern Bangladesh.

The first empirical model on income trajectories will look into how the households recover after asset and income shocks caused by cyclone Aila and whether any divergence or convergence occurs in income growth in the recovery path. Both the basic and expanded models show a pattern of convergence as income growth diminishes with the increase in pre-cyclone income level. As the estimation results of Table 4.4 show, households with 10% higher income in the pre-shock period have 9.44 percentage points less income in the recovery period according to the basic model and 9.03 percentage points according to the expanded model. In addition, the expanded model shows that sensitivity of asset loss to income growth in the recovery period differs significantly among the different income groups. The people who were in the lowest pre-Aila income quartile show greater sensitivity to asset losses than the other three higher income quartiles. Family size, the education level of the household head, access to mobile phones and an NGO contributed positively to income trajectory in the recovery period. Those who had access to a credit market before Aila were better to cope with the income shocks due to Aila.

The second empirical model will investigate how the consumption pattern behaves after asset and income shocks from cyclone Aila. This research will also examine whether any divergence or convergence occurs in consumption in the recovery path. Both the basic and expanded models show a pattern of convergence in consumption in the recovery period. As the estimation results in Table 4.5 shows; households with 10% higher income decrease consumption expenditure by 0.22 percentage points in the basic model and 0.32 percentage points in the expanded model. In addition, households in all the four income quartiles have almost equal sensitivity of income losses to consumption, which are also examined by the Wald test for equality of the coefficients. Family size, education level of the household head, and NGO involvement contributed positively to consumption trajectory in the recovery period. Households with access to credit experienced lower consumption growth compared to households without access to credit in the recovery period while the households with access to the labour market before the cyclone, did better in gaining consumption growth in the same period.

This research employs the 'difference in difference' (DID) estimation method to investigate the income loss from cyclone Aila compared to the non-affected similar areas. It also attempts to look at how resilient the households in the treatment areas are in gaining income growth in the recovery period. Koilashganj, a union of Dacope sub-district has been selected as the control area for this research[16]. Considering the income levels as a dependent variable, this research finds that households in the Aila affected area acquire lower income compared to the non-affected areas in the recovery period. Furthermore, while this research considers the income growth as a dependent variable, it finds that households in the affected areas accelerate higher income growth compared to the control area in the recovery period. While doing these DID estimations, this research also tries to control some exogenous variables (education, age, sex and

[16] Union is a local government unit of Bangladesh. Every sub-district consists of a number of union.

family size), and time-varying variables (access to electricity, mobile, NGO, credit and labour market).

This research contributes to the literature in several ways. Firstly, since researches show that effect of disaster on poverty is context specific, the current research on the effect of cyclone Aila will provide a new context of the effect of disaster. Secondly, this research compares the effects of disaster between the affected and unaffected areas in a quasi- experiment set up which is not commonly done in the similar literature. Thirdly, this research is intended to explore the effect of disaster in the medium run while most literature on the effect of disaster considers the immediate or short run effect. Fourthly, this research incorporates the ex ante characteristics of the households and their impacts on the ex post disaster effect which is not done in the similar literature. Finally, this research will set up a new dimension of exploring the link between poverty and disaster focusing income, asset and consumption that can be applied in other developing countries of the world.

There are two strands of literature on impact assessment of the natural disaster. First strand represents the immediate impact assessment mainly in the form of amount of damage and loss (Khandlhela & May, 2006; Strobl, 2011; Hallegatte, 2014). The second strand represents medium and long term effect of natural disaster on income, asset, inequality, poverty etc.(Benson & Clay, 2004; Skidmore & Toya, 2002)). This research contributes to the s econd strand. In addition, the existing researches on Aila (Kumar, Baten, Masud, Osman, & Rahman, 2011; Akter & Mallick, 2013; Ahsan & Takeuchi, 2015) focus on the immediate impact of the cyclone . Therefore, there is a research gap to look into the impact of the recovery from the cyclone Aila in the longer period than immediate. Moreover, the present research compares both the poor and non-poor households of the affected areas with those of the less or no affected areas which is a new dimension on the research on Aila. Hallegate et al. (2016) mentions that impact of disaster is context specific. Therefore, research on Aila will add a new context in the impact study of disaster.

This research bears an immense importance for policy formulation in developing countries like Bangladesh. How households with different asset and income levels respond to this natural disaster both during and in its' aftermath will be useful for the policy formulation of the social safety net program. How access to credit or the labour market, and also the socio-economic background of the households both play their roles during the road to recovery from the income and asset shock will be another interesting finding of the research. This research will also describe the consumption behaviour of the people after the environmental shocks. This will help to formulate policies related with food security.

The rest of the paper is structured as follows. Relevant literature will be reviewed in section 4.2. Sections 4.3 and 4.4 deal with the theoretical framework and empirical methods respectively. Section 4.5 presents the data used in this research. Sections 4.6 and 4.7 present the estimation results of income trajectory and the consumption path respectively in the recovery period. Section 4.8 also presents the estimation results of the income effect of cyclone Aila compared to the non-affected areas. Section 4.9 discusses the implication of the estimation results and section 4.10 ends the paper with conclusions and policy implications.

4.2 Risk of Climate Extremes: Vulnerabilities and Impact

Extreme weather and climatic events, also referred as natural disasters[17], claim thousands of lives and cause billions of dollars of damage globally (Hallegatte,

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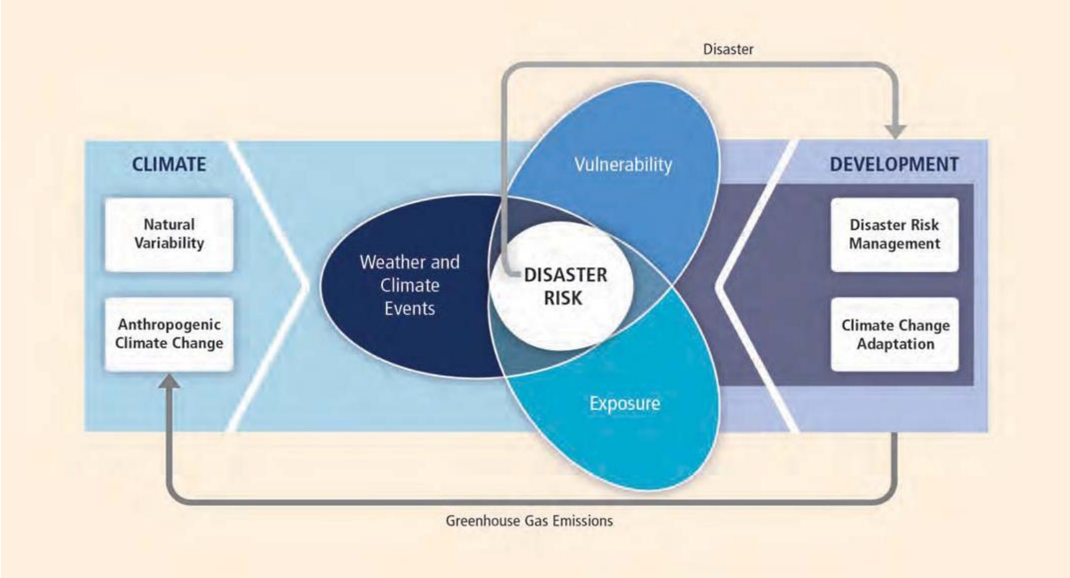
[17] A disaster is defined as a severe interruption of the functioning of a community or a society, involving widespread human, material, economic or environmental losses and impacts that exceed the ability of the affected community or society to cope using its own resources (adopted from UNISDR 2009). From an economic perspective, a natural disaster can be defined as a natural event that causes a perturbation to the functioning of the economic system, with a significant negative impact on assets, production factors, output, employment, or consumption. Examples of such natural events are earthquakes, storms, hurricanes, intense precipitations, droughts, heat waves, cold spells, and thunderstorms and lightning (Hallegatte, 2012). The potential impact of disasters is described by the term 'disaster risk' (UNISDR, Fizi report, 2008).

2012). These events produce severe disturbance to normal life leading to extensive adverse human, material, economic, or environmental effects that require an immediate emergency response to respond to critical human need (Hare et al., 2013). The World has experienced a wide range of massive climate extreme events including a Tsunami in East Asia, a tidal surge in Japan, and hurricane Sandy in the USA in the last decade alone, implying that countries irrespective of economic status are victim of climate extremes. The impacts of climate extremes are not only determined by physical exposure to them, but are also dependent upon the vulnerability of the local community. Social and economic vulnerability to natural disasters is disproportionate with income at country level. Developing countries are more vulnerable to climate extremes as evidence shows that 24 of the 49 least developed countries (LDCs) are under extreme threat of natural disasters, and developing countries experience 97 percent of all human deaths from natural disasters (Schmidt, Bloemertz, & Macamo, 2005).

4.2.1 Risks of Climate Change and Extremes

Natural climate variability has led to an increase in the frequency, intensity and duration of climatic extremes in the recent past few decades (Cameron, Norrington-Davies, te Velde, & Mitchell, 2012). Evidence shows that climate variability increases volatility in precipitation levels, sea level rises, drought, floods and so on since the 1950s, creating new risks in the development process and creating human crises. The fifth Assessment report of IPCC shows that sustaining the current rate of fossil fuel burning will cross the two degrees Celsius threshold leading to more frequent and longer heatwaves, more precipitation, faster sea level rises etc. Those will cause huge loss and damage to the global economy pulling more people under poverty line.

Figure 4.1: Defining disaster risk



Source: (IPCC, 2012)

The World Resource Institute shows that 61.4% of global GHG emissions by sector are attributable to energy, 3.4% to industrial processes, 31.7% to agriculture and land-use change (principally deforestation), and 3.6% to waste. Due to urban development, patterns of land-use change, deforestation has become quicker and industrial development has been rapid. Moreover, overall consumption growth has always put upward pressure on investment in the industrial sector. All these processes posit a new risk of climate change in the development process. The physical nature of climate change makes it a cross-border and inter-generational issue.

Risk of huge loss and damage to the economy stemming from climate change demands mitigation and adaptation measures from its stakeholders. Due to externality and a high volume of investment need, mitigation is not attractive for all countries; rather, planned adaptation is more pragmatic and implementable. Due to the multi-sectoral nature of climate change, adaptation requires huge investment which in turn demands the involvement of both public and private sector. Climate extremes appear as a major shock to public finances through their impact on output and the need for reconstruction and relief expenses. In developing countries, where the insurance penetration is very low to reduce climate risk, are in need of external assistance to finance the reconstruction, relief and other expenses to regain the momentum in their growth processes.

4.2.2 What is Vulnerability?

Defining vulnerability is not straightforward as it involves a wide range of factors. Inadequate capacity to defend oneself from damaging effects of exogenous events (natural or man-made) and to recover speedily from the effects of the events can be described as vulnerability. The institutional, economic and socio-cultural factors prevailing in a society determine the shape of this vulnerability. Inadequate knowledge, absence of coordinated institutional arrangements, lack of financial resources and insufficient legislation are the major socio-cultural factors to influence vulnerability (Schmidt et al., 2005). Rodriguez-Oreggia, De La Fuente, De La Torre, and Moreno (2013) also consider vulnerability to natural disasters as a complex matter as multiple factors - economic structure, stage of development, prevailing social and economic conditions, coping mechanisms, risk assessment, frequency and intensity of disasters are involved with vulnerability.

4.2.3 Vulnerability and Poverty

The poverty situation an individual faces is an important determinant of vulnerability, which ultimately influences the extent of the impact of disaster. The impact of disaster increases the future vulnerability and exacerbates people's poverty situation as a consequence. Therefore, the interaction between poverty and vulnerability is like a cycle of action and reaction. This discussion suggests that poverty and vulnerability can be distinguishable with their own distinctive features. Schmidt et al. (2005) advocates that not all people of a specific vulnerable group are inevitably poor. Juneja (2008) identifies several broad trends in the evolution of the interactions between disasters and poverty since the 1960s which are as follows:

A. Physical Vulnerability

The concept of vulnerability first came about in the discussion of risk of natural disasters and calamities which often leads to the destruction of physical objects. An earthquake causing destructions to buildings, a flood destroying plantations are all examples of such vulnerabilities. Physical vulnerability is the instantaneous impact of the disaster that affects the victims. Khandlhela and May (2006) looked into the vulnerability of a flood in the Limpopo province of South Africa. In their analysis, they found out that 47% of the sampled households lose dwellings and assets; 37% of the household had problems regarding injuries and illness; and 17% suffered a destruction of crops and livestock. Therefore, the most common effect of a disaster was the loss of dwellings and assets, people becoming injured and most importantly the loss of shelter. All these contributes to physical vulnerability.

B. Social Vulnerability

Social vulnerability as defined by Allen (2003) as the persistent state that exists within a system that inherently poses a threat to the human life. Typical analysis of vulnerability most of the time discusses about physical vulnerability. When a disaster occurs, most vulnerability analysis talks about the impact on the human life. To be more precise, the discussion is often limited to the immediate and initial impact of the shock. However, discussion also needs to be made as to the capability of the system to come out of the shock. In other words, vulnerability is viewed as an inherent property of a system arising from internal characteristics of the inherent behavior of the society (Adger, 1999; Adger and Kelly, 1999). However sometimes the word ‘social’ may not be appropriate for the context of the vulnerability obtained inherently from non-human factors. Such vulnerabilities are therefore termed as “inherent vulnerabilities”. Social vulnerability often refers to factors such as poverty and inequality, marginalization, access to facilities, housing quality etc. (Blaikie et al., 1994; Adger and Kelly 1999; Cross 2001). Social vulnerability has been a prime area of focus for the field and community level research of vulnerability. This type of research is concerned with identifying the most vulnerable members of the society, identifying the difference in vulnerability across geography etc (Downing and Patwardhan, 2003). According to Adger and Brooks (2003) social vulnerability is viewed as one of the underlying reasons of physical vulnerability.

In another analysis, O'Keefe, Westgate and Wisner (1977) proposed that vulnerability should be something that not only takes into account the external shocks or calamities rather endemic conditions that are inherently present in a particular society. According to this analysis natural disasters were not accidental but rather a characteristic of that particular society and location. This particular thinking says that historical, cultural, social and political processes are the root cause of unsafe conditions (Blaikie et al., 1994). One of the pioneering work in the human aspect of vulnerability was carried out by Dynes and Quarantelli (1973). They looked into the community and family aspect of an individual's reaction to a disaster.

C. Livelihood Vulnerabilities – Social, Economic and Gendered Perspectives

Livelihood vulnerabilities first came into existence with researches on the livelihoods of the poor in the urban and rural habitats. An idea developed in the 1980s is that the exposure to risk is unequal as generated by the social process in making some people prone to disasters than the others (Hilhorst and Bankoff, 2004). This idea portrayed the social inequality was a part of the vulnerability, more specifically, livelihood vulnerability. Livelihood vulnerability has been an important factor in addressing poverty and risks (Chambers, 1989; Chambers and Connway 1999). Livelihood is being used as a measure of a degree of vulnerability of a community, household and individual. In many studies, it was seen that households were willing to accept a higher hazard exposure for an urban location that provided an access to employment and services. This is supported by Hallegate et al. (2016) stating that poor people who usually migrated to the urban areas to ensure their livelihood used to live in the disaster exposure areas in urban areas.

D. Well-being, Human Development and a Safer World Agenda

The concept of well-being came into discussion in the 1990s and replaced the conventional approaches that economics took to poverty. This approach is centred on the concepts of assets and entitlements put forward by Amartya Sen in the early 80s. Further developments were made in studying these relations and a greater focus was put on the risk-poverty relation. The Yokohama Strategy in 1994 explored and acknowledged the disaster-poverty link. During the 1990s, it was given a more increased role with the publishing of the Human Development Index. The HDR argued that even though economic prosperity helps towards living a more empowered life however, quality of life is determined by the health, education among many other factors (UNDP, 2007).

E. Governance and Accountability: Combating Disaster Risk, Climate Change and Urbanization

Another trend quickly gaining popularity is the emphasis on governance (O'Brien et al. 2006). In light of climate change specially for the urban population (Satterthwaite et al. 2007) a key area of research has been the linkage of the ongoing environmental degradation and the change in people's habitats and way of life. Such studies include Brockelsby, 2000 in Bangladesh and Durand 2007 in Mexico. This approach discusses that the poor governance and the lack of policy and planning in the urban sector leads to a more vulnerable community. Thus, through the 1990s an increased emphasize was put on good governance and urban planning (IIED, 2002). However, there is still a growing concern over the effect of geological and climatic hazard on poverty.

An increase in the frequency of natural disasters may lead to increase the vulnerability of the people. Vatsa and Krimgold (2000) point out that the increasing occurrence of natural disasters is highly associated with increasing vulnerability of households and communities in developing countries. Moreover, existing socio-economic vulnerabilities may exacerbate the effect of a natural disaster and make the recovery process more difficult.

Assessing the impact of a disaster is very useful for policy makers as it enables them to formulate effective policy and programmes. Impact assessment of a disaster also helps policy makers identify the different sections of society who are affected which ultimately supports the effective development planning process of a country (Lindell & Prater, 2003). A growing literature which recognizes the importance of disaster impact assessment considers natural disasters or climate extreme events as truly potential impediments to economic development with significant poverty impacts. Climate change extremes in the earlier literature were limited to impact assessment in terms of damages, death, agriculture losses and GDP. In the earlier literature, two contradictory opinions were present. One opinion states that natural disasters are setbacks for economic growth, while another is opposite, although overwhelming earlier literature supports the first opinion. As, for example, Benson and Clay (2004) contend that natural disasters have negative impacts on economic growth in the long-run, while Skidmore and Toya (2002) argue in favour of a positive impact on growth in the long run. Skidmore and Toya (2002) also argue that natural disasters reduce the returns on physical capital but may lead to an increase in human capital, which ultimately generates higher growth. Based on the research on impact of hurricanes on the US coastal region, Strobl (2011) finds that hurricanes reduce that county's economic growth primarily by 0.8 per cent. Climate extremes like floods, cyclones, and tsunami lead to a large shock in peoples' consumption (Hallegatte, 2014).

A number of papers (Jacoby, Rabassa, & Skoufias, 2015; Skoufias, Rabassa, & Olivieri, 2011; Thurlow, Zhu, & Diao, 2012) have attempted to look at the impact of climate change on economically relevant outcomes ranging from economic growth, poverty, inequality, employment, agricultural output, livelihood, food intake, health and education. Carter, Little, Mogues, and Negatu (2007) show that extreme events like drought cause a poverty trap situation in Ethiopia. A relatively newly-growing body of literature is focusing on consumption shocks, fiscal impacts and overall macroeconomic effects. Bowen and Stern (2010) explore the links between economic growth and the impacts of climate change suggesting that some adjustments in growth policy are due to climate change. Acknowledging the macroeconomic linkages with climate change, Hallegatte (2014) provides a set of policies to increase economic resilience and a list of indicators that can be used to build a resilience indicator. Another body of recent literature considers climate extremes as a major issue for public finances and debt sustainability in particular (Borensztein, Cavallo, & P., 2007; International Monetary Fund, 2009; Melecky & Raddatz, 2015; Rasmussen, 2004).

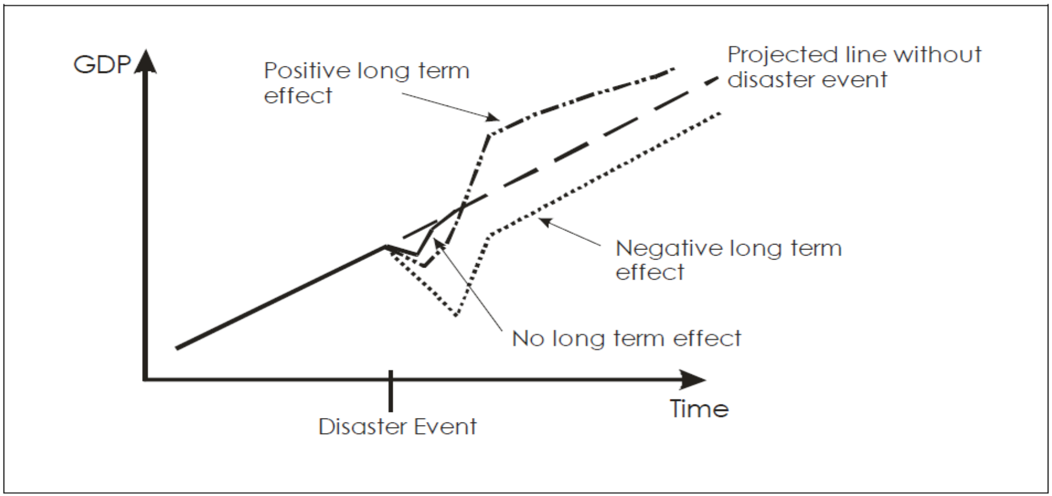
The impact of a natural disaster may also exacerbate inequalities. Poor people are badly affected by natural disasters as they have inadequate access to financial instruments in the aftermath of a disaster leading to a consumption-shock and a decline in other household indicators as well. The assets of rich people are also exposed to vulnerabilities as a result of natural disasters. In developing countries, insurance markets are not developed enough to provide insurance coverage of the assets of the non-poor people. Moreover, in the aftermath of a destructive disaster, financial markets may occasionally provide the non-poor limited access to financial service. Therefore, non-poor people after experiencing a destructive shock from a natural disaster may fall into poverty as a consequence. Shahabuddin and Ali examine the relationship between disasters and poverty and suggest the important conclusion that flood-prone areas are marked with food shortages, the incidence of extreme poverty, insufficient income, illiteracy, and a high concentration of a wage labour population. They also conclude that without concerted effort, up to 325 million extremely poor people from the 49 countries will be most exposed to the full range of natural disasters in 2030. Based on the research on impact of droughts in Ethiopia and hurricanes in Honduras, Carter et al. (2007) show that the impact of natural disasters leads to an increase in poverty and deprivation.

The magnitude of the impact of a disaster also depends on the disaster management process during and after the disaster. Specifically, the effective institutional measures regarding the disaster and subsequent post-disaster rehabilitation efforts determine the impact of a disaster. Peacock and Girard (1997) examined the recovery path after hurricane Andrew in Florida and found that organizational setbacks rather than lack of resources determined the impact of the disaster. Further, Auffret (2003) found that natural disasters increase consumption volatility in the Caribbean because of inadequate risk management. Elliott and Pais (2006) studied the impact of hurricane Katrina and argued that the impact of a disaster is also determined by class system and racial issues.

The effect of a disaster is not random, rather some factors determine it. Lindell and Prater (2003) suggest that the impact of natural disasters should consider mitigation activities, emergency preparation, and assistance to determine the real impact. Investigating the effects of tornadoes in the US, Donner (2007) finds that factors such as environment, organization, demography, and technology have an influence on the impact of a disaster. Some mechanisms used for coping during and after the incidence of natural disasters may lead to affect the degree of impact of disasters at the community and household level. For instance, Alpizar (2007) shows that access to institutional financial services reduces the negative impact of natural disasters for El Salvadorian farmers. Further, de Janvry, Finan, Sadoulet, and Vakis (2006) find that the presence of cash transfer programmes before a disaster acts as a safety net in the cases of the uninsured and non-extremely poor people. In addition, Skidmore and Toya (2002) find that a strong financial sector, higher education, open economy and smaller but effective governments determine the impact of natural disasters on development. Disasters have an impact on wages. Banerjee (2007) investigates the impact of floods on agricultural wages in Bangladesh and finds that depending on the timing of the occurrence, climate extremes reduce the demand for labour and put a decreasing effect on wages. Rodriguez-Oreggia et al. (2013) show that the impact of a natural disaster on the poor could be disruption in some basic services, damaging physical and human capital accumulation and a probable escalation in child labour and crimes.

Hochrainer (2009) provides a framework which shows that exposure to climate change extremes by any vulnerable society leads to direct losses of physical, human and environmental capital which ultimately has a consequence for GDP. Comparing counterfactual with observed gross domestic product, Hochrainer (2009) finds that in a medium-term analysis, natural disasters on average can lead to negative consequences and their magnitude depends mainly on the size of the shock. Figure 1 depicts the possible trajectory of GDP after extreme events.

Figure 4.2: Possible trajectories of GDP after extreme events



Source: Hochrainer, 2009

4.3 Cyclone Aila : Immediate Impacts

The districts located by the coast of the Bay of Bengal are known as the safe landing ground of cyclones. Specifically, the coastal districts of the country were smashed by a number of cyclones with various intensity from 2007 to 2009. Cyclone Sidr hit the area in 2007 and finally, the most severe Cyclone Aila appeared on 25 May 2009. However, Shatkhira district from which the treatment areas have been selected is one of the lowest damage and loss experiencing districts from cyclone Sidr in the south-eastern coastal areas of the country (Government of Bangladesh, 2008). Therefore, the impact of cyclone Sidr will not create any problem in separating the impact of cyclone Aila on the treatment area. The Indian Ocean is a place where many tropical cyclones originate. Its northern region produced cyclone Aila on 21 May 2009 which was the second tropical cyclone to form in that Ocean during 2009. Cyclone Aila turned into a devastating cyclonic storm on 25 May 2009. It affected about 3.9 million people across 11 coastal districts with tidal surges up to 6.5 metres. Cyclone Aila immediately claimed 325 lives leaving about 7,200 people injured. A significant number of livestock, to be specific, around 100,000 died, and about 350,000 acres of cropland were entirely devastated. Southern areas of the country are crisscrossed by hundreds of rivers and almost all of those rivers are enclosed by embankments. Because of the tidal surge of cyclone Aila, the water of the rivers overflowed the embankment and flooded the habitat and other lands. In many places, river embankments were damaged. The United Nations (2011) reported that over 1,742 kilometres of embankments were washed away by the tidal surge of the cyclone which prolonged the continuation of flooding for up to 2 years in several parts of the cyclone affected areas. Because of the effect of a full moon, the high tidal surge associated with the cyclone worsened the flooding situation in the affected areas. A 7,500km long network of flood embankments protect the communities in this area from storms, tidal surges and cyclones. The existing networks of embankments were developed in 1960 under the 'Coastal Embankment Project'. The central government through the Water Development Board maintains the embankment system including polders and sluices. It was widely recognised that the networks of embankments were debilitated due to successive cyclone and storm damage during the previous years and by structural damage caused by shrimp cultivation, and lack of timely and adequate maintenance (United Nations, 2011).

Box 4.1: Cyclone Aila- Basic Information and Immediate Impacts

Basic Information

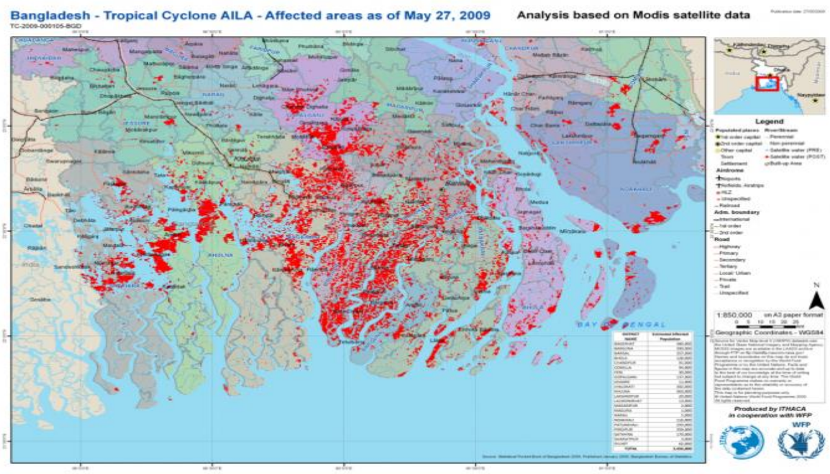
- Formed within the Northern Indian Ocean
- Formed on 21 May 2009
- Maintained a cyclonic intensity for approximately 15 hours after making landfall
- Tidal surge: up to 6.5 meters
- No. of Affected Districts: 11

Immediate Impact

- 325 Deaths
- 72000 injuries
- 3.9 million affected people
- Affected crop land: 350,000 acres
- Livestock casualty: 100,000
- Embankment washed away: 1742 km
- Total damage: 552 million USD

Source: (United Nations, 2011)

Map 4.1: Coverage of Cyclone Aila



Source: (United Nations, 2011)

It is widely recognised that the damage of cyclone Aila is much higher than its intensity would suggest. It is quite explicit that the immediate impacts of the cyclone Aila displays the physical vulnerability of the Aila hit areas. But whether this area was vulnerable in terms of social, livelihood, governance and accountability aspects of vulnerability is an almost unexplored area of research on Aila. However, in terms of social, governance and accountability aspects of vulnerability, Aila hit areas share the common features as like other parts of Bangladesh. But in terms of livelihood aspects of vulnerability, Aila hit areas are a bit different from other parts of the country as the people of the coastal areas are more dependent on fisheries than other means of livelihood. Cyclone Aila is considered a category 1 cyclone because of its sustained wind speed of between 65 and 75 miles per hour[18]. Uttaran (2011) states that even if Aila is by definition a weak category cyclone, its economic cost offset the impacts of the previous cyclones and brought in long-term suffering for the south-western people of Bangladesh. However, small number of research papers has come out focusing the impact of Aila on the welfare of the people of the affected areas.

Kumar, Baten, Masud, Osman, and Rahman (2011) report that during the cyclone a small number of the affected people take shelter in the cyclone shelter and other local buildings. People cannot manage to keep their assets in the protected places. All these indicate a lack of institutional measures in the disaster management process to tackle the cyclone Aila. Akter and Mallick (2013) reported that coastal communities in the subdistrict of Shyamnagar in the southwest of Bangladesh, after Cyclone Aila hit in 2009, unemployment rose steeply (from 11 to 60 percent between 2009 and 2010) and per capita income decreased sharply (from $15,000 before the storm to $10,000 after). The poverty headcount rate increased from 41 to 63 percent between 2009 and 2010. Using the data of the survey conducted after 7 months of Cyclone Aila in Koyra sub-district under Khulna District, Ahsan and Takeuchi (2015) found that tropical Cyclone Aila invoked detrimental impacts on the communities, especially in terms of consumption, employment and access to resources. Their empirical findings also revealed that the poor were more vulnerable and thus suffered significantly higher financial, settlement, and physical damage. However, they did not find any evidence to suggest that the burden of detrimental impacts from cyclones is likely to be disproportionately borne by the poor households.

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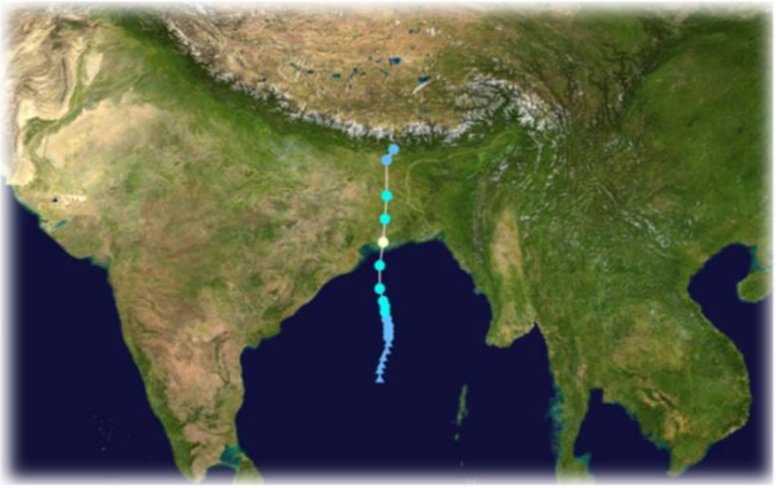
[18] There are 5 categories of cyclone depending on the wind speed measured at **Saffir-Simpson Hurricane Wind Scale** to understand the magnitude of the hurricane's impact. However, this categorization does not consider other aspects of hurricane, such as storm surge, rainfall-induced floods, and tornadoes. But it helps disaster management organizations and people to undertake the safety measures to be taken before a hurricane makes landfall.

All these researches focus on the immediate impact of the cyclone Aila. Therefore, there is a research gap to look into the impact of the recovery from the cyclone Aila in the longer period than immediate. Moreover, the present research compares both the poor and non-poor households of the affected areas with those of the less or no affected areas which is a new dimension on the research on Aila. Moreover, Hallegate et al. (2016) mentions that impact of disaster is context specific. Therefore, research on Aila will add a new dimension in the literature of the impact of disaster.

Figure 4.3: Cyclone Aila Pathways



Source: (United Nations, 2011)

The figure shows that cyclone Aila formed in the Bay of Bengal and passed through the south-western area of Bangladesh. The survey area of this research is located in the same area.

4.4 Theoretical Motivation and Framework

Every household faces a range of risks which can be divided into two parts; systematic risks, and unsystematic or idiosyncratic risk. Risk from climate extremes can be referred as idiosyncratic risk as climate extremes don't follow any pattern.

At first, we consider a type of community where some community level mechanisms such as kinship, social networks and institutional mechanisms exist to allocate risk efficiently. Through these community level mechanisms, households in the community share risk among each other and achieve Pareto efficient allocation of risk. We also consider that there is no access to a credit market or to storage in this community.[19] An utility maximizer household living in a community face the following situations:

A. when a Pareto-efficient allocation of risk is prevailing within a community, households face only a community level aggregate risk. In this case, unsystematic or idiosyncratic income shocks are entirely insured within the community. A consumption smoothing motive between two periods does not lead the household to increase income, as the income shocks are insured by the community. But the Pareto efficient allocation of risk within a community is almost impossible to achieve under the rationality assumption, as the marginal utility of aggregate social or communal work for risk-pooling will be different for different individuals. Therefore, moral hazard in the community will break down the risk pooling structure of the Pareto program (Carter, 1997; Rosenzweig & Parry, 1994; Ruthenberg, 1971).

B. Now, we consider a type of community where Pareto-efficient allocation of risk is not achieved and so cross-sectional risk pooling does not help households adjust with the effects of aggregate community-level shocks to income. In this situation, households face the following equation that implies the permanent income hypothesis:

$$c_t = \frac{r}{1+r}\left(A_t + E_t \sum_{\tau=1}^{\infty}(1+r)^{-(\tau-t)}\, y_t\right) \quad (1)$$

This states that current consumption is the annuity value of current assets plus the present value of the expected stream of future income.

We now consider the different types of shock that the household may encounter under different assumptions concerning risk-sharing and insurance. Now suppose that in terms of access to credit and nature of disaster shocks to income, four situations may arise while we consider the consumption-income relations of the equation (1).

[19] The details of the derivation of the permanent income hypothesis have been given in the annex of the chapter.

a. Access to credit market and transitory income shock

If the income shock is transitory, there will be little or no change in the expected future income stream. Therefore, according to the equation (1), the consumption will change little in response to transitory income shock from a disaster.

b. Access to credit market and permanent income shock

If the income shock is large, there will be a big change in the expected future income stream. Therefore, according to the equation (1), in this case, the income shock will be treated as permanent and consumption will decrease dramatically in response to the income shock from disaster.

c. No access to credit market and transitory income shock

If this community doesn't have any access to credit market along with the absence of Pareto efficient allocation of risk, equation (1) can be rewritten as:

$$c_t = A_t + Y_t \tag{2}$$

In this case, household consumption is equal to the income level (current asset plus current income). Therefore, even a transitory income shock from disaster under this situation will cause a change in consumption.

d. No access to credit market and permanent income shock

In this state, equation 2 will prevail and due to large income shock from disaster, consumption declines drastically as current consumption depends on only current income.

Following the implication of the theories described above, we have investigated the consumption smoothing behaviour under shocks and the people's perception towards income shock from disaster. On the basis of above theoretical foundations, this research intends to answer the following research questions:

1) How the households recover after asset and income shocks caused by cyclone Aila? Whether any divergence or convergence occurs in income growth in the recovery path?
2) How the consumption pattern behaves after asset and income shocks from cyclone Aila?

3) Whether any divergence or convergence occurs in consumption in the recovery path?

4) How resilient the households in the treatment areas are in gaining income growth in the recovery period?

4.5 Empirical Methods

This research is based on primary data collected directly from households in the hurricane Aila affected area of Bangladesh. All households who are hit by the cyclone Aila are the population of the survey. I have used stratified random sampling method where the entire population has been divided into two subgroups- Aila affected and unaffected. Then the final subjects have been randomly selected from each group. As we can see in Map 4.1 that coastal 10 districts were hit by the cyclone Aila in 2009. Shaymnagar sub-district from Shatkhira district is chosen as Aila affected area as different reports on hurricane Aila (Kumar et al., 2011; United Nations, 2011) designates this sub-district as among the highly disaster-affected areas. Households from two unions – Gabura and Munshiganj of Shaymnagar sub-district of Shatkhira District are chosen as sample unit of this survey. The total number of sample elements from the disaster-affected areas is 595, of which 296 households are from Gabura and 299 are from Munshiganj. Another area which is hit, but not affected by Aila has been chosen as another strata of the survey. After careful scrutiny of the Aila hit areas, we are lucky to find an area which is hit, but not affected by Aila. Koilashganj under Khulna district is such an area located at the coastal zone which shares similar physical and socio-economic characteristics with the treatment area Shaymnagar is chosen as control area. For this research, we choose Koilashganj under Khulna District as control area. 297 households have been selected as sample unit from control area Koilashganj of Khulna district. Random sampling methods are used to select the households from each groups so that the households covered in this survey are representative.

I designed the questionnaires with both open-ended and close-ended questions and adopted a face-to-face interview method to complete them. The questions on income, consumption, assets, aid and tackling disasters are open-ended; while those on sex, race, access to labour, the credit market and climate change adaptations are closed-ended. Since Hurricane 'Aila' landed in March 2009, this research considers the previous year of Aila as pre-shock period, the following year as the post-shock period and several years after the shock as post-recovery period (2013). Information at those time points was collected during the household survey by applying retrospective recalling, which is a widely used method in social-science research.

Local NGOs working on Aila rehabilitation informed that around 10 percent people of the Aila affected areas migrated after cyclone Aila. They also confirmed that both rich and poor people migrated equally in the wake of Aila. Rich people migrated to new safer place by establishing new residences while poor people generally moved to the cities and usually lived in the slums. Although migration is a potential sampling problem for the Aila affected areas, migration of both poor and rich at a time can minimize this sampling problem to greater extent. Secondly, this survey includes the questions on the income, asset, asset loss during Cyclone Aila after 5 years of the event which is a potential recall data problem. To minimize this recall data problem, we have engaged the local enumerators who are well aware of the socio-economic condition of the households of the Aila affected areas and who had expertise and pre-experience in data collection on Aila affected areas. Moreover, data has been rechecked with the local NGO personnel who had been working on the impact of Aila in the affected areas.

Validity check with other data source indicates very low discrepancies between the collected data and other data source. Average annual income of the families of Padmapukur union, another Aila affected area just beside the treatment area of this research is 85,584 BDT in 2013 (Moniruzzaman et al., 2014).

The survey of this research that took place at the same year 2013 shows that average annual income of the households of the treatment area is 80,845 BDT. Average damage of the household assets due to Aila in the Padmapukur area amount to 56,371 BDT (Moniruzzaman et al., 2014). In the survey conducted for this research, average damage of the household assets in the treatment due to Aila is found to be 57,427 BDT.

To find out the answers to the research questions I employ different econometric techniques in this research, which will be discussed in the following sections. We have looked into the income acceleration from pre-shock to recovery and consumption smoothing under shocks in the treatment areas only as the households of the treatment area underwent asset losses in the cyclone Aila.

4.5.1 Income Acceleration from Pre-shock to Recovery

This sub-section presents an econometric approach for investigating the impacts of environmental shocks on income acceleration from pre-shock to post-recovery period. Now consider the following model for an individual household i:

$$g_{pi} = I_{pi}\beta_I + \theta_i B_\theta(I_{pi}, L_i, K_i) + \varepsilon_i \beta_\varepsilon (I_{pi,}L_i, K_i) + \beta_X X_i + \mu_i \quad (3)$$

Where g_{pi} is the household i's income growth from pre-Aila to the recovery period. This model capture two central themes of growth theory- (i) it considers those factors that generate income such as labour (L_i), capital (K_i) and other indicators of socio-economic condition (X_i), such as age, education, family size, access to electricity and mobile; and (ii) it also includes asset shocks and income shocks from the hurricane that may make income acceleration path unstable in the recovery period. The estimate of β_I indicates whether household's income converges or diverges in the recovery period from the pre-Aila period. A negative value of β_I implies convergence and vice versa. The coefficients of asset loss B_θ and income shock β_ε capture the impacts of asset loss and income shock from Aila on income growth respectively. Following the conceptual discussion of the previous section, those impacts also depends on the pre-Aila income level, and access to labour and capital markets. In addition, the vector X_i in regression model (3) symbolizes the socio-economic variables as control variables. Finally, the term μ_i measures random impact from other variables that are not included in the regression equation.

4.5.2 Consumption Smoothing Under Shocks

This research considers two types of shocks from hurricane Aila - income shock and asset shock. To investigate any consumption smoothing motive under both types of shocks, let us consider the following regression model:

$$C_{pi} \;=\; I_{pi}\beta_{CI} + \; g_{pi}\beta_{cp+}\,\theta_i\, B_{c\theta}\big(I_{pi}\,, L_i, K_i\big) + \; \varepsilon_i\,\beta_{c\varepsilon}\,\big(I_{pi,}L_i, K_i\big) + \; X_i\beta_{cX} + \; v_i \qquad (4)$$

where C_{pi} is the growth of consumption expenditure from pre-Aila to recovery period. The estimate of β_{CI} implies whether consumption expenditure for the households with different income levels in the pre-Aila period converges or diverges in the recovery period. The negative value of the coefficient (β_{CI}) of pre-Aila income level (I_{pi}) implies convergence in the consumption expenditures in the recovery period and vice versa. The coefficients of asset loss $B_{c\theta}$ and income shock βc_{ε} capture the impacts of asset loss and income shock from Aila on consumption expenditure growth respectively. Since the conceptual discussion of the previous section states that any shocks to income or asset will not reduce the consumption expenditure unless people consider those shocks as permanent. Therefore, the model (4) considers that impacts of asset and income shocks from Aila on consumption expenditure growth also depend on the pre-Aila income level of the household, and access to labour and credit markets. This regression model also includes the socio-economic variables as symbolized by the vector X_i as control variables and the term v_i captures those impacts coming from omitted variables of the regression model.

4.5.3 Income Acceleration from Pre-shock to Recovery: Comparison with Non-affected Area

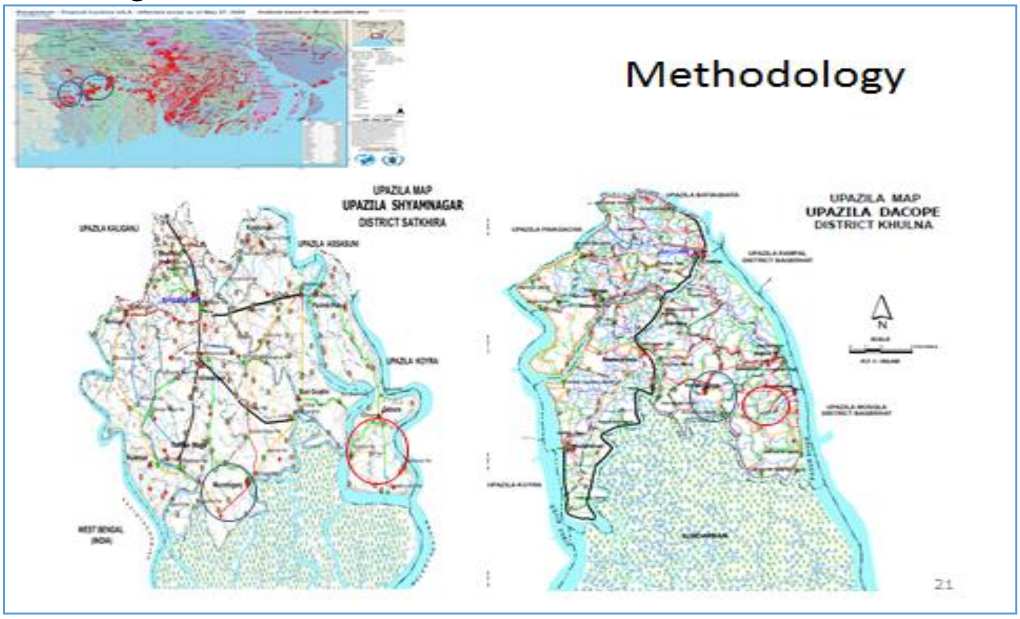
Compared to within-sample estimates of the treatment group and between-sample estimates between the treatment and control groups, the difference in difference (DID) estimation procedure produces better results in terms of estimation as it measures the difference in the differences between the treatment and control group over time. DID has also advantages over propensity score method (PSM) and instrumental variables method.

A limitation of the PSM is related to matching on observables. If unobserved characteristics are important, we can identify a causal effect using instrumental variables but instrumental variables are generally hard to find. Difference-in-difference exploits the time or cohort dimension, and allows accounting for unobservable but fixed characteristics.

This research attempts to estimate the effect of Aila on the households of Gabura and Munshiganj. These are named as a treatment group on the outcome variables' income and consumption growths by following the DID estimation method. An area located at the coastal zone which shares similar physical and socio-economic characteristics with the treatment area is chosen as control area. For this research, we choose Koilashganj of Dacope Sub-district as a control area. Both the treatment and control areas have similar type of landscape and livelihood of the people. Ethnicity, religion and other social institutions are similar across the treatment and control areas. Local government institutions and property right mechanism are also similar across the areas. Moreover, in terms of connectivity, both areas are disconnected from district headquarter by river.

The Figure 4.4 represents the locations of Aila affected areas, treatment and control areas chosen for this research.

Figure 4.4: Aila affected, Treatment and Control Area



Source: (United Nations, 2011)

Let me discuss the DID estimation set-up procedure in the following:

Two groups:

D=1: Treated groups who are affected by the cyclone Aila: Gabura and Munshiganj

D=0 : Control groups who are not or less affected by the cyclone Aila: Koilashganj

Two Periods:

T=0 : Preiod from Pre-Aila to immediate past Year of Aila

T=1: Post Treatment period- Year 2013

At first, I consider income growth of household i designated as Y_{iDT} as potential outcome. Table 4.1 presents the difference in difference estimation in potential outcome Y_{iDT} .

Table 4.1: DID estimation in potential outcome Y_{iDT}

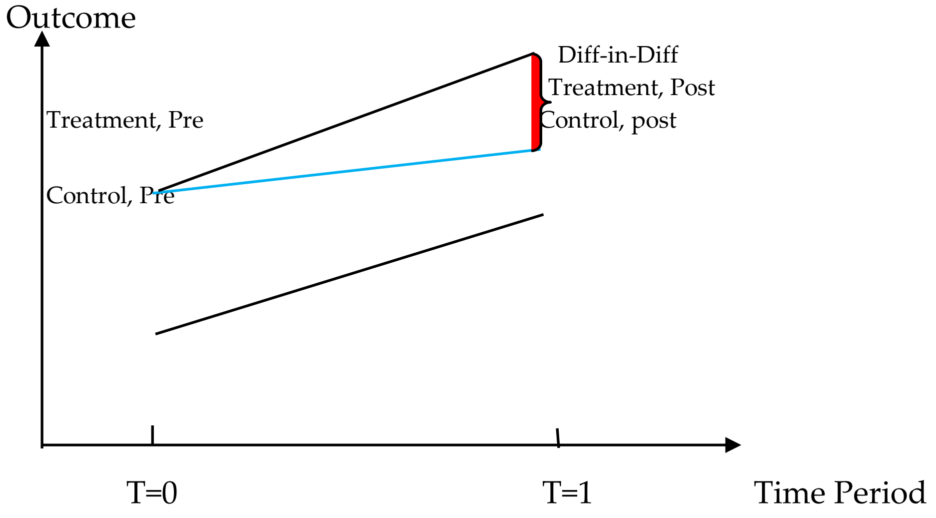
Y_{iDT}	**Post-Period (t=1)**	**Pre-Period (t=0)**	**Difference**
Treated D=1	$y_{11}=E[Y_{11} \mid D=1]$	$y_{01}=E[Y_{01} \mid D=1]$	$y_{11} - y_{01}$
Control D=0	$y_{10}=E[Y_{10} \mid D=0]$	$y_{00}=E[Y_{00} \mid D=0]$	$y_{10} - y_{00}$
Change	$y_{11} - y_{10}$	$y_{01} - y_{00}$	**$(y_{11} - y_{01}) – (y_{10} - y_{00})$**

Diff in Diff Estimator: $\delta = (y_{11} - y_{01}) - (y_{10} - y_{00})$

$= \{E[Y_{T=1} | D=1] - E[Y_{T=1} | D=0]\} - \{E[Y_{T=0} | D=1] - E[Y_{T=0} | D=0]\}$

Figure 4.5 shows that in the treatment areas, output grow less compared to the control areas at T=1. DID estimation procedure assumes that if the treatment area didn't experience the treatment event, it could grow similarly with the control areas. In the figure, the vertical length of the red second bracket will be the amount of difference in difference estimation.

Figure 4.5: Diagrammatic presentation of DID estimation



Let us consider the following regression equation,

$$Y_{iDT} = \alpha + \beta.D + \lambda.T + \delta(D.T) + \epsilon \quad (5)$$

where β shows the average income growth effect of the treatment compared to the control group while λ indicates the income growth effect in the recovery period compared to pre-shock period. At the same time, δ, the difference in difference parameter, i.e., Average Treatment of the Treated (ATET) shows the difference in the difference between the treatment and control groups' income growths over time. In other words, the parameter of the interaction term D*T, δ measures the impact of the treatment event on the household income in the treatment area compared to that of the control areas over the time period from pre-treatment to the post-treatment event. The intercept α is the average household income in the control group before the treatment event while the parameter λ captures the change in household income in both treatment and control group from pre to post-treatment event. The coefficient of D, β measures the location (treatment) effect on income that is not due to the presence of the treatment event.

Other than the treatment event, there may have some other characteristics of the household that may influence the income. For example, education of the household head, household size and access to market may have an influence on income generation. In order to control the household characteristics and access variables, let us consider the following regression,

$$Y_{iDT} = \alpha + \beta.D + \lambda.T + \delta(D.T) + X'\pi + \epsilon \qquad (6)$$

where X represents a set of covariates of the households. Parameter π represents the effect of control variables on income.

When we will include the control variables in the DID estimation, we need to check whether the control variables are exogenous or endogenous. There are two types of control variables in the regression model. The fixed covariates which are not time varying are all exogenous. For example, education, sex of household head, age and the household size at the pre-disaster period are all exogenous of the treatment event and so those have been included in the limited covariates specification. A set of time varying covariates which may be affected by the treatment event has been included in the full covariates specification. In order to avoid the endogeneity problem of the time varying covariates, the time varying covariates at the pre-disaster time period have been included in the full covariates estimation. We have also checked the endogeneity of the time varying and fixed covariates by checking the causality between each covariate and the dependent variables. Since most of the covariates are categorical variables and dependent variable income is continuous variable, causality test will not be meaningful. Therefore, we find the level of association of the categorical covariates with the outcome variable income.

This research will extend the DID model by including interaction terms among covariates, time and treatment dummies and the regression equation will be

$$Y_{iDT} = \alpha + \beta . D + \lambda . T + \delta(D.T) + X' \pi + \mu DX + \theta X DT + \epsilon \qquad (7)$$

where the difference in difference parameter (ATET) will be $\delta + \theta X$. So, the ATET in regression (20) will depend of the value of the variates. Table 4.2 describes the list of the outcome and control variables and their types used in the different regression models in this research.

Table 4.2: List of outcome and control variables

Variable Name	Type
Income level	Log of per capita income in BDT
Income growth	Percent
Consumption growth	Percent
Age of head of household	Year
Sex	Binary (0=female, 1= male)
Family Size	Number
Labour market access	Binary
Credit market access	Binary
Access to electricity	Binary
Access to mobile	Binary
Access to NGO	Binary
Asset loss	Currency, BDT
Coping Strategies	Currency, BDT

DID assumes all the assumptions of the OLS estimation method while it assumes the parallel assumption between control and treatment groups. Compositional difference is the key threat to validity of the DID estimation in case of cross sectional data. Repeated cross-section is valid when the target population does not change between the pre- and post- treatment period. In this research, we have collected the data of households for both the periods at a single point of time. So, this gives us the opportunity to use the same composition of households in both pre- and post- treatment period. Non-parallel dynamics of the outcome variable, another threat to the validity of DID estimation, depends on un-observables. This research attempts to cover a number of control variables including socio-economic status, market information and policies to reduce the threat of non-parallel dynamics. Moreover, both the control and treatment areas are located in the southern part of Bangladesh sharing common features like landscape, anthropological background, environment, endowments, socio-economic conditions, and government policies. Distance between the treatment area and its district town is almost same as the distance between the control area and its district town. Moreover, in terms of road connectivity, both treatment and control areas share similar characteristics. The following section will present a comparison of socioeconomic characteristics between treatment and control area numerically.

4.6 Data Description

This research uses 593 households as treatment group representing two unions- Gabura and Shaymnagar- of the cyclone affected Shaymnagar sub-district of Shatkhira District while it uses 297 households as control from Koilashganj union of Dacope sub-district of Khulna district. Table 4.3 presents a number of pre-cyclone characteristics of the households of both treatment and control areas along with the probability of rejecting the alternative hypothesis of non-equality between the two means. It shows that in case of the most of the characteristics, both households of the treatment and control areas resemble. Specifically, among the nine characteristics of the households, in terms of three characteristics (male headed households, access to electricity and labour market), difference between treatment and control areas are not zero while in case of the rest six characteristics, the differences are zero.

Table 4.3: Pre-cyclone household characteristics of the treatment and control Area

Variable	Treatment Area	Control Area	Probability*
Mean age of household heads(years)	44.14	46.48	0.00
Mean education of household heads (years)	4.39	6.35	0.00
Mean Household size (person)	4.74	4.60	0.057
Male headed households (%)	88.53	96.66	0.25
Households involved with NGO (%)	65.76	57.86	0.01
Households using mobile phone (%)	40.20	38.80	0.093
Households using electricity (%)	13.54	21.07	0.27
Access to credit (%)	47.43	83.95	0.00
Access to labour market (%)	58.91	65.22	0.33

*This is the probability of rejecting the alternative hypothesis that the difference between the two means/proportions are not equal to zero.

Figure 4.6 presents the household average annual income in Bangladesh Taka (BDT) in the pre- and post- cyclone period. Annual income of 2013 has been used as recovery period income that has also been presented in the Figure 4.6. The figure shows that in the treatment area, the households' annual average income plunged to 50,978 BDT in the post-cyclone year from 78,995 BDT in the pre-cyclone year. In the recovery period, it went up to 80,846 BDT, just above the pre-cyclone income level. The figure also shows that control group households experienced a continuous increase in annual average income throughout pre-cyclone to the recovery period. Specifically, annual average income has almost doubled from pre-cyclone to the recovery period in the control area. Here one thing is worth mentioning that in the pre-cyclone period, average annual income of the households of the treatment area is much higher compared to those of the control area. But it will not affect this research as we are considering the income growth effect instead of income level in this research.

Figure 4.6 : Household average annual income (BDT) in the pre, post and recovery period

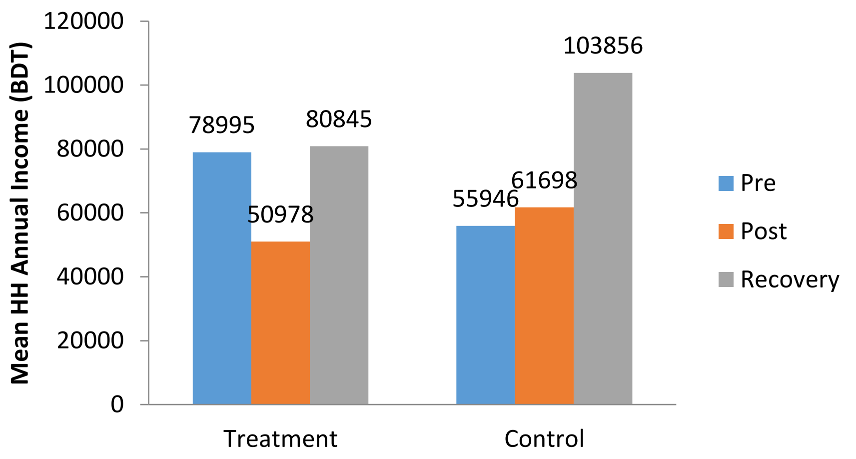
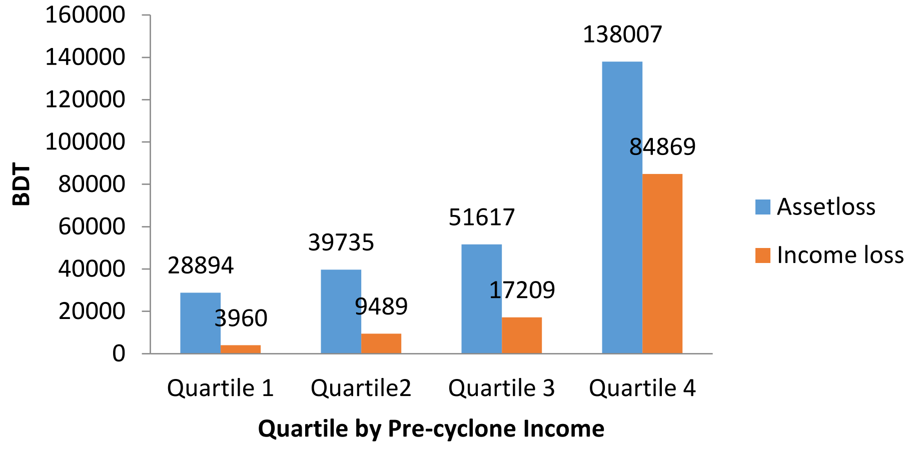


Figure 4.7 presents the asset loss from the cyclone by different pre-cyclone income quartiles. It also depicts income loss that is defined as the difference between pre- and post- cyclone annual average income. Income loss increases almost by double from quartile 1 to 2 or from quartile 2 to 3. But, from quartile 3 to 4, income loss increases by five times. This indicates that high income people incur more income loss from cyclone compared to low income people. In case of asset loss, for the first three income quartiles, asset loss increases by almost 50 percent, but, from quartile 3 to 4, asset loss increases by more than double. Finally, it can be said that both asset loss and income loss increase more proportionately for high income people.

Figure 4.7: Asset loss and income loss (BDT) by quartile in treatment area



4.7 Income Acceleration: Pre-Aila to Recovery in the Treatment

The regression framework given by equation 3 in section 4.4 permits to investigate the pattern of income trajectory in the recovery period of cyclone Aila. Table 4.4 presents the estimated results of two alternative specifications of (3). The basic model, a parsimonious specification includes pre-Aila income and assets to test for convergence and asset losses by different income groups to look at the sensitivity of asset losses to income growth. The expanded model includes additional variables to see the impact of Aila on income growth in the recovery period when we include socio-economic indicators, access variables and village specific situations in the model. The coefficient of pre-Aila income, AI(log) coefficient less than -100 would imply that households had reduced their income in the recovery period, while a coefficient greater than -100 would indicate at least partial recovery from the shock.

Both the basic and expanded models show a pattern of convergence as income growth diminishes significantly with the increase in initial income. As Table 4.4 shows, 10% additional income of the households in the pre-shock period leads to have 9.44 percentage points less income in the recovery period according to the basic model and 9.03 percentage points according to the expanded model. In addition, households who were in the lowest pre-Aila income quartile show greater sensitivity to asset losses than other three higher income quartiles. In both models, the coefficients of the asset shock vary among the different pre-Aila income quartiles. The results for the basic model show that a 10% asset loss would be expected to reduce income growth for a first quartile household by about 0.20 percentage points, 0.14 percentage points for a second quartile household and 0.11 percentage points for a top income quartile household. When the expanded model controls a set of additional variables, sensitivity to the asset loss among the different income groups decreases from the basic model. The results for the expanded model state that a 10% asset loss would be expected to reduce income growth for a first quartile household by about 0.12 percentage points, 0.07 percentage points for a second quartile household and 0.065 percentage points for a top income quartile household.

It appears from the estimation results of Table 4.4 that the pattern of impact of asset loss is non-linear across income levels. The Wald test has been used to examine this nonlinearity. In the basic model, a Wald test for equality of the 4 coefficients of the asset losses of the households grouped into four quartiles is accepted[20]. This acceptance implies that the pattern of impacts of asset losses on income growth during the recovery among the different households is linear across income levels. But, in case of the expanded model, a Wald test for equality of the 4 coefficients is rejected at 10 percent significance level[21]. This rejection indicates that sensitivity of asset loss to income growth in the recovery period differs significantly among them.

Table 4.4 also shows how the households with different socioeconomic characteristics and access to different institutions mitigate the impacts of shocks. Family size contributed to income trajectory positively in the recovery period. At

[20] The value of F (3, 467) statistic 1.3 and prob>F is 0.27.
[21] The value of F (3, 449) statistic 2.24 and prob>F is 0.08.

the same time, male headed households recover better compared to female headed in the wake of the cyclone. Households with a mobile phone connection performed better in terms of income growth after the cyclone. Those which had access to the credit market before Aila were better able to cope with the income shocks due to Aila. As can be seen in Table 4.4, households with access to credit secured 3.46 percent higher income growth compared to non-access households in the recovery period at a 10 percent level of significance.

Table 4.4: OLS estimates of income growth from pre-Aila to recovery

	Dependent variable: Income growth from pre-Aila to recovery	
	Basic model	Expanded model
Pre-Aila income, AI(log)	-94.411***	-90.302***
AI ^2	3.450***	3.268***
Pre-Aila Asset	3.265***	1.810**
Sensitivity to asset losses, θ (by Pre-Aila income)		
θ × Q1I	-2.006**	-1.230
θ × Q2I	-1.442*	-0.702
θ × Q3I	-1.316*	-0.653
θ × Q4I	-1.176	-0.657
Demographic and other controls		
Sex of household head		2.994***
Access to mobile		2.373*
Household size		0.617**
Education of household head		0.080
NGO involvement		0.450
Access to credit		3.465***
Village level controls		
River		-5.813***
Days flooded		0.008**
Constant	601.335***	580.411***
R^2	0.370	0.430
Number of observations	475	465

Note: *, **, *** indicate 1 %, 5% and 10% significant levels.

Lastly, the village specific control variables in the expanded model show that two important situations resulted from Aila. Firstly, as we know, households are affected by storm and flood water. Households located near the river got submerged quickly when the cyclone Aila washed away the riverbank.

Therefore, households living in the villages beside river got 5.81 percent lower income growth compared to those of the landlocked villages. Since Aila washed away many riverbanks, households near the river remained submerged for a considerable time after the cyclone. But the local NGO sources confirmed that households accommodated the changing situation by adapting their livelihoods by, for example, fishing in the new water bodies created from the flood water. As Table 4.4 shows, the coefficients of the variable 'days flooded' are positive (0.008) which supported the preceding discussion. Although this coefficient is statistically significant at 5 percent level, it is very small or insignificant in amount.

4.8 Consumption Path: Post-Aila to Recovery in Treatment

The regression framework given by (4) in section 4.4 allows us to look into consumption trajectory in the recovery period of cyclone Aila. Table 4.5 presents the estimated results of two alternative specifications of the regression model (4). The basic model includes pre-Aila income to test for convergence in consumption growth and income losses by different income groups to look at the sensitivity of income losses to consumption growth. The expanded model includes additional variables such as socio-economic indicators, access variables and village specific situation to see the impact of Aila on consumption growth in the recovery period. Like the regression results of Table 4.4, the same implication for the coefficient of pre-Aila income, AI(log) will also sustain for consumption growth in the estimated results of Table 4.5.

Both the basic and expanded models show a pattern of convergence in consumption in the recovery period as consumption growth diminishes with the increase in pre-Aila income level. As Table 4.5 shows, households with 10% additional income decrease consumption expenditure by 0.22 percentage points in the basic model and 0.32 percentage points in the expanded model. In addition, households in all four quartiles are almost equally sensitive to income losses from Aila. A Wald test for equality of the 4 coefficients is accepted for both models[22]. The results for the basic model indicate that a 1% income loss would be expected to reduce consumption growth for all quartiles by about 0.022 percentage points while in the expanded model, it reduces to 0.017 percentage points.

The expanded model in Table 4.5 presents how the households with different socioeconomic characteristics and access to different markets contributed to the consumption growth in the recovery period. Family size and education of the household head contributed positively to consumption trajectory in the recovery period. The households who were involved with NGO activities before cyclone achieved higher income growth after Aila. Households with a mobile phone connection performed worse than non-users in terms of consumption growth after the cyclone. Those which had access to a credit market before Aila were able to do better to cope with the income shocks due to Aila if their access to credit was sustained after Aila. But local sources confirmed that credit operations were suspended for 12 months after Aila. Most of the credit operations in this area run microcredit and the beneficiaries of this micro credit have to pay installments from the first week of receiving the loan. Therefore, in the recovery period of the cyclone, loan receivers are more prudent when deciding whether to receive credit, while the financiers are more cautious about disbursing credit among the cyclone affected people. As can be seen in Table 4.5, households with access to credit secured 3.23 percent lower consumption growth compared to non-access households in the recovery period at 10 percent level of significance. But, the households who had access to labour markets before the cyclone did better in gaining consumption growth after Aila. The reason is that households with access to labour markets before the cyclone were basically labour class people and during the hard time after the cyclone, they showed more income earning resilience. This occurs because labour markets in that area are

[22] The value of F (3, 449) statistic 2.24 and prob>F is 0.08

basically based on physical labour and the well-off households before the cyclone would not be able to enter such kind of labour market once the cyclone appeared.

Table 4.5: OLS estimates of consumption growth from post-Aila to recovery

	Dependent Variable: Consumption growth from post-Aila to recovery	
	Basic model	Expanded model
Pre-Aila income, AI(log)	-2.230	-3.259*
Annual average income growth from post-Aila to recovery (%)	0.113***	0.092***
Sensitivity to income losses, ε (by pre-Aila income)		
ε × Q1I	2.235***	1.756***
ε × Q2I	2.226***	1.694**
ε × Q3I	2.109***	1.653**
ε × Q4I	2.218***	1.743***
Demographic and other controls		
Access to mobile		-0.355
Household size		0.806***
Education of household head		0.262**
NGO involvement		2.491**
Access to market		
Access to credit		-3.235**
Access to labour market		4.407***
Village level controls		
River		0.862
Days flooded		0.009***
Constant	10.661	17.932
R^2	0.131	0.234
Number of observation	464	459

Note: *, **, *** indicate 1 %, 5% and 10% significant levels.

Households of the villages beside the rivers are consuming more than those of the villages without access to a river. In addition, longer floodwater stagnancies in the villages lead to increase the consumption expenditure of the villagers, although the amount is very negligible. Those are in-line with the discussion about village level controls in the preceding section.

4.9 Impact of Cyclone Aila: Quasi Experiment Analysis

This section presents the effect of cyclone Aila in terms of income (level +growth) in the cyclone affected areas in comparison with the non-affected areas. A difference in difference estimation method in panel data setting will be used to estimate this income effect. The empirical method section has already stated that Gabura and Munshiganj of Shaymnagar sub-district are Aila affected areas are selected as treatment and Koilashganj union of Dacope sub-district as control in this research. The following two sub-sections will present the empirical results of the effects of income and growth due to the cyclone Aila.

4.9.1 Income Level Effect

Income effects from the cyclone Aila in the treatment area will be estimated by three alternative specifications of equation 6. The most important explanatory variable in the estimation results of the difference-in-difference models in the Table 4.6 is D*T, i.e. interaction between treatment and time dummies. The coefficient of D*T shows how the treatment event impacts on the income level in the treatment areas. As Model 1 presents, the coefficient of D*T is -0.591 implying that households of the treatment areas over the recovery period earned less income by 0.591 (log value of amount of income) that can be attributed to the cyclone. The coefficient of D in model 1 is 0.356, location effect of the treatment area which implies that when we consider the average income of both pre-treatment and post-treatment periods, households of the treatment areas have higher income compared to the control areas by 0.356. On the other hand, the coefficient of T, the time effect of the combined areas is 0.649 indicating that households in the combined treatment and control areas have higher income by 0.649 in 2013 than pre-cyclone period.

Model 2 in Table 6 adds up a number of pre-treatment household characteristics that are constant and exogenous of the treatment event. Those are education, sex, age of household heads and family size. To look at the effect of those exogenous variables in the recovery period, the interaction of each exogenous variable with treatment and time dummies will be added in this model. Model 2 shows that coefficient of the interaction term D*T is -0.544, much lower than that of model 1. But the coefficient of D*T is not ATET in the Model 2. The ATET in the Model 2 will be -0.544 + 0.001*Education of HH+0.099*Sex of HH + 0.000*Age of HH+ (-0.030)*Household size, indicating that the value of the

ATET will be household specific. Model 2 indicates that male headed households in the treatment areas with average education, age and household size over the recovery period earned less income by 0.5906 that can be attributed to the cyclone. Female headed households with similar characteristics of male are more vulnerable compared to the male headed households as they earned less income by 0.689 due to cyclone.

The coefficient of education of household heads is 0.038 implying that household heads with more education earned higher income. But, the coefficient of the interaction between education and treatment dummy is negative (-0.003) meaning that educated people were less productive in the treatment areas compared to the control areas. In addition, the coefficient of the interaction term, education of HH*D*T takes positive value (0.001) indicating that household heads with more education in the treatment area after treatment event earned higher income, although it is not statistically significant. Households with male heads earned higher income compared to female-headed households. But in the treatment areas, male-headed households earned less compared to the control areas. Furthermore, male-headed households in the treatment areas earned higher income compared to others after the event. As model 2 shows, coefficient of Sex of HH*D*T is 0.099, but this is not statistically significant. Model 2 shows that the older the household head the higher the income. But in the treatment areas after treatment event, households with older heads earned the same income as those in control areas. Household size, a proxy of the source of labour shows a positive impact on income by taking coefficient value of 0.072. Its interaction with D takes positive value (0.032) meaning that family size contributed higher income in the treatment areas compared to the control areas. But the coefficient of the interaction term, household size*D*T takes a negative value implying that household size in the treatment areas after the event became less effective in income generation compared to the other areas.

Table 4.6: DID estimation of income effect: Aila-affected vs. control areas

Dependent Variable: Income level at pre-treatment and recovery

	Differences-in-differences (1)	Limited covariates specification (2)	Full covariates specification (3)
D	0.356***	0.616***	0.474**
T	0.649***	0.649***	0.649***
D*T	-0.591***	-0.544***	-0.584***
Education of HH		0.038***	0.024***
Education of HH*D		-0.003	-0.004
Education of HH*D*T		0.001	0.002
Sex of HH		0.114	0.127
Sex of HH*D		-0.136	-0.162
Sex of HH*D*T		0.099	0.105
Age of HH		0.006***	0.004**
Age of HH*D		-0.004	-0.001
Age of HH*D*T		0.000	0.000
Household size		0.072***	0.081***
Household size*D		0.032*	0.013
Household size*D*T		-0.030*	-0.031*
Electricity			0.107*
Electricity *D			0.048
Electricity*D*T			-0.025
Mobile			0.095*
Mobile*D			0.155**
Mobile*D*T			-0.026
NGO			0.015
NGO*D			0.005
NGO*D*T			0.012
Access to credit			0.174***
Access to credit*D			-0.035
Access to credit*D*T			0.045
Access to labour			-0.260***
Access to labour* D			0.225***
Access to labour* D*T			0.036
Constant	10.689***	9.721***	9.819***
R^2	0.091	0.219	0.285
Number of Observations	1784	1778	1762

Note: (a) All the household variables in this estimation are derived from pre-Aila period, (b) HH indicates household head, (c) *, **, *** indicate 1 %, 5% and 10% significant levels.

Model 3 includes some other time-varying control variables such as access to electricity, mobile phone, NGO, credit and labour markets. We already mentioned in the subsection 4.5.3 that in order to remove the endogeneity problem, we have used the time-varying covariates at the pre-disaster time period. Like model 2, the value of the ATET will be household specific. Since all the additional covariates of model 3 are binary in nature, there are a number of combinations of households. For simplicity, we are mentioning two types of households. Male headed households in the treatment area who have access to electricity, mobile, NGO, credit and labour market at the pre-disaster period with average education, age and household size earned -0.620 less compared to the households with similar characteristics of the control area. In case of female headed households with similar characteristics, this magnitude will be -0.725. On the contrary, male headed households in the treatment area who have no access to electricity, mobile, NGO, credit and labour market at the pre-disaster level with average education, age and household size earn -0.626 less compared to the households with similar characteristics of the control area. In case of female headed households with similar characteristics, the value of the ATET will be -0.731.

Since we have added up all the time varying access variables at the pre-disaster level in model 3, we need to interpret their coefficients very cautiously. Coefficients of electricity, mobile phone, NGO and credit market are all positive implying that access to these factors at the pre-disaster period positively contributes to generate income in the recovery period. The interactions of access to electricity, mobile phone and NGO with treatment dummies take positive values and indicate that those pre-treatment access variables contribute positively to income generation in the treatment areas compared to the control areas. But in the case of interaction with access to credit, the coefficient was negative. This implies that households who have access to credit at pre-disaster period is less productive in income generation in the treatment areas compared to the control areas in the recovery period. Furthermore, the interactions of access to electricity and mobile phone with both time and treatment dummies take negative values and imply that access to those facilities at pre-disaster time period decreases in income in the treatment areas after treatment event. In addition, the coefficients of the interactions of access to NGO and credit with time and treatment dummies are negative, implying that those accesses in the pre-disaster time period generate more income in the treatment areas after the treatment event. Households' access to labour in the pre-disaster period contributes positively to income generation compared to the control areas. When we consider the value of the coefficient of the interaction term, access to labour*D*T, it implies that access to the labour market in the treatment area at the pre-disaster time period brings higher income compared to the control area after the treatment event.

4.9.1 Income Growth Path: Resilience of Households in Affected Areas

The estimations of this subsection differ from the preceding estimations by a dependent variable. Here, the income growth from pre-treatment to the recovery period is considered as a dependent variable when the time dummy, T is zero (T=0). In addition, income growth from post-Aila to the recovery period is considered as a dependent variable when time dummy, T is one (T=1). In order to find out the resilience of the affected areas, here income growth has been considered as dependent variable instead of income level. Like the estimations of the preceding subsection, the impact of income growth from natural disaster in the treatment area will be estimated by three alternative specifications of equation 6. The coefficient of D*T shows the difference of income growth between two time periods that the households in the treatment area acquire compared to the control areas. As Model 1 presents, the coefficient of D*T is 15.49 implying that households of the treatment area earned higher income growth by 15.49 in the recovery period compared to the control areas. This shows the resilience of the cyclone affected households as they are trying to reach back to their earlier income acceleration path. The coefficient of D in model 1 is -15.63; a location effect of the treatment area which implies that when we consider the average income growth of both periods, households of the treatment areas have lower income growth by 15.43 percent compared to the control areas. On the other hand, the coefficient of T, the time effect of the combined areas is -2.91 indicating that households in the combined areas (treatment + control) have lower income growth by 2.91 percent in post-Aila-recovery period compared to the pre-Aila-recovery period.

Table 4.7: DID in mean income growth: Aila-affected vs. control areas

	Treatment Area	Control Area	Difference
Pre-Aila to Recovery	2.16 (12.64)	17.79 (17.49)	-15.63 (21.55)
Post-Aila to Recovery	14.74 (21.09)	14.87 (17.74)	-0.13 (27.56)
Difference	-12.58 (24.58)	2.92 (24.91)	15.49

Model 2 in Table 4.8 presents the estimations of extended specification by including a number of pre-treatment household characteristics; education, sex, age of household heads and family size, which are constant and seem exogenous of the treatment event. Model 2 shows that coefficient of the interaction term D*T is 9.584, much lower than that of model 1. But the coefficient of D*T is not ATET in the Model 2. The ATET in the Model 2 will be 9.584 -0.526 *Education of HH+4.173*Sex of HH + 0.041*Age of HH+ 0.569*Household size, indicating that the value of the ATET will be household specific. Model 2 indicates that male headed households in the treatment areas with average education, age and household size earned higher income growth rate by 32.255 in the recovery period compared to the control areas. Female headed households with similar characteristics of male in the treatment areas earned 28.082 higher income growth rate compared to the control area households.

The coefficient of education of household heads is 0.029 implying that household heads with more education earn higher income growth. But, the coefficient of the interaction between education and the treatment dummy is positive (0.003), meaning that education in the treatment areas is more productive compared to the control areas. In addition, the coefficient of education of HH*D*T takes a negative value implying that household heads' education in the treatment area causes a decrease in income growth. Male headed households in the treatment areas show their resilience as they acquire higher income growth compared to all other households. As the estimation results of model 2 in Table 4.88 shows, the coefficient of the explanatory variable, sex of HH*D*T is 4.17 which is statistically significant at 1 percent level. As can be seen in model 2, older household heads earned less income growth. This means that relatively young household heads performed better in making higher income growth in the combined areas in the whole time period. But the coefficient of age of HH*D*T takes a positive value implying that age of the household heads in the treatment areas causes higher income growth after the treatment event. Household size takes a coefficient of 0.24 meaning positive contribution of household members in making income growth. This is also true for the treatment areas after the treatment event as family size in the treatment areas contributes positively (0.57) to income growth compared to the control areas, although it is not statistically significant.

Table 4.8: DID estimation of income growth: Aila-affected vs. control areas

	Dependent Variable: Income growth from pre-treatment to the recovery		
	Differences-in-differences (1)	Limited covariates specification (2)	Full covariates specification (3)
D	-15.634***	-23.988***	-21.542***
T	-2.918**	-2.918**	-2.918**
D*T	15.496***	9.584**	7.133
Education of HH		0.029	-0.092
Education of HH*D		0.003	0.141
Education of HH*D*T		-0.526**	-0.541*
Sex of HH		-2.926	-2.746
Sex of HH*D		5.465	5.459
Sex of HH*D*T		4.173*	4.321**
Age of HH		-0.159***	-0.165***
Age of HH*D		0.161**	0.168**
Age of HH*D*T		0.041	0.038
Household size		0.242	0.255
Household size*D		-0.913	-0.983*
Household size*D*T		0.569	0.514
Electricity			0.806
Electricity *D			-1.730
Electricity*D*T			0.155

	Differences-in-differences (1)	Limited covariates specification (2)	Full covariates specification (3)
Mobile			-0.150
Mobile*D			-0.044
Mobile*D*T			0.749
NGO			-2.711*
NGO*D			3.045*
NGO*D*T			0.319
Access to credit			6.910***
Access to credit*D			-5.342**
Access to credit*D*T			-0.519
Access to labour			0.336
Access to labour*D			0.815
Access to labour*D*T			4.669**
Constant	17.795***	26.786***	23.019***
R^2	0.119	0.137	0.153
Number of observations	1782	1776	1760

Note: (a) All the household variables in this estimation are derived from pre-Aila period, (b) HH indicates household head, (c) *, **, *** indicate 1 %, 5% and 10% significant levels.

Model 3 in the Table 4.8 adds some time varying control variables at the pre-disaster time period which are access to electricity, mobile phone, NGO, credit and labour markets. Since all those covariates are binary in type, the households who don't have any access to those covariates will have the similar result of model 2. But the households who have access to all those additional covariates, will have two different ATET depending on the sex status of the household head. Male headed households in the treatment area who have access to electricity, mobile, NGO, credit and labour market at the pre-disaster time period with average education, age and household size earned 19.096 higher income growth rate compared to the households with similar characteristics of the control area. In case of female headed households with similar characteristics, this magnitude will be 14.775. So, female headed households showed less resilience in income growth compared to male.

The interaction terms of access to electricity and labour markets with time and treatment dummies take a positive value meaning that access to those facilities at the pre-disaster level brings higher income growth in the treatment areas compared to the control areas in the recovery period. But the access to a credit market at the pre-disaster level causes lower income growth in the treatment area in the recovery period. This follows the discussion on the credit and labour market situation in the cyclone affected areas in the recovery period of the preceding subsection. Households with access to mobile phone and an NGO at the pre-disaster time period acquire less income growth in the combined areas in the combined time period. But in the recovery period, these two access variables with the pre-disaster access level bring higher income growth in the treatment area.

4.10 Discussion and Implication of the Results

When we compare the speeds of convergence between income and consumption growth in the recovery period, the estimation results from Table 4.4 and Table 4.5 show that speed of convergence for income is much higher than that of consumption. The implications of this differential in convergence can be explained by a number of theories. Firstly, the Ratchet effect, whereby an individuals' consumption does not fall proportionately with income, supports the convergence differential between consumption and income growth in the recovery period. This is because the households seriously affected by the cyclone, in terms of income and assets, fails to gain momentum in their income acceleration during the recovery period. But they don't squeeze their consumption in proportion to the drop in income to maintain their living standards. In this case, marginal propensity to consume (MPC) falls but average propensity to consume (APC) increases. Secondly, the theoretical framework discussed in section 3 shows that when people consider income loss as transitory, according to the permanent income hypothesis, they will not decrease their consumption. From this point of view, the estimation results of income and consumption growth models assert that people affected by cyclone Aila consider their income losses from the hurricane as transitory. This shows resilience in the behavior of the people.

When we compare the sensitivity of income losses to consumption for highest and lowest income quartiles, they are almost equal. This implies that whether income loss occurs for the lowest or the highest income group, income losses equally influence the consumption growth irrespective of income levels before the cyclone. On the contrary, the impacts of asset loss to income growth are quite consistent with their income levels. As can be seen in Table 4.4, the impact of asset loss for the lowest income quartiles is the highest while that for the highest income quartile is the lowest. This means, asset loss from the cyclone affects the poor segment by the highest extent (negative income effect) in the recovery period. But income loss from cyclone affects the consumption by lesser amount compared to the effect of asset loss to income generation.

Carter et al. (2007) found the convergence in asset growth in the post hurricane Mitch period in Honduras while the current research found convergence in income and consumption in the recovery period after Aila. The present research also found that sensitivity of asset loss to income growth in the recovery period differs significantly among the different quartiles of the households. Similar results have been found in the Carter et al. (2007) where the impact of Hurricane Mitch on asset growth have been estimated using the OLS regression method. Considering the immediate time period of the cyclone Aila, Ahsan and Takeuchi (2015) found that the poor were more vulnerable and thus suffered significantly higher financial, settlement, and physical damage which is in line with the findings of the current research. Hallegate et al. (2016) found that poor people lose relatively more to disasters when affected. This claim is in line with the current research.

The credit market didn't play an effective role in increasing consumption in the recovery period. One explanation of this will be that even if the households had access to a credit market, they didn't receive any credit because of the apprehension of credit default. In fact, after the cyclone, the local market was not so productive for income generation. Therefore, a good number of households may be disinclined to invest in new projects after the cyclone by taking credits. On the other hand, access to the labour market led to accelerated consumption in the recovery period. This might happen because the households with access to the labour market were more flexible to generate income compared to the households with access to credit. Even if the local market is not effective to absorb labour, the households can move to the nearest growth centres or upazila headquarters for informal jobs. This is the resilience the labour class people have shown in the recovery period in order to accelerate income.

The cyclone Aila caused income losses of the households in the recovery period compared to the non-affected areas. But when we compare the post Aila income growth between treatment and control areas, households of the treatment areas gain a higher income growth that can be termed as resilience in the affected people. Why the people of the affected areas show resilience in accelerating their income after the disaster? May be, 'hope' and 'aspirations' to overcome poverty which is in line with Duflo, 2013[23].

4.11 Conclusion

This research puts forward a number of key findings that have policy implications in disaster management. Those are; a) low income people show more resilience in income generation compared to high income people in the post cyclone recovery period; b) low income people are more sensitive to asset losses compared to high income people; c) people in the recovery period don't sacrifice their consumption according to their income loss; d) income losses from the disaster across income groups are almost equally sensitive to consumption; and e) the disaster causes income loss, but people show their resilience by accelerating higher income growth compared to the non-affected areas. Several policy implications come from those findings.

[23] Esther Duflo (2013) advocates hope and aspirations as capability to fight against poverty.

It is widely reported that poor people also receive limited support from social safety nets, ranging from cash transfers to work programs. In many countries, social programs cover less than half of the poorest quintile. In addition, even when poor households are covered by social protection schemes, amounts received are often too small to make a big difference and prevent negative coping strategies. In Bangladesh after the 1998 floods, poor affected households had to borrow an amount equal to six to eight times the level of government transfers (del Ninno, Dorosh, and Smith 2003). Therefore, Government transfer programs may target the poor people to provide income-generating assets in the wake of the disaster. Since, in the wake of cyclone, people are not able to use their savings to maintain their consumption, access to credit needs to be ensured for the low-income people. Access to the labour market is very effective in boosting income and consumption. Therefore, in the wake of the cyclone, government needs to undertake labour intensive social safety net programs in the cyclone affected areas. Since low income people are more sensitive to asset losses compared to high income people, intervention is needed before the cyclone to protect the assets of the poor people. Measures on adaption to extreme events such as establishment of cyclone tolerant house, special measures for saving the productive assets like livestock and savings of life by moving to a safer place before cyclone may help the households to accelerate their income in the post cyclone period. This research finds that in the post disaster period, households have the tendency to smooth their consumption which ultimately deters the households from new capital formation. Therefore, social safety net programs also need to incorporate food based programs for the poor people of the affected areas. Finally, in the immediate period of the disaster, government needs to undertake rehabilitation programs in infrastructure in no time so that repetition of the disaster like flood in the post cyclone period can be protected.

Although this research is based on the primary data, still it suffers from a number of shortcomings. Those are; a) recall data are used for income and asset shock; b) internally displaced/migrated people are omitted in the sample; c) push or pull factors in the adjacent areas are not considered and d) not all post cyclone public policies or steps are considered in the study. All these shortcomings leave scope for further research in this area. Nevertheless, this research presents a wide range of implications that can be important for the households and for the policy makers to frame disaster management policies in developing countries.

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4.12 Appendix

Appendix describes the detail derivation of the permanent income hypothesis taken from the 'Development Microeconomics' of Bardhan and Urdy (2000).

Suppose N households with index i=1, 2,…….., N live in this community and face T time periods indexed by t. s indicates the S states of nature while each household has common known probability of occurrence θs. Each household earns an income of y_{is}>0. Suppose each household has a separable utility function in the form:

$$U_i = \sum_{t=1}^{T} \alpha^{t} \sum_{s=1}^{S} \theta_s u_i(c_{ist}) \quad (1),$$

Where u ( ) is twice continuously differentiable with u'>0, u''<0 and $\log_{x\to 0} u'(x) = +\infty$. A Pareto efficient allocation of risk within the community can be achieved by maximizing the weighted sum of the utilities of N households while each household *i* has a weight of β_i, 0< β_i<1, ∑ β_i=1:

$$\underset{cist}{\text{Max}} \sum_{i=1}^{N} \beta_i U_i \quad (2)$$

subject to the community resource constraint:

$$\sum_{i=1}^{N} c_{ist} = \sum_{i=1}^{N} y_{ist} \;\forall\; s,t \quad (3)$$

and the non-negativity constraint:

$$c_{ist} \geq 0 \;\forall\; i,s,t. \quad (4)$$

The first order condition corresponding to c_{ist} and c_{hst} from the utility functions of two individuals *i* and *h* is:

$$\frac{u'_i(c_{ist})}{u'_h(c_{hst})} = \frac{\beta_h}{\beta_i} \;\forall\; i,h,s,t. \quad (5)$$

Now, suppose everyone in the community has an identical constant absolute risk utility function in the form:

$$u_i(x) = -(1/\sigma)\, e^{-\sigma x} \quad (6)$$

Applying the first order condition (5) to equation (6), I find:

$$c_{ist} = c_{hst} + (1/\sigma)(\ln(\beta_i) - \ln(\beta_h)). \quad (7)$$

This equality (7) is true for all the households living in the community at any point of time. After summing up all the households equalities, I get:

$$c_{ist} = c_{st} + \frac{1}{\sigma}\left(\ln(\beta_i) - \frac{1}{\mathrm{N}}\sum_{\mathrm{h}=1}^{\mathrm{N}} \ln(\beta_i)\right). \tag{8}$$

So, equation (8) implies that household consumption is equal to the average level of consumption in the community and time invariant relative weight of the household in the Pareto allocation of risk. Equation (8) also shows that change in any household consumption between two periods is equal to the change in the average community consumption between the two periods. Therefore, when a Pareto-efficient allocation of risk is prevailing within a community, households face only a community level aggregate risk. In this case, unsystematic or idiosyncratic income shocks are entirely insured within the community. A consumption smoothing motive between two periods does not lead the household to increase income, as the income shocks are insured by the community. But the Pareto efficient allocation of risk within a community is almost impossible to achieve under the rationality assumption, as the marginal utility of aggregate social or communal work for risk-pooling will be different for different individuals. Therefore, moral hazard in the community will break down the risk pooling structure of the Pareto program (Carter, 1997; Rosenzweig & Parry, 1994; Ruthenberg, 1971).

Now, we consider a type of community where Pareto-efficient allocation of risk is not achieved and so cross-sectional risk pooling does not help households adjust with the effects of aggregate community-level shocks to income. Let us consider that households in the community have no scope of cross-sectional risk pooling and access to credit market. The household utility function rewritten from equation (1) is in the form:

$$U_t = E_t \sum_{\tau=t}^{T} \alpha^{\tau-t}\ u(c_t) \tag{9}$$

and subject to constraint:

$$A_{t+1} = (1 + r_t)(A_t + y_t - c_t). \tag{10}$$

Non-negativity constraint on consumption: $c_t \geq 0$ (11)

Transversality condition ($A_{T+1} \geq 0$) will prevail in this set up as the household can be a debtor in any but the final period.

The t period value function of household's asset and income is:

$$V_t(A_t + y_t) = \max_{c_t}\{u(c_t) + \alpha E_t V_{t+1}[(1+r_t)(A_t + y_t - c_t)]\} \quad (12)$$

Equation (12) implies that the value of current resources (asset and current income) is equal to the maximized value of current consumption plus the discounted expected value of next period resources. Optimization implies

$$u'(c_t) = \alpha(1+r_t)E_t u'(c_{t+1}). \quad (13)$$

Equation (13) indicates that saving or lending decision satisfies that marginal utility of current consumption is equal to the discounted expected marginal utility of next period's consumption. If yield on assets offsets the subjective discount rate $(\beta(1+r_t) = 1)\forall\, t,$ (13) simplifies to $u'(c_t) = E_t u'(c_{t+1})$.

If we assume that u is quadratic, then (13) becomes

$$C_t = E_t(c_{t+1}) \quad (14)$$

In this case, households make consumption decisions such that expected consumption is same. As $A_{T+1} = 0$, the resource constraint (3) states that discounted consumption at any time t equals the value of household assets at t plus the discounted value of its income stream from t to T. Combining this with (14), we find:

$$c_t = \frac{r}{1+r}\left(A_t + E_t \sum_{\tau=1}^{\infty}(1+r)^{-(\tau-t)}\, y_t\right) \quad (15)$$

This states that current consumption is the annuity value of current assets plus the present value of the expected stream of future income.

Chapter 5
Natural Disaster, Poverty Dynamics and Poverty Trap: A Study on Cyclone Aila of Bangladesh

Abstract

This research intends to - 1) look at the determinants of poverty dynamics; 2) use several methods to establish the existence of a poverty trap or not; 3) see what determines the depth (level of income) of the poverty trap; and 4) whether consumption side reasons are behind the poverty traps. This chapter examines poverty dynamics in the aftermath of a natural disaster and the effects of different levels of asset loss on the prospects of different income groups. This chapter also investigates the existence of a poverty trap in the coastal region of Bangladesh, where cyclone Aila hit in 2009. How disaster coping strategies affect asset growth is also examined empirically. Finally, the impact of Aila on the extent of the poverty trap is investigated by comparing those areas affected by Aila to a control group of areas unaffected by Aila. The research uses primary survey data of around 900 households from the coastal areas of Bangladesh. The theoretical framework shows that when production is non-convex, poverty traps can arise as a consequence of asset loss due to disaster and end up in the lower of multiple equilibria which exist at different asset levels. This research finds that asset losses from a natural disaster, or asset holding in the recovery period, has an impact on the dynamics of the poverty groups. Using the semi-parametric and parametric approaches, we also show the existence of multiple equilibria in the asset index based trajectories in the disaster affected areas which implies the existence of a poverty trap. In contrast, convergence in income between high and low income households is found in the unaffected areas. The empirical approach used illustrates that the depth of the poverty trap is reduced for those parties who are able to implement "coping strategies". Specifically, including coping strategies in the asset index pushes the poverty trap equilibrium to a higher income level. Last, using the natural experimental design, I show that that poorer households are more likely to remain trapped at a lower income level than those that have been unaffected.

5.1 Introduction

This research examines rural household poverty dynamics in the wake of a natural, weather related disaster: cyclone Aila, in the coastal regions of Bangladesh. The dynamics of poverty are investigated by first establishing the existence or other an asset based poverty trap in the areas of Bangladesh that were affected by cyclone Aila. The chapter then intends to answer two research questions. First, did the natural disaster affect the existence and depth of the poverty traps? Second, how did coping strategies (such as savings loss, land sale, livestock sale etc.) affect asset growth and post Aila recovery? The questions are investigated using quasi-experimental methods which exploit the longitudinal structure of the survey data and a control group of unaffected households.

Primary data was collected in the survey of around 900 households in the coastal regions of Bangladesh, in an area which included households located directly in the path of cyclone Aila. This research sets the hypotheses that assets are important to determine poverty, disasters can push the people below the threshold poverty level income and depending on the level of asset accumulation, disaster can push people into a poverty trap. We can investigate these hypotheses by estimating the relationship between the asset levels of pre-disaster and recovery period and finding whether there are multiple equilibria or not in the asset dynamics.

Our theoretical framework emphasises the role of asset levels and collateral as a cause of poverty traps, and how these asset levels can be affected by natural disasters, either via direct losses or as a result of consumption smoothing, both of which can induce a poverty trap. The theory shows that when production is non-convex, poverty traps can arise as a consequence of ending up in the lower of multiple equilibria which exist at different asset levels. Firstly, the results show that multiple equilibria exist in the asset index based trajectories in the disaster affected areas. This result is identified using both parametric and semi-parametric estimations of the asset-income relationship. In contrast, however, the same methods indicate that there is convergence in income between high and low-income groups in the nearby areas that escaped the ravages of cyclone Aila. In an extension to the analysis, we also analyse the role of coping strategies (such as savings loss, land sale, livestock sale etc.) as a means of ameliorating the impact of a natural disaster and potentially avoiding a poverty trap. The results show that coping strategies pushed the lower poverty trap equilibrium to a higher level as coping strategies offset some asset loss. Finally, the results show that Aila created a poverty trap equilibrium for poor people which is at a much lower income level compared to that of the disaster unaffected areas.

This research contributes to the literature in several ways. Firstly, it validates the influence of assets on the household's welfare and uses the asset-based approach with empirical data to examine the existence of a poverty trap as a consequence of a natural disaster. Secondly, both parametric and non-parametric approaches have been used for affected and un-affected areas separately to capture the impact of shocks: this is unique in the relevant literature. Thirdly, this research incorporates the coping strategies in the asset-based livelihood function, which is an improvement over the existing estimation procedure of asset indexing. Fourthly, it will compare the poverty trap situation in the areas affected by the disaster with that of the unaffected areas which is absent in the existing literature. Fifthly, this poverty trap analysis is based on the empirical evidence of consumption smoothing: sacrificing savings and investments which provides a theoretical foundation of the poverty trap analysis.[24] Finally, estimation results and findings of this dissertation resemble with other papers that focus on the impact of different shocks on poverty trap although in some cases different methods have been used in those papers. Among the above-mentioned contributions, the following three things are new

[24] Chapter 4 of this dissertation has found that households affected by the cyclone smooth their consumption in the wake of the disaster which is based on similar data of current research.

in the relevant literature – a) using both parametric and non-parametric approaches for affected and un-affected areas to separately capture the impact of shocks, b) incorporating the coping strategies in the asset-based livelihood function to estimate asset indexing, and c) comparing the poverty trap situation in the areas affected by the disaster with that of the unaffected areas.

Two types of research on assets and poverty traps in developing countries are seen in recent times. The first type is based on micro-economic perspective and uses household-level data about assets to examine the existence of a critical threshold, above which asset acceleration happens, and below which asset dynamics move towards a low-level equilibrium, in which households are trapped in poverty (Barrett, Carter, & Little, 2006; Carter & Barrett, 2006; Carter, Little, Mogues, & Negatu, 2007; Giesbert & Schindler, 2012; Lybbert, Barrett, Desta, & Coppock, 2004; Quisumbing & Baulch, 2013; Barrett, Garg, & McBride, 2016) The second stream of research is based on a macro-economic perspective and investigates the existence of low-level equilibria and the divergence of living standards between regions and countries and to what extent this is linked with 'adverse geography' (Bloom, Canning, & Sevilla, 2003; Bowles, Durlauf, & Hoff, 2006; Kanbur & Venables, 2005). This research follows the first stream.

The rest of the paper is structured as follows. Relevant literature will be reviewed in section 5.2. Section 5.3 provides the snapshot of the poverty situation in Bangladesh. Sections 5.4 and 5.5 deal with theoretical frameworks and empirical methods respectively. Section 5.6 presents the description of the data used in this research. Sections 5.7 and 5.8 present the estimation results of poverty group dynamics and poverty trap analysis respectively. Section 5.9 presents the main findings and policy implications while section 5.10 ends the paper with conclusions.

5.2 Poverty, Shocks and Coping Strategies

Earlier literature on climate hazards was limited to impact assessment in terms of damages, death, agriculture losses and GDP. Two contradictory opinions about the impact of climate hazards were found: one opinion states that natural disasters are setbacks for economic growth while the other opinion is opposite. These events produce severe disturbance to normal life leading to extensive adverse human, material, economic, or environmental effects (Benson & Clay ,2004; Skidmore & Toya, 2002; Strobl, 2011 ; Hallegatte, 2014, Hallegate et al., 2016).[25] On the other hand, there is a productivity effect of a natural disaster (Albala-Bertrand, 1993; Benson & Clay, 2004, Hallegatte, 2014, Hallegate et al., 2016).[26] But the first opinion dominates the other. Relatively newly growing literature on climate hazards focuses the impact of disaster on different specific aspects. Poverty analysis of disaster effect is one of them.

The literature on poverty analysis has seen a gradual evolution in the analysis procedure which has been summarized by Carter and Barrett (2006). The first generation analysis concentrates on static income/expenditure analysis (headcount, poverty gap, Foster-Greer-Thorbecke-FGT measures) while the second generation focuses on dynamic income or expenditure analysis (chronic or transitory poverty distinction). Third generation analysis deals with static asset poverty analysis (structural or stochastic poverty distinction) while the fourth generation focuses on dynamic asset poverty analysis. The current research belongs to the fourth-generation dynamic asset poverty analysis.

The 'poverty trap' is a term used to describe situations in an economy where people are caught in poverty persistently. In other words, 'poverty trap' is a self-perpetuating condition where an economy, caught in a vicious cycle, suffers from persistent underdevelopment.[27] A poverty trap is a spiraling mechanism which doesn't allow the poor people to escape it or makes it very difficult for people to escape poverty. Although there is little ambiguity in the

[25] Details of the negative effects of the natural disaster has been discussed in the section 4.2 of the chapter 4.

[26] Details of the positive effects of the natural disaster has been presented in the section 5.4 of the current chapter.

[27] "Poverty Traps," in L. Blume and S. Durlauf, eds., ***the New Palgrave Dictionary of Economics***, 2nd Edition, Palgrave Macmillan. May 2005 Version

meaning of poverty trap, its nature and causes are very diverse.[28] However, few empirical studies in the poverty trap literature explicitly consider the role of shocks on asset dynamics and the poverty trap. Applying the quantitative and qualitative methods to analysis of asset dynamics over the 1993–98 period, Adato, Carter, and May (2006) find the evidence for a dynamic asset poverty threshold implying that large numbers of South Africans are indeed trapped in poverty. Hoddinott (2006) without applying the asset-based poverty traps framework, finds that poorer households tend to smooth their assets. Poor households maintain a minimum level of two oxen or cows to ensure access to transport and plough to tackle future income losses as a result of drought. This paper also finds that households staying above this threshold level smooth consumption by selling their livestock. Carter et al. (2007) find evidence of poverty trap as a consequence of hurricanes in Honduras and a drought in Ethiopia. They find that poor households in Ethiopia sacrifice consumption during the long drought to protect their productive assets for income generation in the future. Using the household-level panel data of assets in Mozambique, Giesbert and Schindler (2012) find that poor and rich households converge to a single equilibrium that is close to the poverty line income; implying no poverty trap situation. Quisumbing and Baulch (2013) examine the determinants of land and asset accumulation over time and investigates why some households may be trapped in asset poverty. They find evidence for a concave dynamic asset frontier, and no evidence for multiple equilibria. Their interpretation of this result is that the factor markets in rural Bangladesh, e.g. for land, labour and so forth, are well-functioning. But, the claim of well-functioning land market is not always true for Bangladesh as land rights problems are there because of the traditional survey and settlement procedure of the country.

There is even less evidence of the impact of household shock coping strategies on asset accumulation. Carter et al. (2007) consider different household

[28] Section 5.4 (Theoretical Motivation and Framework) of the present chapter describes the different causes of the poverty trap later.

strategies to cope with drought in Ethiopia and their impact on consumption and asset smoothing over an extended period of drought conditions. Quisumbing and Baulch (2013) examine asset accumulation and the poverty trap, but don't consider the coping behaviour in response to shocks. Giesbert and Schindler (2012) take the coping behaviour into account while investigating the poverty trap in Mozambique, and yet this paper does not consider the impact of coping behaviour on asset growth to estimate asset index which has been addressed in this research. Moreover, so far, the literature has not addressed the question of the effect of shocks on the existence or extent of a poverty trap in the shock affected and unaffected areas. This comparison is very important in terms of policy implication as any impact on the likelihood of ending up in poverty, and being trapped there, is a crucial determinant of household poverty dynamics. The impact and the effect of coping strategies is highly policy relevant therefore.

5.3 Poverty Trends in Bangladesh

The Head Count Rate (HCR) of poverty provides the estimate of the percentage of people living below the poverty line as a share of total population. The Cost of Basic Need (CBN) method is an estimate of counting the poor staying above the consumption expenditure threshold as a percentage of the whole population. By using the upper poverty line in HIES 2010, it is found that the HCR of incidence of poverty are estimated at 31.5 percent at the national level, 35.2 percent in rural areas and 21.3 percent in urban areas as shown in the Table 5.1. In HIES 2005, these rates were 40.0 percent at the national level, 43.8 percent in rural areas and 28.4 percent in urban areas respectively. The HCR registered a reduction by 8.5 percentage points (1.7 percent per annum) at the national level, 8.6 percentage points in rural areas and 7.1 percentage points in urban areas during the period 2005 to 2010. In 1991-92 the HCR of poverty was 56.7 percent at the national level. In a period of about twenty years, Bangladesh experienced 25.2 percentage points reduction in HCR, close to achieving the Millennium Development Goal (MDG) of halving poverty by 2015 (Bangladesh Bureau of Statistics, 2011).

Table 5.1: Poverty trends in Bangladesh, 2005-10

Indicator	**2005**			**2010**		
	National	Rural	Urban	National	Rural	Urban
Poverty rate	40.0	43.8	28.4	31.5	35.2	21.3
Extreme poverty rate	25.1	28.6	14.6	17.6	21.1	7.7

Source: Bangladesh Bureau of Statistics

By using the lower poverty line in HIES 2010, it is found that the HCR of incidence of poverty is estimated at 17.6 percent at the national level, 21.1 percent in rural areas and 7.7 percent in urban areas[29]. In HIES 2005, these rates were 25.1 percent at the national level, 28.6 percent in rural areas and 14.6 percent in urban areas. Thus, HCR recorded a reduction by 7.5 percent at the national level, 7.5 percent in rural areas and 6.9 percent in urban areas during the period of 2005-2010. Using the lower poverty line, the HCR of incidence of poverty was estimated at 41.1 percent in 1991-92. Currently, it is less than half (17.6 percent) indicating that Bangladesh has already achieved the MDG target of reducing the incidence of extreme poverty by half by 2015 (Bangladesh Bureau of Statistics, 2011).

5.4 Theoretical Motivation and Framework

This section will first discuss the poverty trap mechanism from different perspectives. Then it will provide a theoretical framework which will be the basis of investigating the research questions of this thesis.

The literature on poverty trap analysis describes the poverty trap from different perspectives (both macro and micro). Romer (1987), and Ciccone and Matsuyama (1996) designate market size and division of labour as catalysts for the poverty trap. Romer argues that the market share is one of the factors leading

[29] Lower poverty line is estimated by adding food poverty line (a diet corresponding to 2122 K. Cal per day per person) with lower non-food allowance.

to production efficiency. The larger the markets and the larger the number of firms leads to efficient absorption of inputs in all stages of production. The study conducted by Ciccone and Matsuyama used a dynamic monopolistic competition model to show that an economy that has a small range of specialized inputs are trapped into a lower stage of development. The low availability of specialized inputs leads to a more labor intensive production process. This implies that the efficiency of labor is not high compared to the production process which uses some sort of intermediate inputs. This in turn means less production in the economy. This lower level of production signifies that the development levels are lower and in turn more difficult to get out of the poverty trap.

Acemoglu and Zilibotti (1997) present the trap as a consequence of financial development. The paper argues that the lack of risk taking mentality reduces the possibility of investing in risky projects which slows down the capital accumulation process. This inability to diversify risks leads to the capitals underperforming and therefore a slower growth. The paper also argues that the development often contains a prolonged capital accumulation process that will lead to take off eventually. This means that a prolonged accumulation period will be mean a longer time before steady growth.

Basu (1999), and Doepke and Zilibotti (2005) explain the trap as a demographic phenomenon. Basu looks into the situation of child labor and how it is affecting the labor markets. He argues that child labor became an important input to the economy all over the world during the industrial revolution, although advocacy against it is gaining momentum. However, as Basu suggests, eradicating child labor not only impacts the children directly, but also has spill over effects to the economy. On the flip side, Basu (1999) says that the lack of education and other facilities of the child labor creates a cycle of poverty.

Barret, Travis and Dasgupta (2011) identify four distinct classes of mechanisms that define distinctive interlinkages between biodiversity and poverty. Those four classes of mechanisms are as follows: dependence on inherently limited resources, shared vulnerabilities, failure of social institutions and unintended consequences and lack of informed adaptive management.

Bernanke and Gertler (1989), and Matsuyama (2005) mention low investment and low wealth as causes of the poverty trap. Bernanke and Gertler (1989) suggests that the net worth of borrowers is an important factor in output dynamics. It says that the higher the credit worthiness of the borrowers the easier it is to take finances as the agency cost is reduced. However, people living under poverty do not necessarily have a good portfolio, which makes it difficult for them to obtain finance. This in turn limits their options for income generation and consequently their ability to move out of poverty. Matsuyama (2005) looks at creditworthiness from the point of view of the macro–economy and finds that economies with more businesses and more entrepreneurs will have more trading potential and trades.

Banerjee and Newman (1993) mention that credit market imperfection creates poverty traps as poor people are unable to afford collateral, and therefore, depress wages by crowding the labor market. The paper argues that economic development is a process of institutional transformation derived from the interaction of the occupational decisions of the agents and their wealth. The paper says that the poor agents are the ones choosing a work for wage rather than self-employment. However, the rich agents tend to become entrepreneurs. The paper goes on to explain that without sufficient inequality there will not be any employment contract but rather self-employment will dominate. The paper then explores the occupational structure in a static and a dynamic model. The results conclude that the initial distribution of wealth decides the type of specialization and development path. An economy with higher inequality will have a more industrial structure with more wage labour. On the other hand, an economy with a fairly less inequality will have a more cottage based self-employed structure.

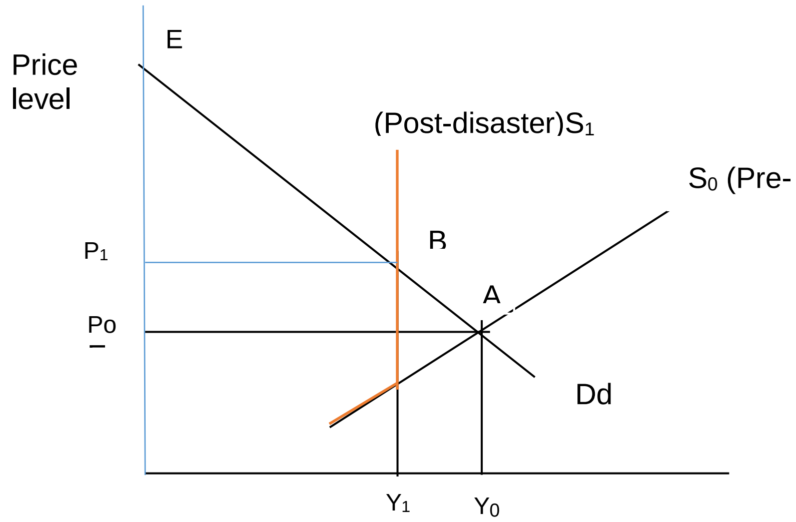
From another perspective, Galor and Zeira (1993) state that poverty traps originates as credit constrained households cannot overcome a minimum threshold size of investment. The paper shows that with in a credit market with imperfections and indivisibilities in investment in human capital, the initial wealth distribution has a significant impact on aggregate output. This also affects investment in both short and long run due to the possibility of different steady states. The paper also shows that the difference in adjustments of aggregate shocks among countries are affected by distribution of income and wealth among other things. Thus, a country with low endowments will take longer to deal with shocks compared to a country with high endowments.

5.4.1 Theoretical framework

Rural households in the developing countries usually lead a part of their livelihood by using their own household labour in their farms and generally consume a share of their own production. Therefore, households make simultaneous decisions about production (the level of output, the demand for factors, and the choice of technology) and consumption (labour supply and commodity demand). Whether the production decisions of the household are separable from its consumption decisions, depends on the conditions on the market. With complete markets, the production decisions of the household are separable from its consumption decisions. But when the markets are incomplete, the separation property breaks down and production decisions depend on the preferences and endowments of the households (Bardhan & Udry, 1999). In the developing countries, markets from the supply side (land and labour) and demand side (goods and services) usually do not function properly. Moreover, when a disaster happens, both supply and demand sides are interrupted. Consequently, there is a high possibility that in case of the households of the disaster affected areas in the developing countries, production decisions are not separable from consumption decision. Therefore, the consumption smoothing motive (if any) in the post disaster period will have an impact on asset accumulation. Furthermore, when the separation property no longer holds and the household no longer maximizes profit. This situation during and after the shock can be basis of the poverty trap as different farms have the scope to perform differently.

The demand-supply situation of the household immediately after the disaster is displayed in Figure 5.1 (Hallegatte, 2014). Before disaster, equilibrium is at A and the consumer surplus is AEPo. In the post-disaster, the red line will be the new supply curve as output will be inelastic in the short run and the income will be fixed at Y_1. The supply curve is truncated as climate hazards lead to a loss of machinery, land, and other form of household capitals and make the supply curve inelastic. The new consumer surplus will be BEP_1. Figure 5.1 shows that a disaster will reduce income and increase price levels in the short run. Now the question is, how is this income loss distributed among different households? This distribution of income loss will be the foundation for the emergence of poverty trap in the medium run.

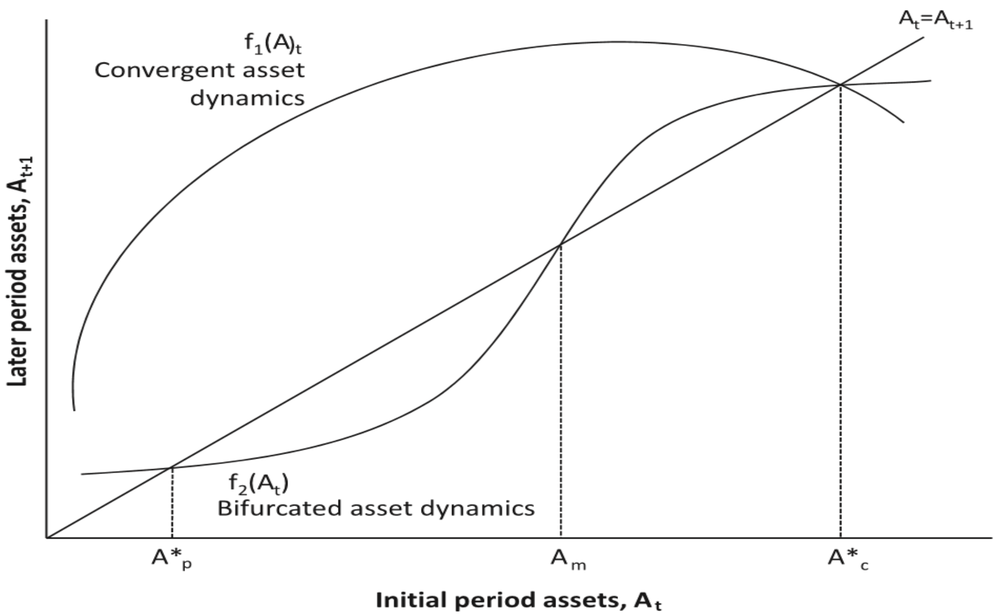
Figure 5.1: Supply and demand in the pre and post-disaster situation



Source: (Hallegatte, 2014)

Now I am going to focus on the household and on the dynamics of assets as a determinant of rural poverty and poverty traps. Adato et al. (2006) present the possible alternative asset dynamics to explain the poverty trap. This is displayed in figure 5.2. The approach is very close to the concept of minimum threshold size of investment described in Galor and Zeira (1993). The horizontal axis represents the initial or first period asset, $L(A_0)$ and the vertical axis measures asset stocks for the second or later period, $L(A_t)$. The 45-degree line gives not equilibrium. These are just the points where $L(A_t)=L(A_0)$. The equilibria are where the curved line crosses the 45 degree line. These crossing points might be stable or unstable depending on the direction of the crossing. Figure 5.2 describes two types of asset dynamics; convergent, and bifurcated. In convergent asset dynamics, poorer households converge to the equilibrium level, whereas in the divergent asset trajectory, there is a critical asset level which split the asset dynamics. Households staying below that level converge to the low-level equilibrium while households above the critical level converge to the higher level equilibrium. Thus, bifurcated asset dynamics create the poverty trap which is displayed in the figure 5.2.

Figure 5.2: Hypothetical asset dynamics in the post-disaster period



Source: (Adato et al., 2006)

Let me consider that individuals in the disaster affected areas face the following production function before the shock:

$$Y_0 = f(K, L) \qquad (1)$$

where Y_0=output, K=capital stock, L=Labour.

When a disaster hits the area, a portion of capital stock is destroyed and the production function will be:

$$Y_1 = f(\overline{K}, L) \qquad (2)$$

This is the immediate impact of the disaster on production function. But in the medium-run, rich households ensure a more rapid turnover of capital by replacing the capital and installing new technologies and the production function will be:

$$Y_2 = f(\bar{K}^1, L) \qquad (3)$$

Where $\bar{K}^1$ is the new capital stock after replacing. Rapid embodiment of new technologies has an effect termed as 'productivity effect' or 'Schumpeterian creative destruction effect'. This effect has also been mentioned by Albala-Bertrand (1993), and Benson and Clay (2004). Hallegatte (2014) argued that when a natural disaster damages capital, destroyed capital can be replaced with more up-to-date and productive capital which can accelerate income growth. Now the question arises as to whether the poor households can replace their destroyed capital. For instance, in the rural economy, poor households have very limited liquid assets to replace their destroyed capital into newer and more advanced capital. Even if the poor households have limited physical assets, it is very difficult for them to make them liquid as the markets don't operate properly in the affected areas in the immediate post shock period. Moreover, poor households have limited liquid savings. On the other hand, rich households have more physical assets or even liquid savings. Considering all these aspects, production function (3) has a distributional impact which is in favour of the rich households. Increasing marginal productivity of capital will bifurcate the income dynamics between poor and rich and ultimately this can create a lower income poverty trap for the low capital owner households. So, the poverty trap conditions from production function (3) are:

$$f_k > 0 \text{ and } f_{kk} > 0$$

The second condition states that marginal productivity is increasing at an increasing rate. If $f_{kk} = 0$, still then poverty trap situation may develop as capital replacement after the shock is in favour of rich households. But, for $f_{kk} < 0$, decreasing marginal productivity of capital, the poverty trap may not exist as this process will lead to a convergence in output. Therefore, uncertainty in the value of second derivative of the production function drives the inequality effect of loss of capital which ultimately leads to the multiple poverty trap equilibria.

A second explanation for the poverty trap is consumption smoothing which leads to permanent reduction in capital and lower levels of productivity with increasing returns to scale. People who are victim of natural disaster employ their savings in order to maintain pre-disaster consumption levels because of the consumption smoothing motive[30]. This decrease in savings constrains the poor household to reach minimum threshold size of investment. Carter & Lybbert (2012) empirically confirm the co-existence of consumption and asset smoothing regimes using a household panel data set from West Africa.

On the basis of above theoretical foundations, this research intends to answer the following research questions:

1) Is there a poverty trap?
2) What level is the poverty trap?
3) Do coping strategies impact on the level of poverty trap?
4) Is the poverty trap exacerbated by consumption smoothing?

We can answer these questions by estimating the relationship between the asset levels of pre-disaster and recovery period and finding whether there are multiple equilibria or not.

Basically, what this research intends to do is - 1) look at the determinants of poverty dynamics; 2) use several methods to establish the existence of a poverty trap or not; 3) see what determines the depth (level of income) of the poverty trap; and 4) whether consumption side reasons are behind the poverty traps.

5.5 Empirical Methods

This section will be divided into two parts; the first part will discuss the procedure for determining the poverty status and the empirical strategy to look

[30] In chapter 4, it is already empirically found that the consumption smoothing motive exists in the post-shock recovery period in the disaster affected areas.

into the poverty dynamics in the post shock period; the second part will present the empirical methods used to investigate the existence of the poverty trap.[31]

5.5.1 Poverty Status Determination and its Dynamics

This subsection will present how the poverty dynamics will be determined empirically.

5.5.1.1 Determining Household Poverty Levels and Poverty Groups

The field study area of this part of the research is in the Shatkhira district of Bangladesh and is defined as a rural area of the country. Shatkhira district is one of the coastal districts of Khulna division. The Household Income and Expenditure Reports of 2005 and 2010 provide the poverty line incomes of the country.[32] Using the linear trend between these two poverty line incomes, the poverty line income of 2009 has been calculated. Since there is no poverty line income of rural people from any recognized source for 2013, poverty line income for 2013 has been calculated using the average GDP growth trend between 2010 and 2013.[33] Following this process, it is found that the poverty level income of 2009 is 12575.64 BDT while it is 15378.84 for 2013. Households whose per capita income was less than 12575.64 BDT in 2009 are defined as poor and those above 12575.64 BDT are called non-poor. Similarly, households whose per capita income is less than 15378.84 BDT in 2013 are defined as poor and those above 15378.84 BDT are called non-poor.

Poverty is a dynamic process and households move in and out of it over time. Because of this dynamic characteristic of poverty, defining poverty groups has been complicated. Different authors have used different methods to define poverty groups. One convincing way of defining poverty groups is done by Jalan and Ravallion (1998), and Jalan and Ravallion (2000). They defined the chronic

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[31] Details of the sampling methods/information have been presented in the section 4.5 of the chapter 4.

[32] Definition of poverty line income has been given in the Section 5.3 Poverty Trends in Bangladesh.

[33] Bangladesh has household income and expenditure survey (HIES) data with 5 years interval. The latest completed HIES was conducted in 2010 and compilation of the HIES data of 2015 is not yet finished. Therefore, there is no poverty line income for Bangladesh after 2010. That's why we have used GDP growth as proxy to calculate the poverty line income of 2013.

poor as households whose mean consumption over time is below the poverty line. Transient poverty is defined as those who are poor in at least one observation and whose living standard varies over time. In this chapter the method of Jalan and Ravallion (1998 & 2000) is followed to define the poverty components with slight modification. Households who are non-poor in pre-disaster and recovery period are considered as 'non-poor' (Group 0). But, the households who were non-poor in pre-disaster period, become poor in the recovery period is called 'transient poor' (Group 1). Poor households who are poor both in the pre-disaster period and also the recovery period are defined as 'chronic poor' (Group 2) while those who are poor in the pre-disaster period and non-poor in the recovery period are defined as 'transient non-poor' (Group 3). Table 5.2 describes the classification of the four groups in details.

Table 5.2: Classification of four poverty groups

Group Number	Pre-Aila, 2008	Recovery Period, 2013	Group Name
0	Non-poor	Non-poor	Non-poor
1	Non-poor	Poor	Transient poor
2	Poor	Poor	Chronic poor
3	Poor	Non-poor	Transient Non-poor

Source: Jalan and Ravallion, 1998 & 2000

5.5.1.2 Empirical Strategy of Poverty Determinants: Multinomial Logit Model

In order to do this and look into the characteristics of the chronic and transient poor as compared to the non-poor, we estimate a multinomial logit model (MNL) in which non-poor will be the base group.[34] The MNL model will regress poverty groups (0, 1, 2 and 3 from Table 5.2) on household characteristics, access to market, asset positions and some characteristics of the shock.[35] Let me consider that X is the set of the explanatory variables and Y denotes the poverty groups (0, 1, 2, 3), then the MNL will estimate the probability of falling into any group of

[34] Here multinomial logit model has been used as the selection of the different groups are discrete. Since there is no criteria for making the order of the groups, ordinal logit model has not been used here.

[35] This empirical method (MNL) has also been applied in Baulch, B., & Vu H.D. (2011) and Garza-Rodriguez et al. (2015) to study the dynamics of poverty.

poverty against the base group because of the effect of a particular explanatory variable. So, the probability function will be:

$$\Pr(y_{i=j}) = \frac{\exp(X_j\beta_j)}{1+\sum_{j=1}^{j}\exp(X_j\beta_j)} \qquad (1)$$

where j is the non-base poverty groups and X is the explanatory variable.[36] Along with coefficients of the MNL model, relative risk ratio will be estimated for the simplicity of the interpretation. Then, using the estimated coefficients of the MNL model, a simulation under different assumptions of asset loss and asset holding will be undertaken to find the effects of asset level or asset loss on poverty group dynamics.

5.5.2 Poverty Trap Estimation

This subsection consists of two parts - first part will present the empirical methods to examine the existence of the poverty trap by using semi-parametric approach while the second part will present the parametric approach to investigate the emergence of a poverty trap in the post shock period. Through parametric approach, different socio- economic variables including the polynomials of the asset index are controlled while semi-parametric approach is the manifestation between asset indices of the two time periods.

5.5.2.1 Empirical Strategy: Semi-parametric Estimation of Poverty Trap

In addition to MNL analysis, a semi-parametric approach is taken to estimating the relationship between poverty and assets. For this, we have used a modified version of the Carter and Barrett (2006) model to test the existence of a poverty trap at household level. Adato et al. (2006) have developed an asset index that is derived from a set of assets likely to determine a household's future welfare. The index is constructed using a livelihood regression which put weights on assets according to their marginal contribution to the livelihood. For our purposes, the livelihood regression has been modified by including household characteristics and the coping strategies along with assets. This reflects the fact that households

[36] Here groups other than non-poor are non-base poverty groups as non-poor group has been considered as base broup.

adopt different coping strategies in the recovery period of the shock which directly shape the amount of assets of the households. This modified livelihood regression developed in this research has been termed a comprehensive livelihood function:

$$\theta_{it} = \sum_{j=1}^{J} \beta_j A_{ijt} + \sum_{k=1}^{K} \gamma_k C_{ikt} + \varepsilon_{it} \qquad (2)$$

where livelihood θ of household i in time t is a function of a vector of assets A, aggregated over the total number of J assets owned by a household and the copies strategies, a vector of strategies C, aggregated over the total number of k strategies taken by the households i in t time to tackle the effect of the shocks in the post shock. Error term Ɛ is normally and identically distributed. "Livelihood" is defined as per capita income of a household divided by the region-specific poverty line income. In this research, both cyclone affected and non-affected areas have same poverty line income as they are situated in the same region of the country. The comprehensive livelihood function (Eqn.2) is estimated using Ordinary Least Squares (OLS). Following Jalan and Ravallion (2000) the predicted values from the estimated coefficients of the livelihood function constitute the household-specific asset index. The comprehensive asset index is based on 22 different assets, 10 household characteristics (family size, age of household head, education level of household head, access to credit and labour market etc.) and 13 coping strategies (see Table 5.4 for a full list). Since households acquire some of these assets over lengthy periods of time, the comprehensive asset index represents household's welfare in the medium term.[37] Asset index will be estimated with and without coping strategies for the affected areas while it will be estimated without coping strategies for the unaffected areas as households of the unaffected areas don't adopt any coping strategies. Some of the coping behaviour (livestock sale, land sale etc.) are directly linked while some (relief, using savings etc.) are indirectly linked with asset stock. Therefore,

[37] Here short run refers to the period immediate after the disaster while medium term indicates the recovery period.

estimating asset index with and without coping behaviour will lead to study the extent of poverty trap influenced by the coping strategies.

One advantage of using an asset index instead of other alternative methods, such as principal component and factor analysis, is that it combines different types of assets measured in different units (monetary, years, number of people) into a single measure with a continuous distribution.[38] The livelihood-based asset index measured in Poverty Line Units (PLU) provides a more intuitive interpretation of the results. An asset index below one indicates households with an income below the poverty line; an asset index above one indicates households above the poverty line (Giesbert & Schindler, 2012). In this research, household specific asset indices will be estimated separately for affected and non-affected areas and for a pre-shock period (2008) and the post shock recovery time (2013).

In a second step, in order to answer the research question (is there a poverty trap?), a local polynomial asset recursion function is estimated to find the relationship between the household's recovery (2013) and pre-shock (2008) asset indices by using a semi-parametric technique:

$$A_{it} = f(A_{it-1}) + \varepsilon_i \qquad (3)$$

Where A represents the asset index of household i, t represents the recovery period (2013) and t-1 the pre-shock period (2008). This approach is a direct estimation of the curve in the figure 5.2. Through this graph, the existence or absence of multiple equilibria above and below the poverty line can be tested. Equation 2 assumes the error term ε_i to be normally and identically distributed with zero mean and constant variance. A local polynomial regression is used for

[38] PCA takes a set of correlated variables while the asset index method used in this research uses uncorrelated variables.

estimating Equation (3) by using Epanechnikov kernel weights[39]. This regression is called local as the estimate is in the vicinity of the chosen value of the asset index in the pre-shock period. The asset index in the recovery period will be estimated with and without coping strategies for the affected areas. This will provide the opportunity to see the extent of poverty trap influenced by the coping strategies. This is new in the relevant literature.

5.5.2.2 Empirical Strategy: Parametric Estimation of Poverty Trap

A parametric estimation of the poverty trap attempts to control the household characteristics and other determinants of the households that may influence the asset acceleration in the recovery period. Parametric estimation of the poverty trap will be done with and without coping strategies for the affected areas while it will be done without coping strategies for the unaffected areas. This is something new in the relevant literature. Specification of the parametric poverty trap estimation will be:

$$\Delta A_i = \beta_1 A_{it-1} + \beta_2 A_{it-1}^2 + \beta_3 A_{it-1}^3 + \beta_4 A_{it-1}^4 + \beta_5 X_{it-1} + \beta_6 C_{it} + \varepsilon_i \qquad (4)$$

where ΔA_i is the asset growth of household i from pre-shock (2008) to recovery (2013), $\beta_4 A_{it-1}^{1,2,3,4}$ is 4th degree polynomial expansion of pre-shock asset, X_{it-1} is invariant household characteristics in the pre-shock period and finally C_{it} is the set of coping strategies taken by the household i - in the post shock recovery period t. Polynomial expansion of pre-shock asset will confirm the nature of the asset growth expansion path during the recovery period. A strong test of convergence would be to reject $\beta1 = \beta2 = \beta3 = \beta4 = 0$ in favour of $-2 < \beta1 \leq 0$ and $\beta2 = \beta3 = \beta4 = 0$ (Barrett et al., 2006; Naschold, 2013; Quisumbing & Baulch, 2013). Convergence would indicate a unique stable and dynamic equilibrium in which less wealthy households with lower amount of assets grow faster until they reach the equilibrium, while the asset growth of households with higher assets decelerates. A weaker test of convergence is if the expected value of change in

[39] The advantage of using Epanechnikov kernel weights is that they don't consider the value of the borders. We use a second order polynomial and a kernel bandwidth of 0.2 (balancing the smoothness of the regression function with bias), which fit the data best.

assets is non-negative and the first derivative of the expected change in log assets with respect to lagged assets is negative, otherwise the equilibrium would not be stable (Quisumbing & Baulch, 2013).[40] We conduct this test at the 10th, 30th, 50th, 70th and 90th percentiles of the base period asset distribution. Equation 4 is estimated for affected and non-affected areas separately so that we can compare the convergence paths (if any) in both areas.

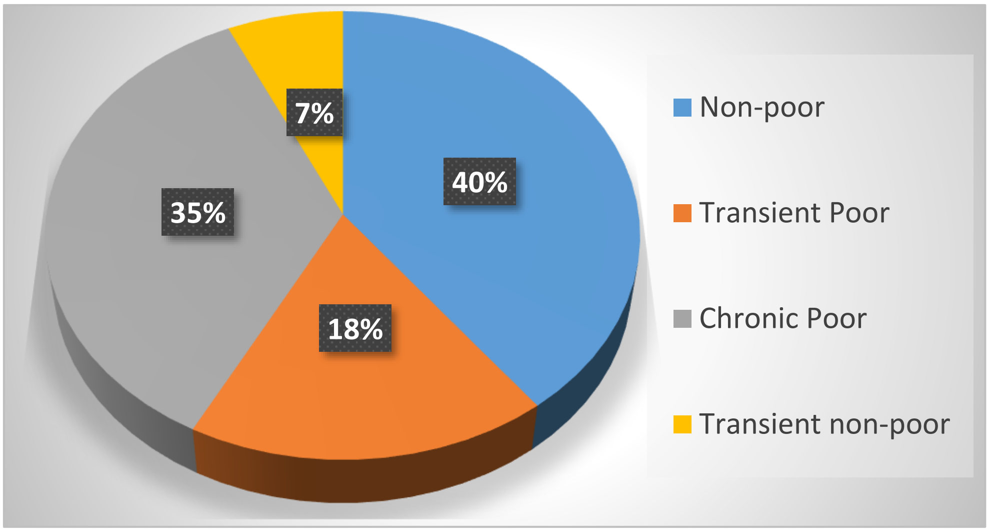
5.6 Data Description

This research uses 593 households as a treatment group representing two unions; Gabura, and Shaymnagar, of the cyclone affected Shaymnagar sub-district of Shatkhira District. It also uses 297 households as a control from Koilashganj union of Dacope sub-district of Khulna district.[41] Since the link of asset loss and poverty dynamics will be explored in this chapter, here only the descriptive data for the treatment group is discussed. Moreover, only the treatment group has undertaken coping strategies. Therefore, poverty groups with different levels of coping strategies will be presented in this section. The non-poor is the largest segment (40%) of poverty groups while transient non-poor is the lowest (7%) in the cyclone affected areas. Figure 5.3 presents the different poverty groups which have been classified following the procedure delineated in the Table 5.1 in the sub-section 5.1.1. The figure also shows that chronic poor is the second largest group among the four. But the negative point is that 18% of the households have become poor between the pre-shock (2008) and the recovery period (2013).

[40] Please note that the convergence asset path has been shown in the figure 5.2 of this chapter before.

[41] Whether the treatment group are similar with the control group has been tested by P value in the Table 4.3 of the chapter 4.

Figure 5.3: Different dynamic poverty groups



Non-poor household heads are more educated and have a smaller family size compared to the other three groups. Assets of the non-poor households are more exposed to the shocks compared to the other three groups in terms of amount of asset loss. Table 5.3 shows that asset loss of non-poor households is 90956.66 BDT as against the average loss of 63397.09 BDT. Assets that generate immediate income have been classified as productive assets. Table 5.3 also shows that non-poor households experienced highest productive asset loss (45.97%) compared to other three groups. In some characteristics (mean age of household heads) transient non-poor gets the highest value. Households in the chronic poor group face the highest death rates as a consequence of the cyclone (3.83%) followed by transient poor (3.74%) indicating that poor and transient poor are the most vulnerable groups in the cyclone in terms of occurrence of death from cyclone.

Table 5.3: Characteristics of households by poverty groups

Variables	Non-poor	Transient Poor	Chronic Poor	Transient Non-poor	Total
Mean age of HHH(years)	43.90	43.65	44.43	45.37	44.15
Education of HHH (No. of classes)	5.58	3.85	3.43	3.95	4.39
Male HHH (%)	88.94	87.85	87.14	95.12	88.53
Mean household size (in person)	4.10	4.58	5.11	4.41	4.57
Asset loss (in BDT)	90956.66	54018.73	39520.52	52203.59	63397.09
Productive asset loss (in BDT)	41818.98 (45.97%)	22461.68 (41.58%)	15161.90 (38.36%)	21862.88 (41.88%)	27506.30 (43.39)
HH with death (%)	3.42	3.74	3.83	2.44	3.55
HH with injury (%)	7.79	4.72	13.94	12.20	9.73

Note: HH stands for household and HHH for household head in this table.

Now we will look at the trajectories of households' characteristics by poverty group. This is important as those characteristics usually influence the poverty dynamics between the shock and the recovery period. Table 5.4 illustrates the trajectories of households' characteristics, including different input and market access variables by poverty groups. In the case of access to electricity, all the four poverty groups gain more access to electricity in the recovery period compared to the pre-disaster time period. Here it is worth mentioning that in Bangladesh, access to electricity depends not only on the purchasing power of the households, but also the availability of the electricity supply system. All the poverty groups gain a rapid increase in mobile phone access over the period. Access to credit is the lowest among the chronic poor (64.76%) access to poverty in the recovery period. In the pre-disaster period, non-poor had the highest level of access to credit (52.99%) and transient poor the lowest (40.57%). In the recovery period, non-poor is still the highest in terms of access to credit (74.79%). But the chronic poor ends up having the lowest access to credit in the recovery period. The transient poor have the lowest level of access to labour (55.66%) in the recovery period.[42] Involvement with the NGO has increased significantly from pre-disaster to the recovery period. In the pre-disaster period, chronic poor was the

[42] Access to labour indicates the scope of being hired as labour.

lowest (36.67%) in terms of involvement with NGO followed by transient poor (37.38%). In the recovery period, chronic poor is the lowest (61.43%) in terms of NGO involvement.

Table 5.4: Trajectories of households' characteristics by poverty groups

Variables	Non-poor		Transient Poor		Chronic Poor		Transient Non-poor		Total	
	Pre	Rec	Pre	Rec	Pre	Rec	Pre	Rec	Pre	Rec
Access to electricity (%)	23.50	46.15	7.14	40.19	7.14	36.67	12.5	53.66	14.55	42.23
Access to mobile (%)	38.62	78.97	28.04	72.90	17.14	64.76	12.19	65.85	27.24	71.91
Access to labour (%)	58.12	61.54	52.83	55.66	48.53	70.67	60.97	65.86	58.91	64.01
Access to credit (%)	52.99	74.79	40.57	66.04	43.27	64.90	48.78	70.98	47.03	68.76
Involved with NGO (%)	42.73	64.10	37.38	66.36	36.67	61.43	53.65	65.85	40.47	63.68

Note: 'Pre' represents the pre-cyclone period and 'Rec' represents recovery time, i.e. 2013.

This survey covers 13 coping strategies undertaken by the households to tackle the effects of the disaster after the post disaster period. Table 5.5 lists the 13 coping strategies and the percentage of households adopting these strategies. Disaster significantly affects the households' necessary consumption in the post disaster period. Table 5.5 displays that 70.78% households had to decrease their necessary consumption to tackle the effect of the disaster. The effects of the disaster have forced people to spend from their savings. As Table 5.5 shows, 41.05 percent of people used their saving to meet their expenditure in the post-disaster period. Around half of the households had to cut their expenditure for education and health while 22.30 percent of households had to take institutional loans. Livestock is also a productive asset for the rural households. In the post-disaster period, 21.42 percent of households had to sell this asset. More than half of the people received relief from government and NGOs. Very few households sold their lands or mortgaged them out to tackle the effects of the disaster. One argument behind this may be that lands after the disaster are not attractive to buyers due to long standing flood water. Since households with different income levels adjust their coping strategies differently, those 13 strategies are not potentially collinear.[43]

Table 5.5: Number of households by coping strategies and poverty groups in the affected areas

No	Coping Strategy	% of households	Non-poor	Transient Poor	Chronic Poor	Transient Non-poor
1	Using Savings	41.05	38.67	16.30	37.57	7.46
2	Land sale	1.52	44.44	11.11	33.33	11.11
3	Livestock sale	21.42	44.09	18.90	19.13	18.87
4	Decrease in necessary consumption	70.78	39.52	18.33	36.19	5.95
5	Decrease in unnecessary consumption	54.61	35.58	19.23	39.42	5.77
6	Institutional loan	22.30	42.86	18.05	33.83	5.26
7	Un-institutional loan	21.74	40.65	13.82	39.84	5.39
8	Land mortgage	2.70	52.94	11.76	35.29	0.00
9	Decrease in education and health expenditure	49.24	41.44	18.15	34.59	5.82
10	Charity	13.37	33.75	15.00	48.75	2.50
11	Relief from government	52.43	35.41	18.03	38.36	8.20
12	Relief from NGOs	51.20	32.77	20.77	40.34	6.72
13	Others	1.69	50.00	0.00	50.00	0.00

Table 5.5 also shows that non-poor groups are generally more advanced in adopting coping strategies. For instance, 38.67% people who use savings to tackle the disaster are non-poor. In case of livestock sale, 44.44% people are non-poor followed by chronic poor (19.13%). Non-poor represent the biggest group (39.52%) in term of decrease in necessary consumption followed chronic poor group (36.19%). The same pattern also exists in case of institution loan, un-institutional loan, land mortgage and decrease in education and health

[43] Collinearity among the coping strategies has been tested in the subsection 5.8.2 of the current chapter.

expenditure. Chronic poor are the highest receiver of charity, relief from government and NGOs in the wake of the disaster.

So far, we have defined the different dynamic poverty groups, trajectories of households' characters and coping behavior by poverty groups. In order to understand the relationship between the dimensions of poverty and the dynamics of poverty, and the relative importance of these dimensions, the following section undertakes a multivariate analysis of poverty status. This will substantiate the importance of household assets to determine the dynamism of the poverty group status.

5.7 Estimation Results: Poverty Dynamics

This section will present the estimation results of the determinants of poverty dynamics and simulated results of the effects of asset holdings or asset loss under different assumptions.

5.7.1 Poverty Dynamics: Multinomial Logit Model (MNL)

Table 5.6, 5.7 and 5.8 displays the coefficients of the MNL model and the relative risk ratios (RRR) of falling into chronic, transient poor and transient non-poor compared to the base poverty group, non-poor respectively. The coefficients of each explanatory variable indicated the log of odds[44]. In all these three tables, the basic model includes some variables that reflect human and physical capital, social capital and market access. Similar variables are also used in other research on poverty dynamics (Garza-Rodriguez et al., 2015). Then, the extended model adds the disaster related variables to the basic model.

Education of the household head is statistically significant for transient poor group compared to the non-poor as shown in the Table 5.6. But RRR of household head's education for transient poverty group is lower than 1 (0.88) indicating that compared to the non-poor group, probability of a household

[44] Log of odds means the log of the probability of success as defined as the ratio of the probability of success over the probability of failure. Very high log of odds produces very high probability: close to 1 and vice versa. For example, log of odds 9.21 and -6.90 have probabilities of 0.99 and 0.001, respectively.

falling into transient poor groups decreases with the education of the household head[45]. It implies that in the post disaster period, education cannot ensure income generation. It can happen because in the post disaster period, demand for physical labour exists due to reconstruction works done by both private and public sectors. In case of household size, the coefficients for transient poor groups are statistically significant and the corresponding RRRs are much higher than 1 in both basic and extended model. It implies that the influence of a household's size on the transient poor groups' propensity to fall into poverty is higher compared to the base group - non-poor. In case of the mobile phone using households, the coefficients for transient poor groups are statistically significant and the corresponding RRRs are much lower than 1 (0.536) in the extended model. It indicates that if the household uses mobile phone, their propensity to fall into transient poor groups is lower compared to the base group - non-poor. In case of the households who have family member with injuries by the disaster, the coefficients for transient poor groups are statistically significant and the corresponding RRRs are much lower than 1 (0.283) in the extended model. It implies that the influence of an injury by the disaster on the transient poor groups' propensity to fall into poverty is lower compared to the base group - non-poor. Higher asset holding in the recovery period decreases the transient poor groups' propensity to fall into poverty compared to the base group - non-poor as the corresponding RRR is much lower than 1 (0.626).

[45] An RRR close to 1 shows the risk of being in one poverty group is the same of the risk of staying in the base group. RRR less than (greater than) 1 implies a decrease (increase) in the probability a household falls into the category compared to the base group.

Table 5.6: Multinomial Logit model of transient poor

Variable	Basic		Extended	
	Coef	RRR	Coef	RRR
Edu of hh	-0.128*	0.880	-0.062	0.940
Sex of hh	0.465	1.591	0.588	1.801
hh size	0.292*	1.340	0.389*	1.475
NGO	0.131	1.141	0.042	1.042
Mobile	-0.361	0.697	-0.624***	0.536
Electricity	-0.286	0.752	-0.354	0.702
Access to credit	-0.330	0.719	-0.584	0.558
Access to labour	-0.249	0.780	-0.082	0.921
Disaster related variables				
Death			0.390	1.477
Injury			-1.261**	0.283
Log (asset cur)			-0.469**	0.626
Log (asset loss)			-0.006	0.994
Log (prod. Asset loss)			0.050	1.051
Log(aid)			0.127	1.135
Height of flood water			-0.472	0.624
Days flood water			-0.001	0.999
Constant	-1.030	0.357	4.378	

Note: a) Number of observations is 593, and b) *, ** and *** indicate 1%, 5% and 10% level of significance respectively.

Table 5.7 shows that education of the household head is statistically significant for chronic poor group compared to the non-poor in the basic model. But RRR of household head's education for chronic poor group is lower than 1 (0.865) indicating that compared to the non-poor group, probability of a household falling into chronic poor group decreases with the education of the household head. In case of household size, the coefficients for chronic poor groups are statistically significant and the corresponding RRRs are much higher than 1 in both basic and extended model. It implies that the influence of a household's size on the chronic poor groups' propensity to fall into poverty is higher compared to the base group - non-poor. Table 5.3 has already shown that family size of the poor households (5.11) is larger compared to that of the non-poor households (4.10). Therefore, in the post disaster period, poor households cannot maintain their livelihood and remain as chronic poor. Access to different kinds of inputs or services (electricity and mobile phone) is statistically significant for chronic poor group and the probability of a household falling into chronic poor group decreases with the use of electricity and mobile. Mobile phone can help the households to have access to different agricultural extension services and market information. In addition, electricity not only helps to maintain better life standard, but also facilitates irrigation and other agricultural activities. Access to credit is statistically significant for chronic poor group and the probability of a household falling into chronic poor group decreases with the access to credit. But in case of households with access to labour, the probability of a household falling into chronic poor group increases with access to labour. Local sources confirmed that workers in disaster affected areas are not fully employed or monthly salaried. They are mainly involved with farms and informal sectors where they can work for a part of the month. Therefore, access to labour in the disaster affected areas cannot help the poor to come out of poverty. Higher asset holding in the recovery period decreases the chronic poor groups' propensity to fall into poverty compared to the base group - non-poor as the corresponding RRR is much lower than 1 (0.425).

Table 5.7: Multinomial Logit model of chronic poor

Variable	Basic		Extended	
	Coef	RRR	Coef	RRR
Edu of hh	-0.145*	0.865	-0.043	0.958
Sex of hh	0.338	1.402	0.783***	2.187
hh size	0.530*	1.698	0.838*	2.312
Ngo	-0.132	0.877	-0.245	0.783
Mobile	-0.715*	0.489	-0.933*	0.393
Electricity	-0.446**	0.640	-0.242	0.785
Access to credit	-0.484***	0.616	-0.673	0.510
Access to labour	0.446***	1.563	0.756**	2.130
Disaster related variables				
Death			-0.116	0.890
Injury			0.343	1.409
Log (asset cur)			-0.857*	0.425
Log (asset loss)			-0.158	0.854
Log (prod. Asset loss)			-0.247	0.781
Log(aid)			0.215**	1.240
Height of flood water			-0.066	0.937
Days flood water			-0.002***	0.998
Constant	-1.177**	0.308	8.315*	

Note: a) Number of observations is 593, and b) *, ** and *** indicate 1%, 5% and 10% level of significance respectively.

Education of the household head is statistically significant for transient non-poor group compared to the non-poor as shown in the Table 5.8. But RRR of household head's education for transient poverty group is lower than 1 (0.877) indicating that compared to the non-poor group, probability of a household falling into transient non-poor groups decreases with the education of the household head. Access to credit is statistically significant for transient non-poor group and the probability of a household falling into chronic poor group decreases with the access to credit. Male headed households perform better compared to the female headed households in graduating to transient non-poor group. As the Table 5.8 shows, probability of a household falling into the transient non-poor group is higher in case of male headed household compared to the base group-non-poor.

Table 5.8: Multinomial Logit model of transient non-poor

Variable	Basic		Extended	
	Coef	RRR	Coef	RRR
Edu of hh	-0.131*	0.877	-0.085	0.918
Sex of hh	1.067**	2.907	1.628**	5.092
hh size	0.163	1.177	0.207	1.230
Ngo	0.278	1.321	0.532	1.702
Mobile	-0.600	0.549	-0.296	0.744
Electricity	0.211	1.236	0.108	1.114
Access to credit	-0.767***	0.464	-0.999***	0.368
Access to labour	0.383	1.467	0.657	1.929
Disaster related variables				
Death			-14.176	0.000
Injury			0.547	1.727
Log (asset post)			0.160	1.173
Log (asset cur)			-0.435	0.647
Log (asset loss)			-0.258	0.772
Log (prod. Asset loss)			0.128	1.136
Log(aid)			1.408	4.087
Height of flood water			-0.003	0.997
Days flood water			-4.432	0.012
Constant	-2.737	0.065	-14.176	

Note: a) Number of observations is 593, and b) *, ** and *** indicate 1%, 5% and 10% level of significance respectively.

Non-government organizations in the disaster affected areas offer different kinds of training programs for the affected people through which different livelihood enhancing information is exchanged. But the results show that involvement with institution like NGO cannot produce any statistically significant coefficients for all the three groups which is counter intuitive. Access to the market is an important factor in determining poverty. Households with access to credit have a lower probability to fall into the chronic poor and transient-non-poor compared to the non-poor groups in the recovery period. Access to labour does not play the expected role in all the three groups and is significant only for the chronic poor. A stringent assumption of multinomial logit models is that outcome categories for the model have the property of independence of irrelevant alternatives (IIA). Stated simply, this assumption requires that the inclusion or exclusion of categories does not affect the relative risks associated with the regressors in the remaining categories. This model does not violate the independence of irrelevant alternatives (IIA) condition.[46] Finally, there is low possibility that all the three multinomial logit models will suffer from reverse causality problem. All decision variables in the RHS of the equation came from the disaster time period while the dynamic poverty groups were formed on the basis of the poverty group status of the time span of disaster to recovery time period. Since poverty status in the recovery period is one period ahead of the decision variables, the possibility of reverse causality is very low.

5.7.2 Poverty Group Dynamics and Productive Asset Loss

Determining the poverty group status under different hypothetical productive asset loss on top of the existing productive asset loss due cyclone is based on the assumption that disaster will cause additional productive asset loss keeping the other effects as constant. Using the estimated results displayed in the Tables 5.5-5.7, a simulation of the effects of the 20%, 50% and 100% additional productive asset loss has been undertaken and figure 5.4 presents the transformed poverty groups. Figure 5.4 shows that if the productive asset loss from the shock increased by 20%, the non-poor poverty group would shrink from 40% to 36% and the transient poor would increase from 18% to 22%. At the same time, transient poor would increase from 35% to 37% while transient non-poor would decline to 5%. This Figure also shows that if the productive asset loss from the shock increased by 50%, the transient poor would increase from 18% to 33%. At the same time, if the productive asset loss from the shock increased by 100%, the transient poor would increase from 18% to 45%. These results imply that the amount of productive asset loss in the shock determines the poverty status in the recovery period.

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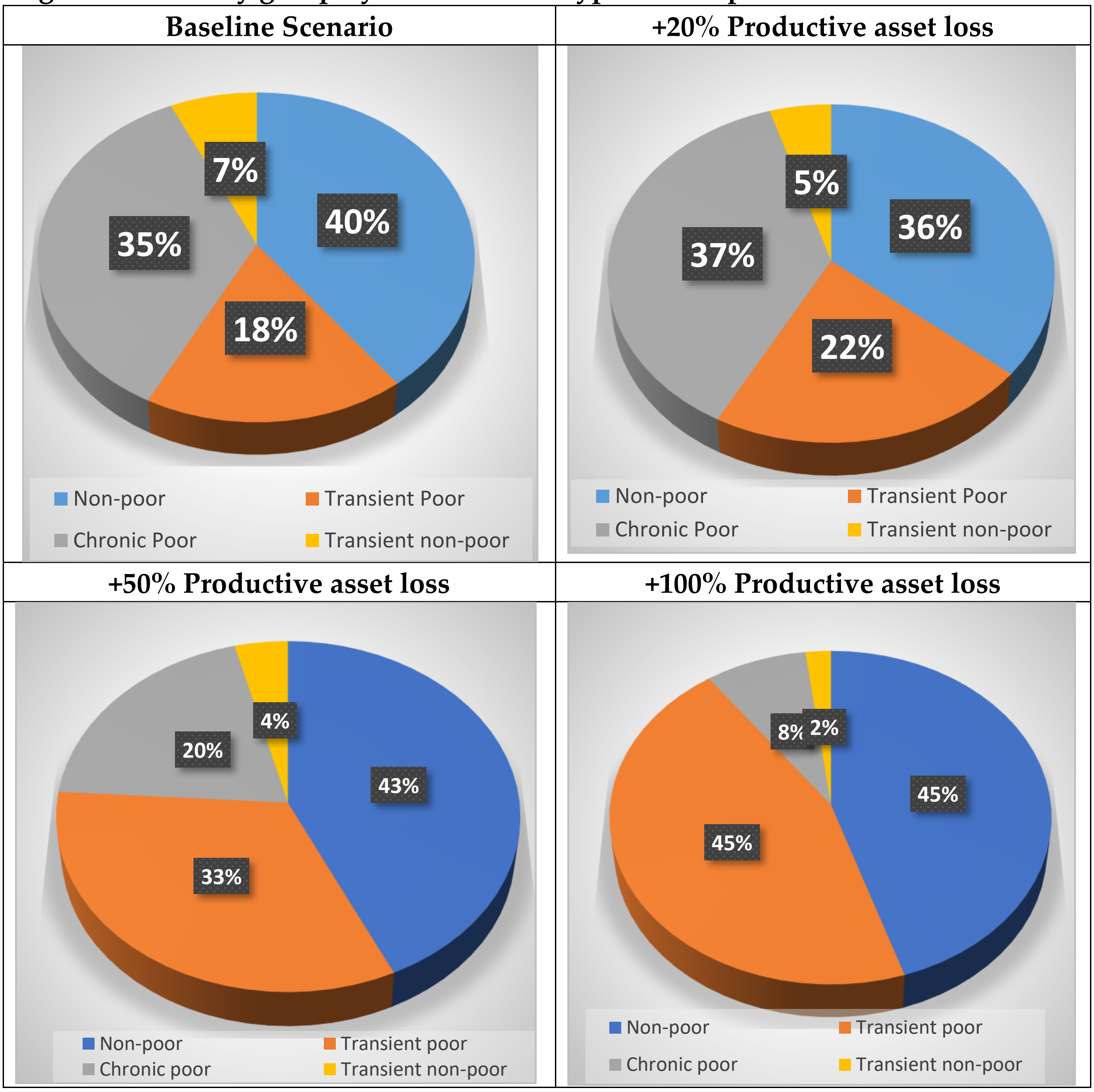
[46] Smshiao test statistics give negative chi-square values for all four poverty groups while Hausman test statistics give positive chi-square values for non-poor and transient poor while negative chi-square values. It may happen as they consider different subsets of sample. However, Hausman and Mcfadden (1984) conclude that negative chi-square value is the evidence that independence of irrelevant alternatives (IIA) is not violated. Since smhsiao test gives negative chi-square values in all types of poverty group, we can conclude that outcome variables don't violate IIA.

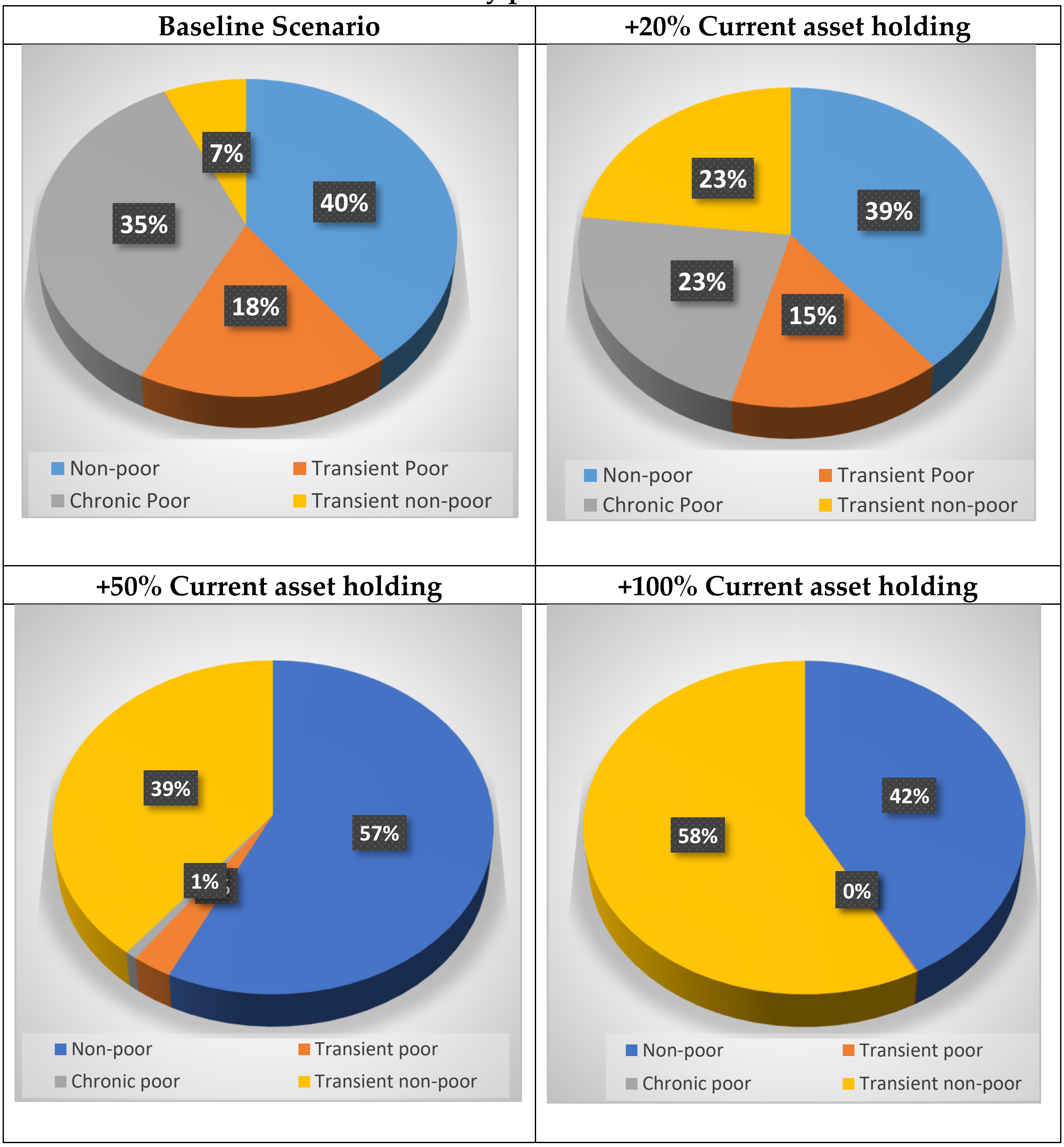
Figure 5.4: Poverty group dynamics under hypothetical productive asset loss



5.7.3 Poverty Group Dynamics and Current Asset Holding

Determining the poverty group status under different hypothetical current asset holding on top of the existing current asset holding is based on the assumption that households will have additional current asset keeping the other things as constant. Using the estimated results presented in Table 5.5, a simulation of the effects of a 20% additional asset holding in the recovery period has been completed and figure 5.5 displays the transformed poverty groups. Figure 5.5 shows that if the asset holding in the recovery period increased by 20%, the non-poor poverty group would shrink from 40% to 39% and the transient poor would decline from 18% to 15%. At the same time, transient poor would increase from 35% to 23% while transient non-poor would decline to 23%. This Figure also shows that if the asset holding in the recovery period increased by 50%, the non-poor poverty group would increase from 40% to 57% and the transient poor would decline from 18% to 3%. At the same time, chronic poor would decrease from 35% to 1%. This Figure also depicts that if the asset holding in the recovery period increased by 100%, there will be no chronic or transient poor. This result signifies that amount of asset holding in the recovery period shapes the poverty status in the recovery period.

Figure 5.5: Poverty group dynamics under hypothetical asset holding in the recovery period



Therefore, the estimated results of the MNL model and the simulated results suggest that lower asset losses from the shock or pre-existing higher household assets are important determinants when defining the dynamism of the poverty group status. This also validates the claim of Carter et al. (2007) that asset based poverty analysis is the fourth generation poverty analysis technique. Additional current asset holding or additional productive asset loss due to cyclone have nonlinear effect on poverty dynamics as probability function in the equation 1 (coefficients of MNL) contains the exponential function. This also indicates that the effect of marginal unit of asset on poverty dynamics assuming the constant effect from other explanatory variables is not constant.

5.8 Estimation Results: Poverty Trap Analysis

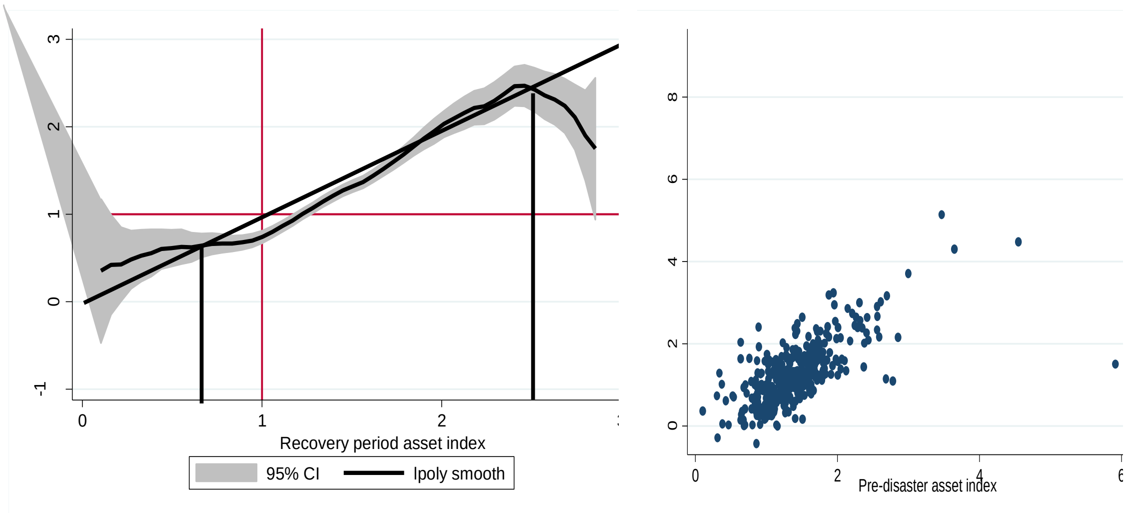
This section will present the estimation results of the semi-parametric and parametric poverty trap analysis.

5.8.1 Semi-parametric Poverty Trap Analysis

Estimation of asset recursion function for the affected areas with and without coping strategies and for the unaffected areas without coping strategies has been done here to look at the asset dynamism from the shock to recovery period (just like asset dynamics of Figure 5.2). The estimated relationship between the comprehensive asset index in the recovery and in the pre-shock period is displayed in Figure 5.6.

The semi-parametric poverty trap analysis for the affected areas shows an evidence for multiple equilibria poverty trap. Figure 5.6 displays that these multiple equilibria poverty traps exist when we don't consider the influence of the coping strategies on assets. Equilibrium poverty line units (PLU) without coping strategies are around 0.60 and 2.5. These are the temporal equilibriums where assets stabilise. This indicates a clear divergence in terms of poverty dynamics among the people of the disaster affected areas. A clear bifurcation among the households happens as the poor households converge to the low level PLU (0.60) and the rich households move to a higher PLU, (2.5).

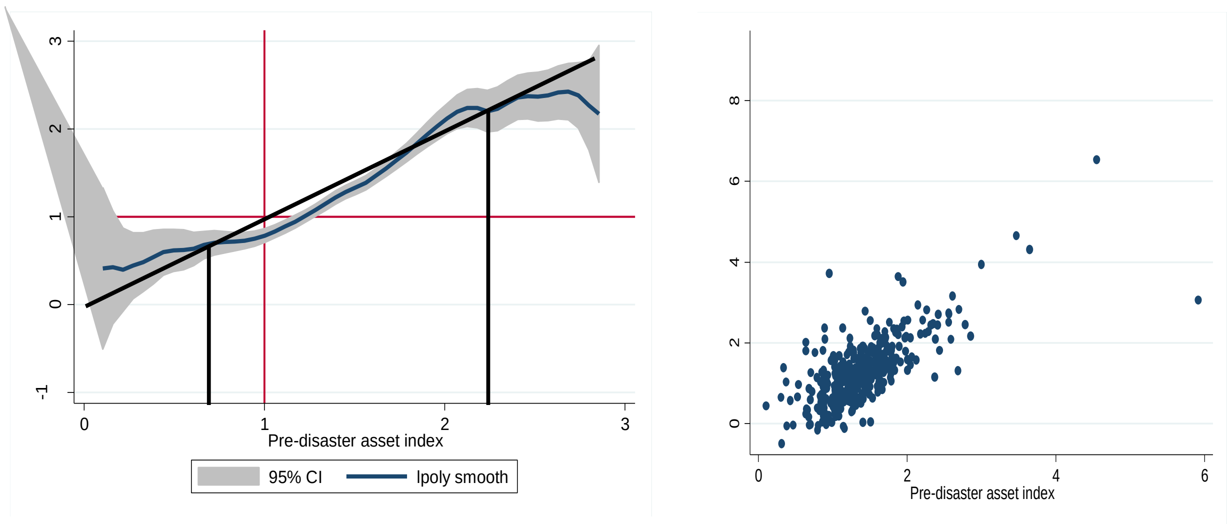
Figure 5.6: Semi-parametric estimation of asset recursion function for affected areas (without coping strategies)



Note: The 2nd order polynomial and a kernel bandwidth of 0.2 are used in this estimation. A value of 1 on either axis indicates the food poverty line in a given year. Asset recursion functions with reasonable confidence intervals are displayed in the figure.

On the other hand, Figure 5.7 also displays the asset recursion function for the affected areas when we consider the influence of post-shock coping strategies in estimating the asset index. Figure 5.7 shows that, like Figure 5.6, multiple equilibria poverty traps also exist here. But the equilibrium level PLU for the poor households increases to 0.70 while for the rich households, it decreases to 2.3. Increase by 0.1 in PLU implies a big difference in money income as it is 10 percent of the poverty level income. This implies that coping strategies affect the poor households positively towards asset accumulation. It also indicates that poor households smooth their asset holdings with coping strategies, while rich ones don't. One reason can be that poor households can sacrifice their consumption and living standard in the aftermath of the disaster without affecting their asset stock.

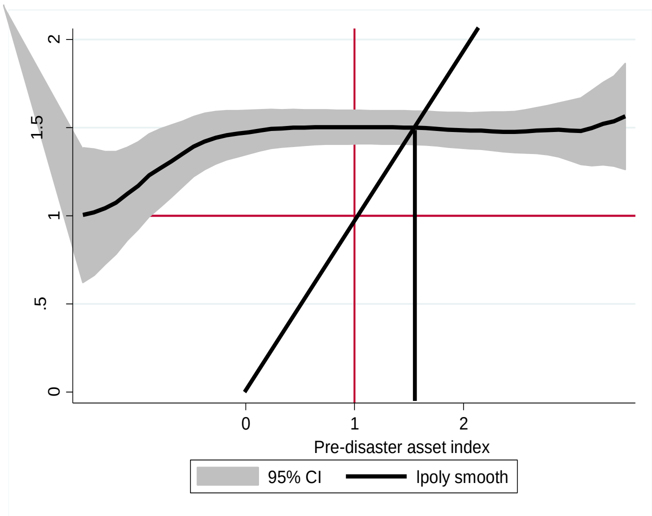
Figure 5.7: Semi-parametric estimation of asset recursion function for affected areas (with coping strategies)

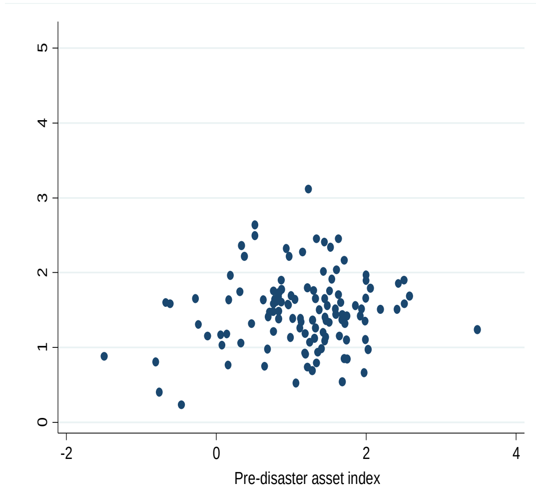


Note: The 2nd order polynomial and a kernel bandwidth of 0.2 are used in this estimation. A value of 1 on either axis indicates the food poverty line in a given year. Asset recursion functions with reasonable confidence intervals are displayed in the figure.

Figure 5.8 displays the estimated relationship between the comprehensive asset index in the recovery and in the pre-shock period in the unaffected areas. It shows that a single equilibrium exists in case of the asset recursion function for the households of the unaffected areas. The single equilibrium indicates that both the low income and high income households converge to the same direction. But, this equilibrium is at PLU, 1.5 which is much higher than the lower level equilibrium (0.7 PLU) for the poor households in the affected areas. Figure 5.8 also shows that poor households in the recovery period stay at the positions higher than 1 in Y-axis indicating that poor households in the unaffected areas are staying above the poverty line income in the recovery period.

Figure 5.8: Semi-parametric estimation of asset recursion function for unaffected areas





Note: The 2nd order polynomial and a kernel bandwidth of 0.2 are used in this estimation. A value of 1 on either axis indicates the food poverty line in a given year. Asset recursion functions with reasonable confidence intervals are displayed in the figure.

5.8.2 Parametric Poverty Trap Analysis

A parametric estimation of the poverty trap controls the household characteristics and other determinants of the households that may influence the asset acceleration in the recovery period. OLS estimation of the parametric poverty trap in the treatment and control areas separately along with the strong and weak test of convergence in asset growth will be done here. A parametric estimation of the determinants of asset growth across the two periods is displayed in the Table 5.9. Households' initial asset level is negative indicating that high income households tend to grow at a lower rate than poorer households, which gives an indication of convergence among the households. There is an evidence of a life-span effect on asset growth over the period. As the age of the household head increases, asset growth of the households over the period of time will be higher. Education level of the household head affects the asset growth positively. The coefficient of the education of the household head is 0.050 meaning that the household head with one class more education will gain higher asset growth by 0.05% in the basic model and 0.045 in the extended model. Small family size is more efficient in securing higher asset growth. The marginal contribution of an addition family member to asset growth is -0.035 in the basic model. Households who lose a family member in the shock experience lower asset growth by 0.15 percent compared to the non-loser households. Asset loss in the shock decreases the asset growth - which is in line with relevant literature. Both the impacts of loss of savings and land mortgage as coping strategies on the asset growth are positive, while those of the livestock sale, and uninstitutional loan are negative to determine the asset growth.

Table 5.9: OLS estimates of parametric poverty trap, treatment vs control

Variable	Treatment Affected		Control Unaffected
	Basic	Extended	Basic
Asset Index	-0.338	-1.119	-0.958***
Asset Index^2	-0.321	0.361	-0.011
Asset Index^3	0.241	0.034	-0.040
Asset Index^4	-0.032*	-0.014	0.009
Age hh	0.007***	0.008***	0.007
Edu hh	0.050***	0.045***	0.085***
Hh size at pre-disaster period	-0.035	-0.037*	-0.162***
Death	-0.156*	-0.112	
Injury	0.074	0.063	
Asset loss	-0.000*	-0.000**	
Coping Strategies(000BDT)			
Savings loss		0.005***	
Land sale		0.003	
Livestock Sale		-0.019***	
N.consum decrease		-0.004*	
Un. Consum decrease		0.007***	
Ins. Loan		0.003	
Unins. Loan		-0.002**	
Land mortgage		0.015**	
Edu. & health exp. decrease		0.001	
Charity		0.001	
Govt relief		-0.001	
Ngo relief		-0.037***	
Others Aila		0.005***	
Constant	0.040	0.289	1.490***

Note: Only basic model with limited variables has been estimated for the unaffected areas as the households in unaffected areas don't adopt any coping strategies due to the disaster. Number of observations for affected areas is 593 and 297 in the unaffected areas, b) *, ** and *** indicate 1%, 5% and 10% level of significance respectively, and c) we test the multicollinearity of the coping strategies and find negative results.

As we already stated in the empirical strategy that a strong test checks the existence of divergence or convergence in the asset growth while the weak test checks the existence of multiple equilibria/trap in the asset growth. With reference to the coefficients of the Table 5.9, a strong test of convergence would be to reject $\beta1 = \beta2 = \beta3 = \beta4 = 0$ in favour of $-2 < \beta1 \leq 0$ and $\beta2 = \beta3 = \beta4 = 0$. In the affected areas when coping strategies are not considered, the null hypothesis $\beta1 = \beta2 = \beta3 = \beta4 = 0$ can be rejected (F statistics = 16.54 and Prob > F = 0.00) and the first alternative hypothesis $-2 < \beta1 \leq 0$ can be accepted. But the second alternative hypothesis ($\beta2 = \beta3 = \beta4 = 0$) cannot be accepted (F statistics =21.57 and Prob > F = 0.00). While coping strategies are considered, the null hypothesis $\beta1 = \beta2 = \beta3 = \beta4 = 0$ can also be rejected (F statistics = 23.38 and Prob>F=0.00) and the first alternative hypothesis $-2 < \beta1 \leq 0$ can be accepted. But, the second alternative hypothesis ($\beta2 = \beta3 = \beta4 = 0$) cannot be accepted (F statistics =29.24 and Prob>F=0.00). So, it indicates that convergence in asset growth doesn’t exist among the households in the affected areas.

We need to check the weak test of convergence for the affected areas to see whether there exist multiple local level equilibria. Applying the weak test as presented in the Table 5.10 shows that the expected value of the change in asset is non-negative across the different percentiles and the first derivative is more than −1 across all the percentiles in the affected areas. As we already know that a weak test of convergence is if the expected value of change in assets is non-negative and the first derivative of the expected change in log assets with respect to lagged assets is negative, otherwise the equilibrium would not be stable (Quisumbing & Baulch, 2013). According to this criterion, the weak test shows the existence of multiple local level equilibria in the affected areas indicating that people of the disaster affected areas fall in poverty trap.

Table 5.10: Strong and weak tests of convergence of asset growth in affected and unaffected areas

Variable	Treatment/Affected		Unaffected
	Basic	Extended	
Strong test of convergence (F statistic)			
β1 = β2 = β3 = β4 = 0	16.54***	23.38***	54.98***
-2 < β1 ≤ 0 (p value)	0.14	0.89	1.00
β2 = β3 = β4 = 0	21.57***	29.24***	0.52
Weak test of convergence[47] *Condition: expected value of change in assets non-negative (t-statistic)*			
10th percentile	-17.76		-9.16
30th percentile	-86.93		20.56
50th percentile	-63.78		6.50***
70th percentile	-3.96		36.72***
90th percentile	24.28***		25.05***
First derivative >−1 (F-statistic)			
10th percentile	2.05	1.59	0.00
30th percentile	0.62	1.25	1.32
50th percentile	0.33	0.66	0.19**
70th percentile	0.18	2.49	11.19***
90th percentile	3.47	0.94	0.05***

Note: ***, ** and * represent 1%, 5% and 10% level of significance respectively

In the unaffected areas, a convergence of asset growth occurs which is consistent with the semi-parametric poverty trap analysis. We find strong evidence for convergence using the strong test on coefficients for the unaffected areas. For unaffected areas, we can reject β1 = β2 = β3 = β4 = 0 in favour of -2 < β1 ≤ 0 and β2 = β3 = β4 = 0 indicating a strong evidence of convergence in asset growth among the households. These results fully align with the result of the semi-parametric method. We need to check the weak test of convergence for the people of the unaffected areas to see whether there exist multiple local level equilibria. Applying the weak test as presented in the Table 5.10, we can reject that the expected value of the change in asset is non-negative across the different percentile and the first derivative is more than −1 across all the percentiles. The existence of single local level equilibria in the unaffected areas indicates that people of the unaffected areas don't fall in poverty trap.

[47] Please note that the expected value of changes in assets for different percentiles are same in both basic and extended regression models.

Does consumption smoothing exacerbate poverty trap in the affected areas?

In this section, I argue that both production and consumption side reasons are working behind the poverty trap. Poverty trap analysis using assets represents the production side of the households as assets consisting of different types of capital of production. Since multiple equilibria exist in the affected areas according to the parametric and semi-parametric poverty trap analysis, it indicates the existence of a poverty trap at a low-level income in the affected areas. On the contrary, unaffected area has a single equilibrium at higher level income than PLU indicating the nonexistence of poverty trap.

In order to check whether consumption smoothing exacerbates poverty trap, consumption patterns from pre-disaster to recovery period in both areas need to be compared. In the Table 4.5 of chapter 4 of this dissertation, OLS estimates of consumption growth from pre-Aila to recovery in affected areas shows the convergence in consumption (consumption smoothing) as the coefficient of log of pre-aila income takes the value of -2.23 in the basic (limited variable) model and -3.26 in the expanded (a large set of variables) model.[48] On the contrary, for the unaffected areas, the coefficient of log of pre-aila income takes the value of 1.30 in the basic (limited variable) model and 3.22 in the expanded (a large set of variables) model implying divergence in consumption from pre-Aila to recovery period.[49] Since consumption smoothing motive inspires the people of the disaster affected areas to maintain a sustainable consumption level despite income loss in the wake of the disaster, people of those areas fall in lower level poverty trap compared to the people of the unaffected areas.

[48] Please note that coefficient value more than -1 implies convergence.

[49] Please note that detailed results of the OLS estimates of consumption growth from pre-Aila to recovery in affected areas have not been shown in the dissertation. Only the necessary coefficients have been presented here.

5.9 Major Findings and Policy Implication

This research finds that productive asset loss from a disaster or asset holding in the post shock recovery period shapes the dynamism of the poverty groups. Productive assets include land and some other forms of capital goods that generate immediate income. Of course, saving life and avoiding injuries during the disaster is monumental to accelerate income in the post disaster period. This research also finds multiple equilibria when we apply asset index based income trajectories in the disaster affected areas. This implies that there is no convergence in income between poor and non-poor in the disaster affected areas. Both parametric and semi-parametric approaches show similar results. On the other hand, single equilibrium convergence in income between high-income and low-income households is found in the unaffected areas. In formulating the asset based index, along with assets (both physical and human assets), 13 coping strategies have been added. This research also shows that after including the coping strategies in the asset based index formulation, multiple equilibria, i.e. divergence in income between rich and poor, still exists. But, the inclusion of coping strategies pushed the lower poverty trap equilibrium to a higher level as these coping strategies compensate for some asset loss. Moreover, the Wald test shows all coping strategies when combined are statistically significant in explaining asset growth although all the coping strategies do not have their significant impact on asset growth in the recovery period.

Livestock is an important asset in the portfolio of assets of rural households of Bangladesh. Therefore, livestock sale is an important strategy for the households that has negative impact on asset growth in the recovery period. After disaster, institutional credit market does not function properly. This also happens in the cyclone affected area of this research. Therefore, households of the affected area depend on the non-institutional loans usually with high interest rate which is highly detrimental to asset accumulation. In order to avoid this burden of non-institutional loan, government can take special measure to provide credit to the poor households in the affected areas. Finally, this research concludes that natural disasters create poverty trap and poor people of the disaster affected areas stand at much lower income level compared to the poor people of the disaster unaffected areas.

Estimation results and findings of this dissertation resemble with few other empirical studies in the poverty trap literature that explicitly consider the role of shocks on asset dynamics and the poverty trap. Adato, Carter, and May (2006) find the evidence for a asset poverty trap when the people of South Africa encounter shocks. Hoddinott (2006) finds that poorer households fell in low level poverty trap as a result of drought. Carter et al. (2007) find evidence of poverty trap as a consequence of hurricanes in Honduras and a drought in Ethiopia. Other empirical studies in the poverty trap literature which focus on exploring the poverty trap situation without any situation of shocks, find different findings. Giesbert and Schindler (2012) find that poor and rich households converge to a single equilibrium i.e. no poverty trap situation. Quisumbing and Baulch (2013) find evidence for a concave dynamic asset frontier but no evidence for poverty trap when well-functioning factor markets exist in rural Bangladesh. However, Adato, Carter, and May (2006) find the evidence for asset poverty trap in case of the poor households as social capital at best help stabilizes livelihoods at low level income.

The findings of this research point to a number of policy implications. Protecting productive assets from the shock is essential to accelerate income in the recovery period. So, the disaster management process which has the aim of protecting assets from the effects of disaster is extremely important to when minimizing descent into the poverty trap in the recovery period. In many places, an early warning system has been introduced to save lives and assets from the effects of disaster. Since the poverty trap in the disaster areas are at a lower level of income compared to the non-disaster stricken areas, governments need to formulate safety net programs to tackle the effects of disaster on poverty. The findings of this research advocate that governments need to incorporate asset accumulation friendly features in the post-shock safety net programmes. Government can take measures so that the households of the affected areas can refrain themselves from livestock sale. In addition, arranging credit for the poor households helps to accelerate asset growth in the recovery period.

5.10 Conclusion

This research finds that poor people are the worst sufferers from natural disasters as they fall into a low-income poverty trap as a consequence of the natural disaster. This research can be improved by removing a number of limitations. It has used the data from the survey conducted in 2013 and collected the asset losses from Cyclone Aila which happened in 2009. That indicates that the data used in this research is recall data on income and asset shock, unfortunately there is no other baseline study which can be used in this research instead of recall data. Local sources in the area surveyed estimated that around 5-10 percent of people have been displaced after the disaster, who have not been covered in the sample. Some of the households remaining in the treatment areas are likely to be there because they had no exit strategy over the sample period. This no exit strategy for the households, specially extreme poor households over the sample period may push the poverty trap to lower income level as the poor households staying in the treatment areas cannot mobilise their income generation after the cyclone. Some specific government programmes other than aid have been implemented by the government targeting the poor people of the affected areas, which have also not been considered in this research. As we know, poverty is a multi-dimensional phenomenon; however, this research is limited to only one dimension, monetary poverty. It has considered a number of assets for the households to determine the asset index, but those assets are mainly tangible assets. This paper does not consider the intangible assets such as financial instruments owned by the households. There may be some pull factors because of the existence of the district headquarters located in the nearby areas that are not considered in this research. There is a chance of unreported income and asset data which may also affect this research. In spite of these limitations, this research has unveiled a new method of calculating an asset based index to test the existence of the poverty trap. In addition, this is the first research where the poverty trap has been tested as an effect of a cyclone in a quasi-experiment setting.

5.11 References

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