FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida

THREE ESSAYS ON MANAGING EXTREME WEATHER EVENTS AND CLIMATIC SHOCKS IN DEVELOPING AND DEVELOPED COUNTRIES

A dissertation submitted in partial fulfillment of

the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

ECONOMICS

by

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2018

To: Dean John F. Stack, Jr.
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This dissertation, written by Md Tanvir Pavel, and entitled Three Essays on Managing Extreme Weather Events and Climatic Shocks in Developing and Developed Countries, is referred to you for judgement.

We have read this dissertation and recommend that it be approved.

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DEDICATION

I dedicate this thesis to my family. Without their patience, understanding, and support the completion of this work would not have been possible.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude and appreciation to my major advisor, Dr. Pallab Mozumder, for his continuous guidance, instruction, and constructive remarks in every aspect in completing my dissertation. Dr. Mozumder's supervision, encouragement and inspiration are instrumental in my academic pursuit. I think I owe a lot to him for enabling my commitment to do economic research in general and to finishing this thesis in particular. I would also like to thank all the members of my committee, Dr. Mahadev Bhat, Dr. Mihaela Pintea, and Dr. Tobias Pfutze, for their insightful comments and continuous support.

Equally I would like to convey my sincere gratitude and indebtedness to all my faculty members and classmates of the Department of Economics at Florida International University. I am grateful to the following staff at the Department of Economics for their generous support during my graduate studies: Mayte Rodriguez, Mariela Delgado, and Lorette Garcia.

ABSTRACT OF THE DISSERTATION

THREE ESSAYS ON MANAGING EXTREME WEATHER EVENTS AND CLIMATIC SHOCKS IN DEVELOPING AND DEVELOPED COUNTRIES

by

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Florida International University, 2018

Miami, Florida

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Climate change and extreme weather events are affecting the environment, and people's livelihood in both developing and developed countries. Agriculture, forestry, fishing, livestock, water resources, human health, terrestrial ecosystems, biodiversity, and coastal zones are among the major sectors impacted by these shocks. The challenge of adaptation is particularly acute in the developing countries, as poverty and resource constraints limit their capacity to act. Bangladesh fits in this category, and thus I use data from Bangladesh to analyze the adaptation process in the first and second chapter of my dissertation.

In the first chapter, I investigate whether transient shocks (flood, cyclone) or permanent shocks (e.g., river erosion that leads to permanent loss of lands) have more influence on interregional migration. Findings of the study suggest that the households prefer to move to the nearest city when the environmental shock is temporary, whereas

they tend to relocate over a greater distance when the environmental shock is more permanent in nature.

In the second chapter, I investigate the feasibility of a set of adaptation measures to cope with hydro-climatic shocks (e.g. floods, drought, cyclones, tidal waves) and epidemic shocks (emergence or re-emergence of infectious diseases on livestock and poultry) in the agricultural sector in Bangladesh. Findings suggest that a decrease in agricultural income due to climatic and/or epidemic shocks is likely to induce households to adapt more.

Developed countries are also vulnerable to extreme weather events and climatic shocks. In 2017, United States was hit by three consecutive hurricanes: Harvey, Irma, and Maria. Given the rising exposure and the increasing need to manage coastal vulnerability, the third essay focusses on understanding household preferences for financing adaptation activities in the U. S. and analyzes which mechanism, i.e., state or federal adaptation fund approach, is better suited to managing exposure to such types of natural disaster in the future.

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INTERNAL MIGRATION TO COPE WITH NATURAL HAZARDS: THE ROLE OF TRANSIENT VERSUS PERMANENT SHOCKS

1.1 Introduction

The frequency and intensity of natural hazards are on the rise all over the world (Few, 2003; IPCC, 2007). It is projected that by 2050, nearly 200 million people will be displaced due to environmental disruptions (Myers, 2002). Disasters triggered by extreme weather events and climatic shocks in the form of floods, cyclones, storm surges, river erosion, tornadoes and earthquakes—among others—significantly affect the well-being, economic and otherwise, of households and communities. Although the intensity and impacts of natural hazards vary regionally, the people of developing countries suffer most due to the lack of adaptation and safety net instruments to fight against negative environmental shocks. Between 2003 and 2013, natural hazards caused US $1.5 trillion in economic damage globally; the estimated economic damage due to environmental hazards in developing countries is about US $550 billion (FAO, 2015).

Bangladesh ranked 6th among countries that suffered most from natural disasters between 1995 and 2014 (Kreft et al., 2015). In Bangladesh, more than 60 million people living in coastal areas are highly vulnerable to climate change and other environmental hazards. Natural disasters such as floods and tropical cyclones are very frequent in the coastal areas of Bangladesh and affect millions of people every year. In recent years, the southern coastal region of Bangladesh was hit by three consecutive cyclones: Sidr in 2007, Nargis in 2008, and Aila in 2009 (Kabir et al., 2016; Mallick, 2014). Cyclones alone have claimed more than 100,000 lives and caused property damage of around US $3.5 billion in the last 25 years (Dasgupta et al., 2010).

Located at the delta of the Ganges, Brahmaputra and Meghna rivers and a few feet above the sea level, Bangladesh has experienced flash, riverine, rainfall-induced and storm surge floods. The inundation of floods affects about 20.5% or 31,000 square kilometers of Bangladesh each year (Mirza, 2003).

The erosion of the coastline and the subsequent loss of arable land is of significant concern for Bangladesh. It is one of the principal contributors to the process of destitution and marginalization of rural families due to the loss of productive agricultural lands (Poncelet et al., 2010). It has been estimated that 60,000 individuals are displaced due to riverbank erosion and about 14,000 hectares of arable land are eroded annually (Mutton & Haque 2004; Mirza et al. 2003). These recurrent natural disasters mostly affect the poorest group of coastal community residents and force them to migrate to urban areas (Ishtiaque and Nazem, 2017).

Internal migration as a shock coping mechanism to natural hazards is significant but less widely addressed in the literature. Early studies have largely ignored the role of environmental reasons for migration (Mallick and Etzold, 2015). Only a few recent studies have discussed migration as an alternative strategy to cope with the adverse effects of natural disasters (Afsar 2000; Blaike et al., 2014; Laczko and Aghazarm, 2009; Poncelet et al., 2010). However, there is insufficient empirical evidence of internal migration resulting from environmental change or variability (Black, et al.,2008). With a few exceptions, Chen and Mueller (2018) conduct an empirical study to assess whether households in coastal Bangladesh have at least one internal migrant or international migrant due to flooding and salinity. They found no significant effect of flooding on internal or international migration but a strong positive effect of salinity on internal migration and a negative effect of salinity on international migration. In another study, Chen et al. (2017) found that the probability of at least one member in a household being a migrant decline by 0.6 to 1.8 percentage points during flooding.

This study analyzes internal migration as a shock coping mechanism for natural disasters in the south west coastal regions of Bangladesh. Depending on the nature and duration of the environmental shock, I explore whether transient shocks (floods, cyclones) or permanent shocks (river erosion that leads to permanent loss of lands) have more influence on interregional migration decisions. I also address whether transient or permanent shocks influence households more to migrate to the nearest metropolitan city (Khulna) or to the distant capital city (Dhaka). The study also examines the impact of migration on the per capita food expenditure, non-food expenditure, and total expenditure of households who moved to Dhaka versus Khulna. This finding has significant implications for understanding whether migration is an effective coping mechanism or not.

1.2 Drivers of Internal Migration in Coastal Areas of Bangladesh

Migration has very complex factors of determination, which can be economic, social, political, demographic or environmental (Black et al., 2011; Black et al., 2013; Bunea, 2012). The process of migration can be internal or international, slow or rapid, forced or motivated, or temporary or permanent (Mallick and Vogt 2012; Portes, 2010). In Bangladesh, migration flows are mostly internal movements from rural to urban areas (Poncelet et al., 2010). The most common concept addressed in the fields of rural to urban migration is the push and pull factors. While the reason behind the pull factors of migration is the attraction of better living and economic conditions, push or forced migration mostly occurs due to the desire for survival (Barrios et al., 2006). Though it is commonly believed that economic pull factors have dominance over social or demographic factors of internal migration, environmental push factors also exert a direct and indirect influence on the internal migration decision. However, the concepts of push and pull factors of migration are not adequate to understand the complexity and multicausality of households' decisions to migrate. Therefore, we investigate the internal migration scenario of the coastal areas of Bangladesh through the diverse determinants of natural disaster factors (floods, cyclones, river erosion), households' social and demographic factors (household size, age, gender, education, religion), economic factors (income, assets, home ownership, land) and coping mechanisms (credit, relief), among others.

The uniqueness of this paper is to figure out whether internal migration is a valid coping mechanism for transient and permanent environmental shocks in the coastal communities in Bangladesh. We not only explain how these factors influence households to migrate, but empirically assess the households' preference on where to migrate and the changes in consumption expenditures by migrating to the nearest versus distant locations.

1.3 The Role of Transient and Permanent Shocks on Internal Migration Decision

Households in developing countries face two general categories of shocks: covariate and idiosyncratic (Patnaik et al., 2016). While idiosyncratic shock is likely to affect a household or individual, covariate shock affects groups of households, communities, regions or even entire countries. Thus, a household that experiences an idiosyncratic shock is more likely to rely on its neighbors for support, while a household who experiences a covariate shock is less likely to do so because its neighbors have experienced the same shock. Based on these distinctions, environmental shocks are mostly covariate shocks in nature. It can also be inferred that the impacts of covariate shocks are stronger than the idiosyncratic shocks as it affects the entire households of the same community.

The coastal zone of Bangladesh, which makes up approximately 30% of the total area of the country, is particularly vulnerable to natural disasters. Its topographic and geo-physical location makes it prone to periodic floods, cyclones and river bank erosion. Depending on the nature and consequences of these natural disasters, we classify the covariate environmental shocks into two categories: transient and permanent.

1.3.1 Transient Shocks

Transient environmental shocks can be defined as the unexpected exogenous changes to a community. Depending on the frequency, duration and intensity, floods and cyclones are the most common transient shocks in the coastal areas of Bangladesh.

Bangladesh is one of the most flood-prone countries in the world due to its unique geographical location, topography and exposure to monsoon rainfall. In the last 30 years, Bangladesh has experienced severe floods during 1987-1988, 1998-1999, 2004-2005, 2007, 2010 and 2017. With 50% of the land less than 8 meters above sea level, and a coastline of some 600 km, coastal flooding is an alarming problem for Bangladesh. This creates significant hardship for the people of coastal communities and results in short-term and long-term population displacements.

Cyclone that are usually accompanied by high winds and storm-surges hit Bangladesh every three years on average (Mallick and Etzold, 2015). The coastal areas of Bangladesh have witnessed several cyclones in the last 50 years. Among them, Bhola in 1970, Gorky in 1991, Sidr in 2007, Aila in 2009, and Komen in 2015 are the deadliest cyclones on record. Cyclones that destroy the homesteads and livelihoods of millions of people in the coastal areas of Bangladesh trigger migration internally. Studies have found that the victims of cyclone move away because of a lack of resources, infrastructural damages and failure to ensure social protection, as well as the non-availability of income-generating alternatives (Mallick et al., 2017).

1.3.2 Permanent Shock

While sudden onset events such as floods and cyclones cause the affected households to leave their homes temporarily, slow onset processes—such riverbank erosion—lead households to move permanently. People living in the south west coastal belt are particularly exposed to permanent natural hazards like river erosion and find migration to be an alternative coping strategy to natural hazards.

River erosion is one of the major threats to households living in the coastal and mainland areas in Bangladesh. There are several factors that can gradually affect river erosion. Among these, the breaking of soil in smaller or larger portions, the saturation of river banks from off-stream sources, excessive sand and intense water from rainfall are worth mentioning. Depending on the duration, intensity and magnitude of river erosion, households in the coastal communities tend to predict how devastating this environmental disaster is. The victims of river bank erosion are mostly compelled to displace as they become destitute and vulnerable.

Three major rivers in Bangladesh (Padma, Jamuna, and Meghna) have eroded several thousand hectares of floodplain and several miles of roads and railways, and have displaced people from one region to another region of Bangladesh (Das et al., 2014). This has a long-term impact on the livelihood of the people, society and the economy. However, due to the slow process and scattered incidences, this does not draw the attention of policy makers in the same way victims of flood and cyclones do. For instance, the victims of river erosion receive less support from both the local and central government in the form of credit, relief or any other financial support to fight against this silent catastrophe. As a result, the victims of river erosion leave their area on their own initiative and search for a place to survive socially and economically.

1.4 Survey Design and Sampling Procedure

1.4.1 Study Area

The area of Bangladesh is divided into eight administrative divisions. Among them, Khulna, Barisal and Chittagong are three administrative divisions that are in the coastal zone of Bangladesh. Each division is split into several districts and the number of total districts in Bangladesh is 64. The coastal area of Bangladesh covers 19 districts facing or near the Bay of Bengal (Dasgupta et al., 2014). This study covers the internal migration scenario of households from nine south west districts of two coastal divisions (Khulna and Barisal) in Bangladesh. The survey also tracks the households who migrate to the metropolitan city Khulna of Khulna district and the capital city Dhaka of Dhaka District in Bangladesh. The geo-coded location of the households in the survey area and their migration scenario is shown in Figure 1.1.

The survey was conducted in the year 2015 on 2035 households of south west coastal regions of Bangladesh. We excluded 19 households from our analysis as the people residing in those households migrated overseas. Out of 2016 households, 95% are from two south west divisions (Khulna and Barisal) of Bangladesh. In the Khulna division, I collected the data from three coastal districts (Bagerhat, Khulna, and Satkhira)—information from 1298 households. In the Barisal division, I collected data from six coastal districts (Bhola, Patuakhli, Barguna, Barisal, Perojpur, Jhalokathi), which consist of 636 households. Information from the remaining 98 households was collected from randomly selected source districts in Bangladesh. The proportion of respondents from source districts is shown in Table 1.1.

1.4.2 Survey Methods, Sample Selection, and Data Description

On behalf of the researchers of Florida International University (FIU), a face to face household survey on coastal vulnerability and livelihood security was conducted by the Evaluation and Consulting Services (ECONS) Limited in Bangladesh. The focus of the survey is to identify the link between environmental shocks (transient vs. permanent) and the households' migration scenario (migrate to nearest vs. distant locations). For this, I seek information through the questionnaire of multiple sections in the survey that includes—but is not limited to—the internal migration scenario, list of environmental shocks faced by the households, households' socio-demographic condition, education status of the households' head, ownership of housing, land ownership, value of households' assets, credit, relief and other economic activities of the households. Table 1.2 summarizes the key responses of the households on the above-mentioned sections in the survey.

The survey reveals that about 60% of household heads have migrated from one location to another. Among them, more than 23% of household heads moved to the nearest metropolitan city, Khulna of Khulna district; 19% of the household heads migrated to the capital city, Dhaka of Dhaka district; and more than 17% of the household heads migrated to 35 different destination locations in Bangladesh (see Table 1.3). These internal migrants are mostly permanent or long-term migrants who do not indicate an intention of returning to their location of origin.

Regarding transient and permanent natural disasters, the majority of the households (about 19%) have experienced permanent environmental shocks—river erosion—compared to transient environmental shocks like floods (about 4%) and cyclones (about 13%). The south west coastal region is the most vulnerable to the effects of a rise in sea level. A rise in sea-level is another possible cause of river erosion in the coastal region of Bangladesh (Brammer, 2014). In our sample, the majority of the households in the Bhola district are affected by riverbank erosion. Respondents from the Barguna and Khulna districts of Khulna division have experienced significant threats from cyclones Sidr and Aila respectively.

In the demographic section, I track the geo-coded location of the households, gather information on household size, the head of the household's age, gender, religion and marital status, availability of electricity in the residence, and cell phone ownership among others. The average household size found in our sample is 5.05, which is more than the national average household size (4.35) of the country.[1] The average age of the household head was reported as 46 years, and most household heads have some sort of primary education (four years on average). Most of the respondents are male (93%), Muslim (82%) and married (98%). About 78% of the households have electricity and 90% of the household heads have a personal phone.

To get a clear picture of the economic condition of the households, I have collected data on earnings, assets, land and financial support, such as credit and relief, among others. The average annual income of the surveyed households is about BDT 30,000 ($US 375). Households have only about 0.030 hectares of land (on average) and about 81% have their own house made of hay, bamboo, mud and tally. In addition, 91% of the households have borrowed credit from both formal and informal sources, and about 50% of the households have received some sort of relief during natural disasters.

1.5 Empirical Framework

To estimate the effects of natural disasters on internal mobility, we examine the following two interrelated research questions in our study. First, which disaster shocks (transient versus permanent) have a stronger influence on internal migration? Second, do the determinants of internal migration differ across destination?

We employ a discrete choice logit model to estimate the factors affecting internal migration decisions.

[1] See Bangladesh Population and Housing Census 2011. This can be publicly accessed at http://catalog.ihsn.org/index.php/catalog/4376

$$\ln L = \ln \left(\frac{P}{1-P}\right) = \ln P\,(M_i) = \alpha + \beta X_i + \varepsilon_i$$

where $M_i = 1$ if the head of the household migrates to a different location and 0 if there is no migration. X_i is the vector of explanatory variables, β is the parameter to be estimated and ε_i is the error term. We extend the above equation by including the district fixed effects and estimate the logistic model directly as:

$$M_i = \alpha + \beta E + \theta H + \delta W + \Phi C + \gamma_j + \varepsilon_i$$

where E is the exposure to the natural disaster factors that include both transient shock (flood, cyclone) and permanent shock (river erosion). H is the index of household characteristics that include the size of the households, and the gender, age, marital status, religion and education of the household head. We also asked household heads whether they had a personal phone and electricity in their residence. The income and wealth components are represented by the W index. This includes the income of the household's head, amount of land owned by the household, purchase value of all assets except land, and ownership of the house. As a coping instrument for natural hazards, we include the amount of credit and relief received by the household. We used the district fixed effects (γ_j) to catch spatial heterogeneity. This will allow for unobservable characteristics of the location of origin that are correlated with the explanatory variables and influence the decision to migrate.

While the first research question focuses on the factors affecting internal migration decisions, the second is to see the existence of regional differences in the decision of migration. The choice of a place for migration depends on several factors, including socio-economic and demographic condition of the households, and the nature of environmental shocks faced by the households in the source location, among others. The contact and personal preference of the migrant (Mishra, 2016) and amenities (Von Reichert and Rudzitis, 1992) can also influence households to move to a specific location.

Our multinomial logit model for migration choices is motivated by the framework of the random utility model (see Davies et al., 2001). The head of the household at location i faces j choices, including moving to a different location (migration) or staying at the current location (no migration). The standard utility model of choosing location j is

$$U_{ij} = \beta' X_{ij} + \upsilon_{ij}$$

where U_{ij} is the perceived utilities of migration to location j, X_{ij} is the vector of explanatory variables, β' is the parameter to be estimated and υ_{ij} is the error term. If the household's head chooses location j, then the utility U_{ij} is the highest among all j choices (i.e., $U_{ij} > U_{ik}$ $\forall$ $k \neq j$). Thus, when choice j is made, the statistical model for the probability of moving from location i to location j is

$$P\,(M_{ij} = 1) = P\,(U_{ij} > U_{ik})\ \forall\ k \neq j$$

If we have a total of n destination location choices, the corresponding log likelihood function for multinomial logit model can be represented as

$$\ln L = \sum_{j=1}^{n} N_{ij} \ln P\,(M_{ij}) = \alpha + \beta X_{ij} + \upsilon_{ij}$$

where n is the number of destination location and N_{ij} is the number of household heads moving from location i to location j. In this framework, if the head of the household does not move, they choose to remain in the current location (where j=i for no migration). This is an important aspect of our multinomial logit model as it allows us to estimate the unobserved differences between moving and staying.

1.6 Estimation Results and Discussion

1.6.1 Discrete Choice Logit Model

We used the discrete choice logit model to identify the link between nature of environmental shock and internal migration. Table 1.4 represents the results from the estimated logit model that explains the marginal effects of diversified factors on internal migration decision. It is possible that some of the unobservable characteristics are correlated with the explanatory variables, leading to the problem of endogeneity (Davies et al., 2001). To solve this issue, we used the district (source location) fixed effects at household level. The graphical representation of the average marginal effects of the significant variables (with and without district fixed effects) are presented in Figure 1.2 and Figure 1.3 respectively.

The results reveal that the permanent shock (river erosion) is the key driver of internal mobility. It is a situation in which households observe a continuously deteriorating environment that leads them to move in order to avoid further deterioration of their livelihoods. In other words, the victims of river erosion are forced to migrate as they become destitute (Das et al., 2014). The impact of transitory shock as a determinant of migration is mixed. It is positively significant for flood and insignificant for cyclone. The estimated effects of flood contradict the findings of Chen et al. (2017), who showed a modest negative effect of flooding on internal displacement but supports the findings of Gray and Mueller (2012), who showed that flood has modest effects on internal mobility in Bangladesh, especially for the women and the poor.

Henry et al. (2003) claimed that environmental change is not the only cause of internal displacement. Rather, demographic and socio-economic characteristics are associated with the migratory movements. The size of the household may have an ambiguous effect on internal migration decision. In one sense, larger households might be able to diversify their income by sending one of their members to a different location (Li et al., 2014). On the other hand, the larger the family size, the more difficult it would be to migrate due to the associated cost of migration. This can be a possible explanation for the significant negative coefficient of household size in our study. The estimated marginal effects of males on internal migration is found significantly positive. A possible explanation in support of this result is that the social norms and attitudes in our society towards males gives them more freedom to take the decision of migration positively. Age is found negatively significant for migratory movements. A standard explanation for the negative age effect is that in a finite work life, workers with higher ages are not as motivated as workers of younger ages since they have less time to accumulate more income (Kennan and Walker, 2011). Married households have higher intention to migrate due to increased financial need for the family. Religion (Muslim) is found significant in the absence of district fixed effects and insignificant in the district fixed effects model. It is expected that if the household members have education, they will have more opportunity to seek a livelihood in a new place (Sandefur and Scott, 1981; De Jong, 2000). On the contrary, Marshall and Rahman (2013) found no evidence of education playing any role in motivating households' migratory movements. In our study, we have not found any significant association between the number of years of education of the household head and their decision to migrate. Cell phone ownership, which can be considered as a proxy for social network and communication, is found to be a positively significant factor for migration in the first model but insignificant for the district fixed effects model. Households who have electricity in their residence have more scope to obtain news and information about the disaster condition of the locality and about work opportunities in the other location. This can induce them to take the migration decision positively, and we found this factor has positive significance in the district fixed effects model.

The income and wealth components are complex predictors of migration. For instance, households who have higher annual income and wealth would have higher financial capability to migrate. On the other hand, households who have their own land and house in the locality may not feel encouraged to leave their belongings and to migrate to a new location. In our study, we found annual income of the households to be a significant positive factor for migration, whereas assets is a significant negative factor for migration. Ownership of land and house turned out to be insignificant.

1.6.2 Multinomial Logit Model

The multinomial logit model allows all explanatory variables to interact with all destination choices. For the simplicity of our analysis, we classify the destination choices n=j=4; where j=i indicates the households' preference to stay in the same location. Therefore, considering staying in the same location (no migration) as a base category, we can compare households' preference to move to the nearest metropolitan city (Khulna), distant capital city (Dhaka) and all other cities within the coastal divisions (others). The estimation results of marginal effects from multinomial logit model are presented in Table 1.5. In addition, the graphical representation of average marginal effects on migration to each destination are shown in Figure 1.4 – 1.7.

It is observed that the permanent shock (river erosion) is the key factor of internal migration. This variable turned out to be significant for all destination locations. Thus, if there is a permanent loss of land due to river erosion, households tend to migrate irrespective of their location choices. It is also evident from the study that those who are affected by temporary shock (flood) are ready to move to the nearest metropolitan city (Khulna) and nearest coastal cities (others) compared to the distant capital city (Dhaka). Like the estimation results of the discrete choice logit model, we have found no significant connection between cyclone and migration to different locations. Thus, the key findings of the multinomial logit model are that the households prefer to move into the nearest cities when there is a temporary natural disaster (flood), whereas they tend to relocate any distance when the environmental shock is more permanent in nature.

The estimation results of the multinomial logit model are very similar to the discrete choice logit model. However, the most interesting part of the results is that the explanatory factors towards the nearest metropolitan city (Khulna) are more significant than the distant capital city (Dhaka). For instance, household heads who are male and married are ready to move into the nearest metropolitan city as the coefficients of these two variables are positively significant for Khulna and insignificant for Dhaka. Amount of land is only significant negatively for Khulna. This indicates that the households who have more land are reluctant to leave their location due to the insecurity of permanent loss of lands. Two other explanatory factors (credit, relief) that are considered as coping instrument to natural disaster are only found significant for the location choice of Khulna. This means credit eases the migratory movements of the households to the nearest location, and relief after natural disaster helps households to stay in the same location.

1.7 Impacts of Migration on Per Capita Consumption Expenditures

Although the process of migration has been extensively discussed in the literature of economics, only a few studies have addressed the question of whether migration leads to improvements in households’ well-being (Beegle et al., 2011). The standard economic theories suggest that households participate in migration to improve their livelihood

(Lipton 1980; De Haan 1999; De Brauw et al., 2013). In this section of our study, we not only oversee the outcomes of migration but also extend our analysis to measure the impacts of migration on the consumption expenditures of households who moved to the nearest metropolitan city versus a distant capital city. To figure out the overall changes in consumption expenditure of the migrants; we consider per capita consumption expenditure on food items, non-food items, and the sum of food and non-food items (total consumption expenditure). We computed the per capita food expenditure of the households by asking about the quantity of certain items (rice, food crops, wheat, lentils, edible oil, vegetables, poultry items, dairy items, salt, sugar, dry food, beverages, among others) that they have consumed in last seven days. The value of all the food consumed in the last seven days is measured and scaled up to one month. We asked households to recall the non-food expenditures (non-edible fuel, house rent, transportation cost, educational expenses, household personal toiletries and other expenses, expenditure on cloth and shoes, utensils, medical expenses, among others) of the last month; this includes all cash expenditures on everything except food items. We calculate the per capita total expenditure of one month by adding the monthly food and non-food expenditure. The monthly expenditure of migrants and non-migrants (stayers) is presented in Table 1.6. This shows that the average per capita consumption of food and non-food items is about 7% higher for migrants than non-migrants. The kernel density of the logarithm of monthly food expenditure, non-food expenditure and total expenditure of migrants and non-migrants are shown in Figure 1.7 –

1.9 respectively. This is a useful non-parametric technique for visualizing the underlying distribution of consumption expenditure on food, non-food and the sum of food and non-food items. As measured, the kernel density of the logarithm of consumption for migrants is shifted to the right relative to those who do not migrate. This supports that the per capita consumption for food, non-food, sum of food and non-food (total consumption) are higher at the average among the migrants. It is also observed that the variations of consumption expenditure for non-food items are more than the food items.

We distinguished the impacts of migration on the changes in consumption expenditures through destination locations. This is an important aspect of our study which will allow us to identify whether moving to the nearest metropolitan city or distant capital city is an effective strategy to cope with transient and/or permanent environmental shock. The histogram and the kernel density of the logarithm of monthly food and non-food expenditure of migrants in different locations are presented in Figure 1.10 and 1.11 respectively. This shows that the households who migrate to Dhaka have higher food consumption expenditure than those who migrate to Khulna and other cities. However, this does not ensure that migrating to the capital city provides households more purchasing power than migrating to other locations. One possible explanation for food expenditure being higher in Dhaka compared to Khulna is the differentials of price in the food items between capital city and metropolitan city. On the other hand, those who migrate to Khulna and other cities have higher non-food consumption expenditures than Dhaka. To understand this, we closely observed the geo-coded location of the households' migration to Dhaka and Khulna (see Figure 1). It is observed that those who migrate to Dhaka are mostly settled (clustered) in the slum areas where living standards are miserable compared to those who migrate to different areas of Khulna.

We used kernel density plot to compare the densities of monthly food expenditure and non-food expenditure of migrants (in logarithms) in different locations (Dhaka, Khulna, and Other cities). The kernel plot of monthly food expenditure produces a smooth curve showing little variation in consumption among migrants in different locations, whereas the distribution is distinctly skewed for monthly non-food expenditure of migrants in Dhaka.

1.7.1 Empirical Assessment

To empirically assess the impacts of migrating to the nearest metropolitan city versus distant capital city, we analyze the consumption outcomes of the households who moved to Khulna and Dhaka. We specify the following empirical model in this regard.

$$\Delta \ln C_i = \alpha + \delta \Delta \ln Y_i + \beta E_i + \theta L_j + \Phi X_i + \varepsilon_i$$

where $\Delta \ln Ci$ is the households' ratio of monthly consumption expenditure between after and before migration. We run the above empirical specification for three outcome variables (monthly consumption expenditure on food items, monthly consumption expenditure of non-food items and total consumption expenditure of both food and non-food items). In the explanatory variables, $\Delta \ln Yi$ is the households' ratio of monthly income between after and before migration. We hypothesize that if the households have a higher income after migration, this will lead them to consume more. Households' experience of natural disasters (E) are classified into two categories: transient (flood, cyclone) and permanent (river erosion) shocks. This factor will help us identify whether households who have migrated due to transitory or permanent shocks are better able to increase their consumption or not. The key explanatory variable of this specification is the migrants from different locations (L_j). We wanted to explore whether the migrants of the capital city or metropolitan city are better able to cope with the disaster shock by improving their consumption. Considering other cities as the base category, we compare whether households are benefitted by migrating to Khulna or Dhaka. All other socio-economic and demographic factors are considered in the vector X_i. The estimation results are shown in the first 3 columns of Table 1.7.

We found a significant positive association of the change in income with the change in consumption expenditure for both food and non-food items. More precisely, the increase in income after migration leads the households to increase their consumption after migration. It is also evident that those who migrated due to the transitory and permanent shocks are better able to increase their consumption. The coefficients for the migrants of the nearest metropolitan city (Khulna) are positively significant with increase in consumption, whereas the coefficient for the migrants of the capital city (Dhaka) are found insignificant. This is the most important and significant finding of our study, which indicates that the households that migrate to Khulna are better able to cope with the environmental shocks by increasing their consumption compared to the households who migrate to Dhaka and other cities. It is also observed that the households that are larger in number and who have higher levels of education are more able to increase their consumption of food and non-food items. Being male is found negatively significant in all the models. One of the key reasons behind this is that the female migrants in our survey are mostly involved in the ready-made garments industry of Dhaka, and receive higher pay than the males, who are mostly involved in the informal sectors of the economy. Age has significant and positive associations with the increase in consumption in all the three models. Migrants who have more assets are significantly better able to increase their consumption. However, both the coefficients for relief and credit are found negatively significant with the increase in consumption. This could imply that those who have relief are relatively more reluctant to earn money and those who have obtained credit have the burden of re-payment that dissuades them from increasing their consumption.

As a robustness check, we used the interaction term of the migrants of Dhaka and Khulna with the shocks that motivate them to migrate. This indicates that those who migrate due to the permanent environmental shocks (river erosion) to the nearest metropolitan city (Khulna) can increase their livelihood by increasing food and non-food consumption. All the other interactions in the model are found insignificant. This is shown in the last 3 columns of Table 1.7. The findings of the other coefficient in the interaction term model are very similar to the model without interaction. We do not observe significant variation in terms of impacts by using the interaction terms compared to our base specification estimations.

1.8 Conclusion

This study has explored the nexus of environmental disasters and internal migration in south west coastal households in Bangladesh. Controlling for socio-economic and demographic factors, we found that households migrate due to transient and permanent environmental shocks. However, the influence of internal migration is much stronger for permanent shocks (river erosion) compared to transient shocks (flood, cyclone). It can also be inferred that if institutional and government support were provided to the households of vulnerable communities, some of the migration could have been avoided. The negative association of relief and migration to Khulna is an indication of that. However, this might reduce the migration caused by transient shock, but not the migration caused by permanent environmental shock.

We extend our analysis to identify households' specific reason for migrating to the nearest metropolitan city (Khulna) as opposed to the capital city (Dhaka). The findings of our study suggest that the households prefer to move into the nearest metropolitan city when the environmental shock is temporary, whereas they tend to relocate over any distance when the environmental shock is more permanent in nature. Thus, permanent environmental shock—such as river erosion—is more hazardous than any other environmental shock as it can take all means of survival gradually.

The final question that we examine in our study concerns the impact of migration on the consumption expenditures of households who moved to the nearest metropolitan city versus a distant capital city. With some caveats, we observed that migration is an effective coping mechanism only if the households migrate to the nearest metropolitan city to survive permanent environmental shocks. This finding has significant implications for understanding why Dhaka is not suitable for migrants. Although most internal migratory movements in Bangladesh are towards Dhaka city, the megacity's urban infrastructure and opportunities of work in the formal sector are unable to absorb this huge population influx. That is why those households who migrate to Dhaka live in slums and squats and have miserable socio-economic conditions. Thus, we suggest policymakers and the central government pay close attention to environmentally induced migrants and create greater work opportunities and amenities for them.

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TABLES

Table 1.1 Distribution of Survey Respondents (in %) Across the Districts of Origin

Name of the District	Frequency	Percentage
Bagerhat	558	27.68
Khulna	402	19.94
Satkhira	322	15.97
Bhola	243	12.05
Patuakhali	125	6.20
Barguna	124	6.15
Barisal	63	3.13
Perojpur	56	2.78
Jhalokathi	25	1.24
Others	98	4.86
Total	2016	100.00

Table 1.2 Summary Statistics of Survey Responses and the Variables of Interest

Variable	Definition	Mean	Standard Deviation
Internal migration	If the head of the household has migrated to a different location (1 = yes, 0 = otherwise)	0.598	0.490
flood	If the household has experienced flood in his locality in the last 10 years (1 = yes, 0 = otherwise)	0.042	0.201
cyclone	If the household has experienced cyclone in his locality in the last 10 years (1 = yes, 0 = otherwise)	0.128	0.334
river erosion	If the household has experienced river erosion in his locality in the last 10 years (1 = yes, 0 = otherwise)	0.192	0.394
hhsize	Number of household members	5.058	2.427
male	If the household head is male (1 = yes, 0 = otherwise)	0.932	0.251
age	Age of the household head (in years)	46.43	13.79
married	If the hh head is married (1 = yes, 0 = otherwise)	0.985	0.121
muslim	If the religion of the household's head is muslim (1 = yes, 0 = otherwise)	0.826	0.379
education	Number of years of schooling of household's head	4.352	4.178
cell phone	If the household's head has a personal phone (1 =yes, 0 = otherwise)	0.900	0.299
electricity	If the households has electricity in their home (1 = yes, 0 = otherwise)	0.778	0.415
Income	Household's annual income group (1= no income, 2 = > 0 but < 10000,……..….12 = ≥ 100000)	4.111	3.297
Land	Amount of land owned by the household (in hectares)	0.030	0.048
House	If household owned the house (1= yes, 0 = otherwise)	0.810	0.392
Assets	Market value of households all assets except land (in logarithms)	10.24	1.036
Credit	If the household has received credit from formal or informal sources (1= yes, 0 = otherwise)	0.907	0.289
relief	If the household has received relief after disaster (1= yes, 0 = otherwise)	0.501	0.500

Notes: Monetary Units are measured in domestic currency (Taka) where $US 1 = 83.19 Taka

Table 1.3 Internal Migration Scenarios and Place of Destinations

Migration Scenario	Frequency	Percentage
Migrate to Dhaka	381	18.90
Migrate to Khulna	472	23.41
Migrate to Other Location	353	17.51
Do Not Migrate	810	40.18
Total	2016	100.00

Table 1.4 Marginal Effects from Estimated Logit Model

	Dependent Variable	
	(1)	(2)
	Internal Migration	Internal Migration
	District Fixed Effects: No	District Fixed Effects: Yes
flood	1.143 (0.605)**	1.156 (0.657)*
cyclone	0.262 (0.283)	0.475 (0.305)
river erosion	1.758 (0.319)***	1.925 (0.365)***
household size	-0.221 (0.071)***	-0.279 (0.076)***
male	2.283 (1.127)**	2.373 (1.063)**
age	-0.022 (0.007)***	-0.024 (0.007)***
married	2.627 (1.441)**	2.590 (1.551)*
muslim	0.518 (0.264)**	0.424 (0.271)
education	-0.002 (0.023)	-0.018 (0.024)
cell phone	0.566 (0.334)*	0.501 (0.352)
electricity	0.224 (0.262)	0.597 (0.271)**
income	0.977 (0.091)***	0.953 (0.090)***
land	-0.017 (0.011)	-0.011 (0.011)
house	-0.292 (0.283)	-0.206 (0.298)
assets	-0.286 (0.110)**	-0.245 (0.120)**
credit	0.671 (0.524)	0.609 (0.564)
relief	-0.468 (0.246)**	-0.381 (0.266)
constant	-3.865 (2.265)*	-4.758 (2.168)***
observations	1259	1259
Pseudo R^2	0.62	0.64

Note: Numbers in parentheses are the corresponding standard errors; *** Significant at 1% levels, ** Significant at 5% levels, * Significant at 10% levels.

Table 1.5 Marginal Effects from Multinomial Logit Model

	Dependent Variable		
	Migrate to Dhaka	Migrate to Khulna	Migrate to Other Cities
flood	0.955 (0.664)	2.045 (0.790)***	1.252 (0.708)*
cyclone	-0.454 (0.504)	-0.368 (0.477)	0.362 (0.334)
river erosion	1.783 (0.609)***	1.820 (0.460)***	1.468 (0.485)***
household size	-0.056 (0.085)	-0.249 (0.070)***	-0.248 (0.071)***
male	0.771 (0.989)	2.939 (1.199)***	2.913 (1.214)**
age	-0.021 (0.012)*	-0.018 (0.008)**	-0.024 (0.009)***
married	1.505 (1.180)	3.566 (1.349)***	2.020 (1.053)**
muslim	0.821 (0.412)**	0.913 (0.309)***	0.191 (0.295)
education	0.035 (0.041)	0.023 (0.029)	-0.043 (0.031)
cell phone	0.975 (0.587)*	0.710 (0.383)**	0.389 (0.375)
electricity	0.265 (0.364)	0.404 (0.283)	-0.045 (0.290)
income	1.056 (0.068)***	0.909 (0.573)***	1.011 (0.058)***
land	0.009 (0.012)	-0.044 (0.014)***	-0.008 (0.010)
house	-0.793 (0.570)	-0.428 (0.419)	0.521 (0.503)
assets	-0.557 (0.183)***	-0.276 (0.132)*	-0.263 (0.131)*
credit	1.022 (0.700)	1.359 (0.563)***	0.184 (0.466)
relief	0.095 (0.348)	-0.840 (0.268)***	-0.043 (0.282)
constant	-3.241 (2.335)	-7.172 (2.244)***	-5.053 (2.024)**
observations	1259	1259	1259
Psedu R^2	0.4043	0.4043	0.4043

Note: Numbers in parentheses are the corresponding standard errors; *** Significant at 1% levels, ** Significant at 5% levels, * Significant at 10% levels.

Table 1.6 Migrants and Non-Migrants Per Capita Consumption Expenditure (in Taka)

Items	Mean		Standard Deviation	
	Migrants	Non-Migrants	Migrants	Non-Migrants
Food	4139.93	3858.18	2027.52	2152.67
Non-Food	14804.67	13837.80	17073.20	24586.41
Total	18944.60	17695.98	17576.11	25322.26

Note: All monetary units are measured in domestic currency (Taka) where $ 1 US = 83.19 Taka.

Table 1.7 Impacts of Migration on Change in Per Capita Consumption ($\Delta\ln C_i$)

	Food	Non-Food	Total	Food	Non-Food	Total
Δln Yi	0.492***	0.422***	0.435***	0.483***	0.415***	0.428***
	(0.048)	(0.054)	(0.052)	(0.050)	(0.055)	(0.053)
transient shock	0.356***	0.279***	0.293***	0.374***	0.330***	0.216**
	(0.084)	(0.083)	(0.079)	(0.101)	(0.097)	(0.099)
permanent shock	0.552***	0.520***	0.528***	0.548**	0.285***	0.570**
	(0.126)	(0.112)	(0.111)	(0.269)	(0.075)	(0.283)
migrate to Dhaka	0.032	-0.072	-0.045	0.059	-0.084	-0.045
	(0.132)	(0.129)	(0.127)	(0.165)	(0.162)	(0.160)
migrate to Khulna	0.370***	0.236***	0.163***	0.294***	0.138*	0.160**
	(0.070)	(0.067)	(0.025)	(0.078)	(0.076)	(0.074)
Dhaka*transient shock				-0.354	0.101	-0.004
				(0.266)	(0.276)	(0.261)
Dhaka*permanent shock				0.562	0.215	0.267
				(0.398)	(0.313)	(0.326)
Khulna*transient shock				0.056	0.230	0.188
				(0.195)	(0.190)	(0.184)
Khulna*permanent shock				0.988***	0.929***	0.932***
				(0.290)	(0.199)	(0.207)
household size	0.103***	0.052**	0.252***	0.106***	0.056**	0.066***
	(0.024)	(0.026)	(0.065)	(0.023)	(0.025)	(0.024)
male	-0.971***	-1.229**	-1.185***	-0.962**	-1.217***	-1.173***
	(0.393)	(0.306)	(0.308)	(0.393)	(0.308)	(0.438)
age	0.008***	0.013***	0.012***	0.007**	0.012***	0.011
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
education	0.027***	0.027***	0.027***	0.027***	0.026***	0.027***
	(0.008)	(0.008)	(0.007)	(0.008)	(0.008)	(0.007)
assets	0.084**	0.104***	0.102***	0.076*	0.094**	0.093**
	(0.044)	(0.042)	(0.041)	(0.044)	(0.043)	(0.042)
credit	-0.247*	-0.285**	-0.282**	-0.243*	-0.287**	-0.284**
	(0.131)	(0.136)	(0.128)	(0.131)	(0.137)	(0.128)
relief	-0.263***	-0.312***	-0.303***	-0.224***	-0.266***	-0.259***
	(0.075)	(0.076)	(0.073)	(0.078)	(0.079)	(0.077)
constant	-1.149**	0.428	0.628	-1.042**	0.566	0.761
	(0.593)	(0.536)	(0.529)	(0.596)	(0.541)	(0.534)
R^2	0.417	0.381	0.402	0.431	0.395	0.415

Note: (1) Number of observation is 636. (2) We consider flood or cyclone as transient shocks and river erosion as permanent shocks (3) Numbers in parentheses are the corresponding standard errors; *** Significant at 1% levels, ** Significant at 5% levels, * Significant at 10% levels.

FIGURES

Figure 1.1 Geo-Coded Household Location of Internal Migration

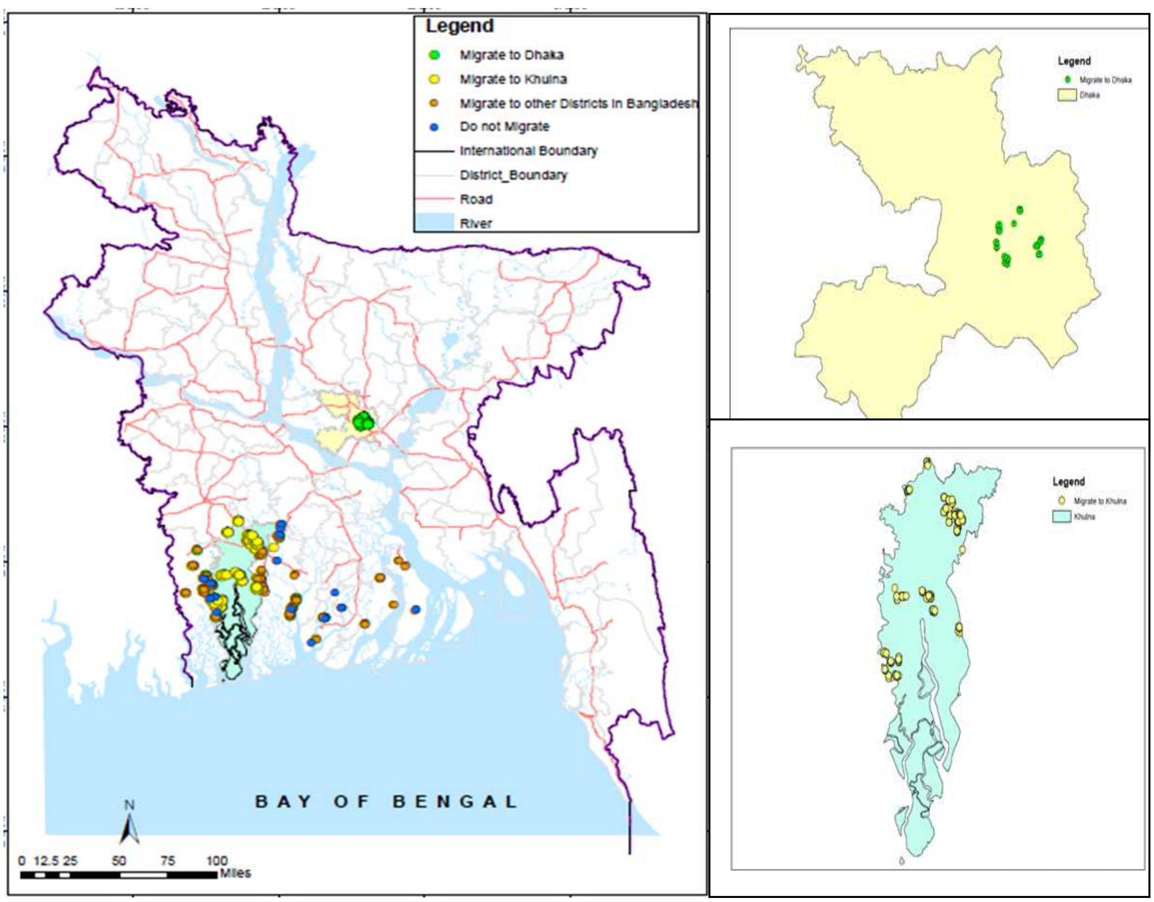


Figure 1.2 Average Marginal Effects of Significant Variables on Internal Migration (without District Fixed Effects)

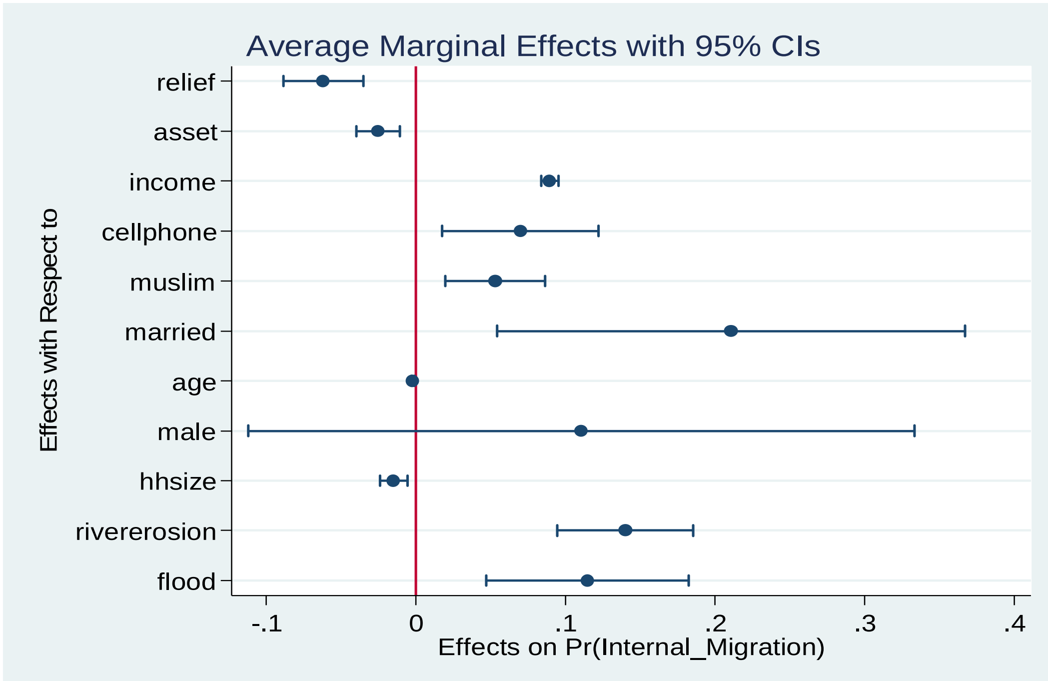


Figure 1.3 Average Marginal Effects of Significant Variables on Internal Migration (with District Fixed Effects)

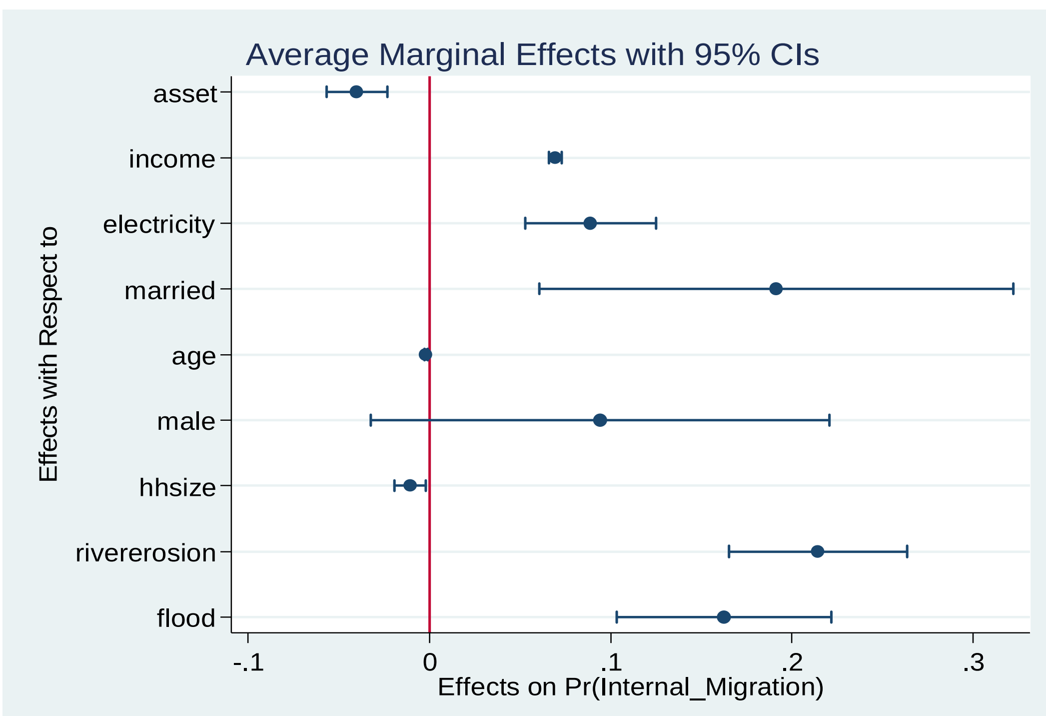


Figure 1.4 Average Marginal Effects on Migration to Dhaka

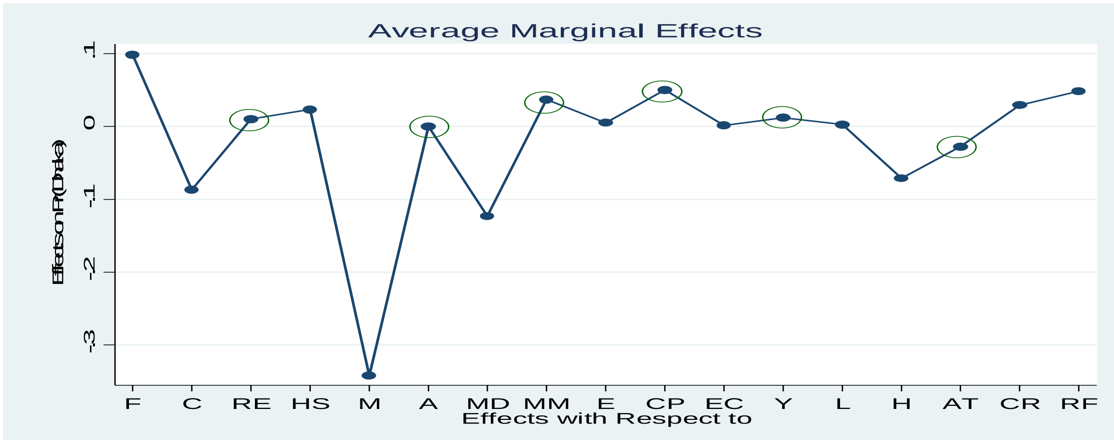


Figure 1.5 Average Marginal Effects on Migration to Khulna

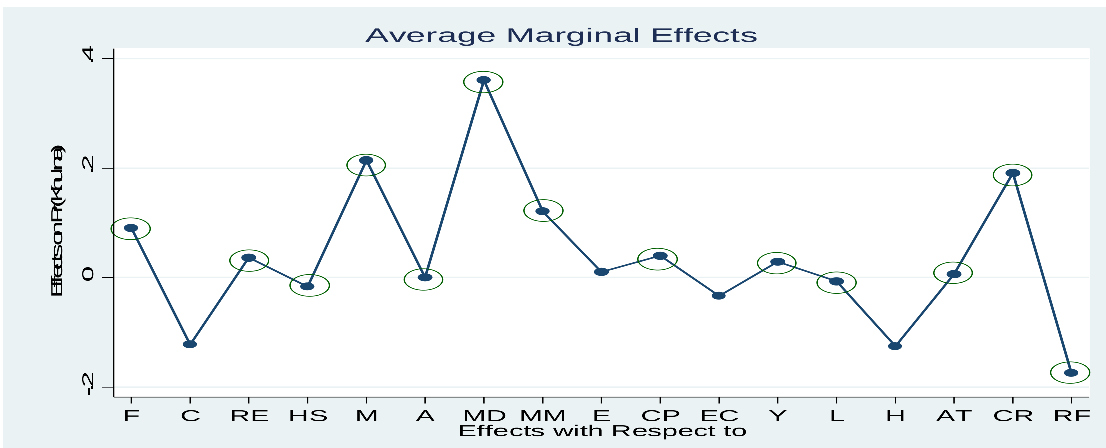
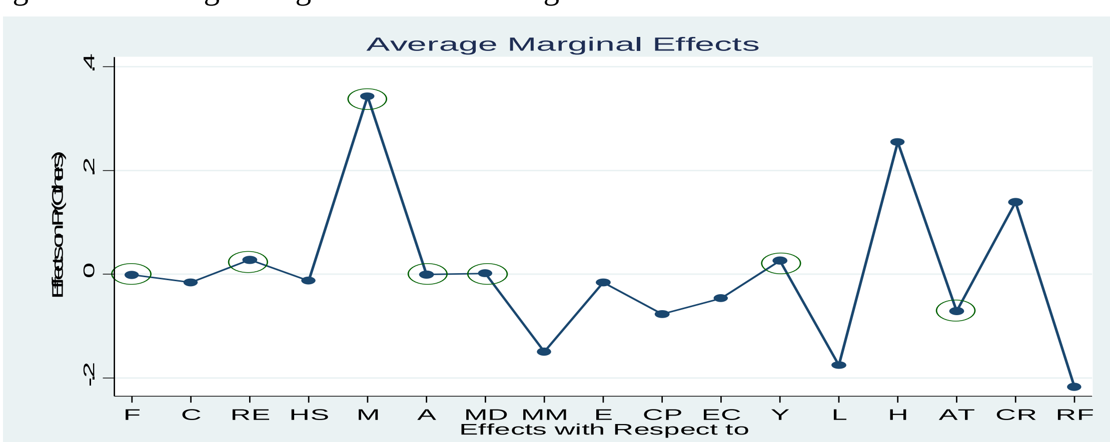


Figure 1.6 Average Marginal Effects on Migration to Other Cities



F=flood, C= cyclone, RE= river erosion, M= male, A=age, MD= married, MM= muslim, E= electricity CP= cell phone, EC= electricity, Y= income, L= Land, H= house, AT= asset, CR=credit, RF = relief

Figure 1.7 Kernel Density Plot of Monthly Food Expenditure between Migrants and Non-Migrants

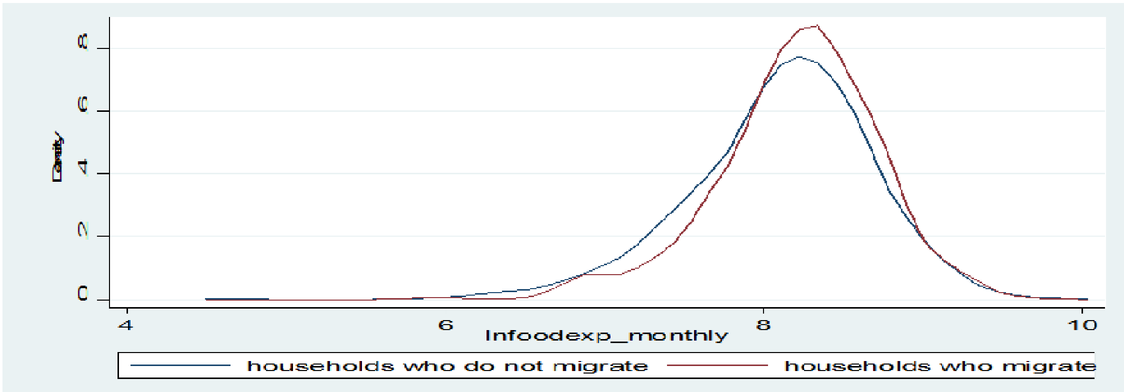


Figure 1.8 Kernel Density Plot of Monthly Non-Food Expenditure between Migrants and Non-Migrants

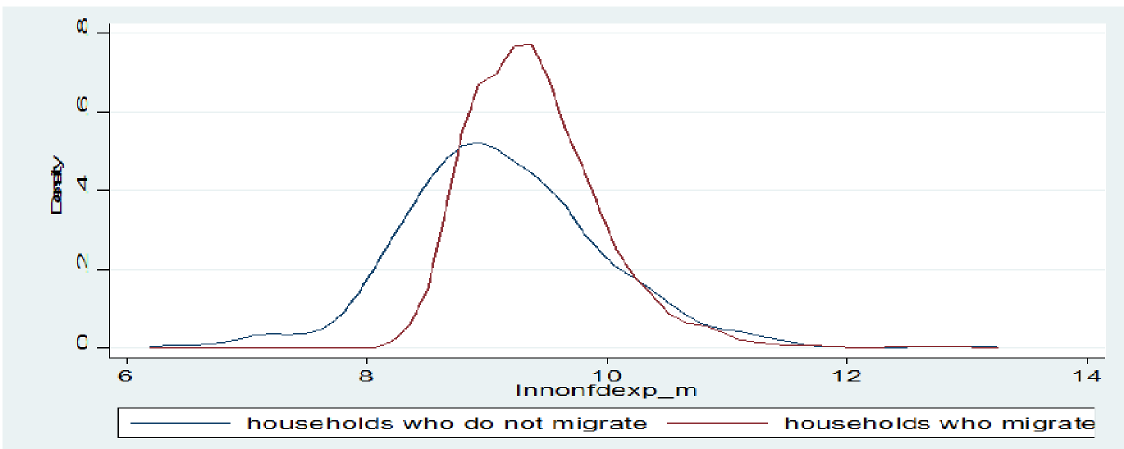


Figure 1.9 Kernel Density Plot of Monthly Total Expenditure between Migrants and Non-Migrants

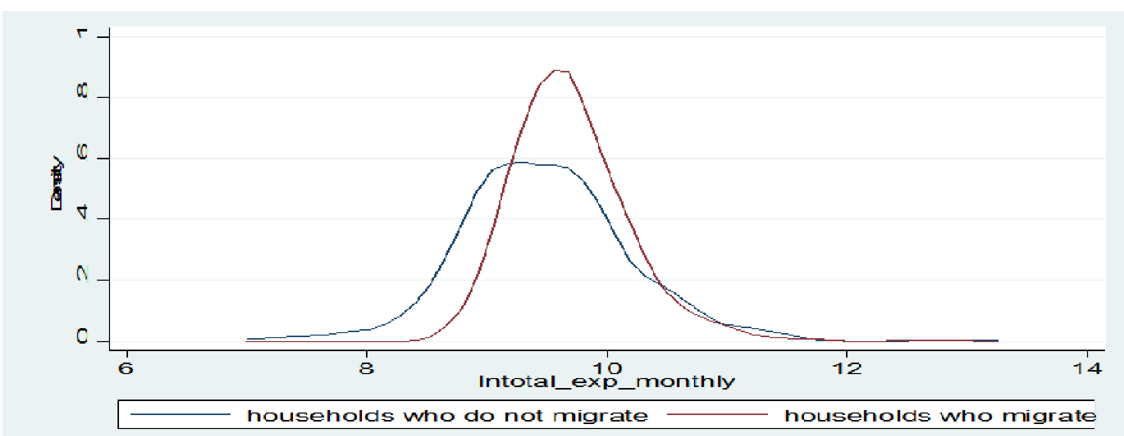


Figure 1.10 Histogram and Kernel Density Plot of Migrants Monthly Food Expenditure in Different Locations

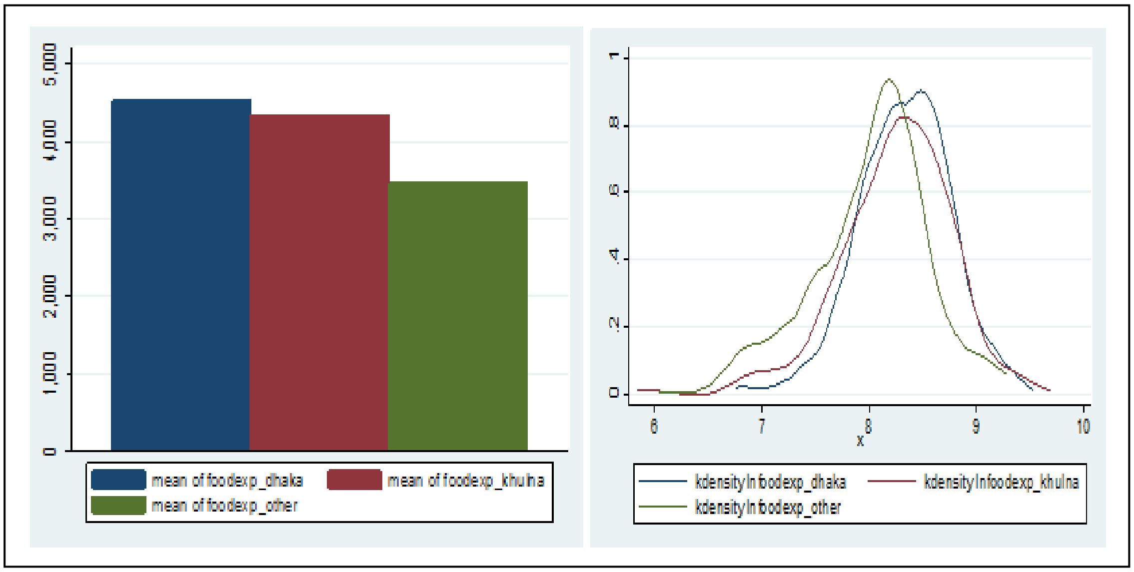
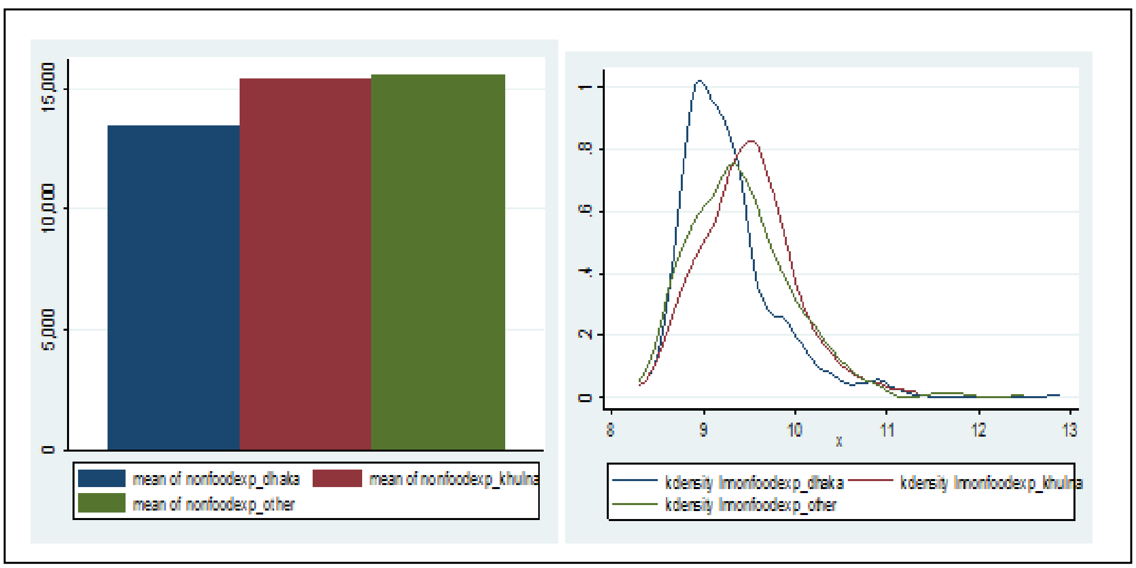


Figure 1.11 Histogram and Kernel Density Plot of Migrants Monthly Non-Food Expenditure in Different Locations



CHAPTER 2

CLIMATE CHANGE AND ADAPTATION BEHAVIOR IN AGRICULTURE: EVIDENCE FROM FARMING PRACTICES IN BANGLADESH

2.1 Introduction

Agriculture is the most important sector in the economy of Bangladesh. It contributes roughly 20 percent of gross domestic product (GDP) of Bangladesh, with about 11.2 percent coming from farming, 2.7 percent from livestock and poultry, 4.5 percent from fisheries, and 1.8 percent from forestry (Thomas et al., 2013). Climate change and extreme weather events in the form of floods, droughts, cyclones, and other environmental conditions pose a direct threat to agricultural production in Bangladesh. Indirectly, the epidemic shocks on pestilence stricken and pest attack affects livestock, poultry, and fisheries, which in turn affects the overall agricultural sector. The households of rural Bangladesh whose main source of livelihoods derives from agriculture are mostly affected by these climate related weather and epidemic shocks.

In recent years, climate change adaptation has attracted much attention. Several studies have shown that adaptation can be the most effective way to reduce the adverse impacts of climatic shocks on agricultural output (Adger et al., 2005; Fussel and Klein, 2006). Stern (2007) estimates that without adaptation, climate change is estimated to cost at least 5% of global GDP each year, and if a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more.

The challenge of adaptation is particularly acute in Bangladesh, as poverty limits the capacity to act. Thus, I used the data from the Bangladesh Climate Change Adaptation Survey to investigate the feasibility of a set of adaptation measures to cope with the risk in an agricultural sector that faces diverse climate related weather (e.g. floods, drought, cyclones, tidal waves) and epidemic shocks (pestilence stricken, pest attack/livestock epidemic).

Some attempts have been made to understand the nature of adaptation to climate change in the agriculture sector in Bangladesh (Delaporte and Maurel, 2016; Harun-ur-Rashid and Islam, 2007; Sikder and Xiaoying, 2014; and Thomas et al., 2013). While most of these studies have focused on different adaptation measures to cope with the adverse impacts of climate change, they have paid little attention to the barriers that farmers face in implementing appropriate adaptation measures and the outcome of relaxing those constraints on their decision to adapt. A few studies conducted on African countries (Ethiopia, Tanzania, South Africa) have looked into some of these constraints and highlighted that lack of access to credit and extension and inadequate knowledge of adaptation methods are major hindrances to the success of adaptation to climate change (Deressa et al., 2008; Komba and Muchapondwa, 2012; Nhemachena and Hassan, 2007; Bryan et al., 2009).

In this study, we will attempt to answer three interrelated questions: Do climatic and epidemic shocks have significant impact on agricultural income? In addition to the extent of climate induced weather and epidemic shocks, what other factors influence the farmer's decision to adapt, and how effective are these adaptation decisions? Will relaxing some of the barriers (e.g. access to credit, agricultural extension, and technological improvement) induce farmers to adapt more effectively? We hypothesize that the climate related weather and epidemic shocks will have adverse impacts on the agricultural output, and that will induce farmers to adapt. In addition, the access to credit, agricultural extension, and technological improvement will encourage more farmers to adapt. Finally, we will be able to check the effectiveness of each factors on certain types of adaptation behaviors.

2.2 Literature Review

Most studies have examined the impacts of climate related weather shocks—changes in temperature, rainfall, flood, cyclones, and tidal waves—on agricultural adaptation decisions (Dasgupta et al., 2009; Cline, 2007). Only very few studies mentioned epidemic shocks as an indirect factor that affects agricultural income and induces farmers to adapt (Walthall et al., 2013). In contrast, a few studies have found no connection between farmers' perceptions of climate change and adaptation (Smit et al., 1996). On a study of Ethiopia and South Africa, Bryan et al., (2009) showed that despite having perceived changes in temperature and rainfall, a high percentage of farmers did not make any adjustments to their farming practices. In this study, I not only incorporate the impacts of weather and epidemic shocks on agricultural income and adaptation, but also focus on the demographic and economic factors that influence households' decision to adapt. While analyzing farmers' adaptation decision, I try to revisit the literature associated with the constraints of adaptation.

Adaptation is alternative agricultural activity to manage the effects of climate change (Fankhauser et al., 1999; Hassan and Nhemachena, 2008). It is one of the essential strategies for reducing the severity and cost of climate change impacts. Adaptation measures help farmers guard against losses due to climate related weather and epidemic shocks. Tol (2005) suggests that the increase in adaptive capacity is more effective than climate change mitigation. Among the different measures of agricultural adaptation, the use of crop varieties, planting trees, soil conservation, changing planting dates, divergence from crops to livestock, and irrigation are the most widely used methods in Africa and South Asia (Kabubo-Mariara, 2009; Ajao and Ogunniyi, 2011; Droggers, 2004; Delaporte and Maurel, 2018; Komba and Muchapodwa, 2012).

There are ecological (biophysical), social (normative and cognitive), and economic barriers (lack of money/credit) to adaptation. In Bangladesh, most of the agricultural workers are financially insolvent to buy necessary equipment and technologies that facilitate adaptation. It can also be argued that if sufficient agricultural credit were to be made available to the farmers, they would be able to hire more labor, purchase inputs such as fertilizer, increase the size of the plot, and consider diversified adaptation options at the same time (Pattanayak et al., 2003; Deressa et al., 2008).

Several other constraints that may directly or indirectly influence farmers' adaptation decisions are lack of information, knowledge, and awareness about climatic variation and adaptation. To control for these, I also consider agricultural extension and information related factors along with the socio-economic constraints of adaptation.

2.3 Household Survey and Study Area

To estimate the impact of climatic shocks on households' agricultural income and farmers ' adaptation options in Bangladesh, we used the first round of Bangladesh Climate Change Adaptation Survey (BCCAS) data. The survey was conducted from December 2010 to February 2011, covering information on the demographic characteristics of the households, agricultural production and income, incidence of climatic and epidemic shocks in the locality in last five years, use of technology and techniques in agricultural productions, adaptation options, and the constraints that individual farmers face when adapting.

The household survey covered 7 broad agroecological zones (AEZs) of Bangladesh as grouped by the Bangladesh Centre for Advanced Studies. The survey respondents are from 40 unions, in which 20 households were randomly selected from each sample union, making a total sample of 800 households. The descriptive statistics of survey data are represented in Table 2.1. This shows that the highest numbers of households are selected from floodplain AEZs. Figure 2.1 shows the geo-coded location of the 40 unions in Bangladesh from where we randomly selected 800 households for the study.

2.4 Empirical Methods and Data Description

Two interrelated empirical models are adopted to conduct the study. The first model analyzes the impacts of climate related weather and epidemic shocks on the agricultural income. The second model determines whether the decrease in agricultural income through climate related weather and epidemic shocks induce farmers to adapt to climate change.

2.4.1 The Impacts of Climate Related Weather and Epidemic shocks on Agricultural Income

Following Deressa et al. 2008; Komba and Muchapondwa 2012; and Delaporte and Maurel 2018, we hypothesize that climate related weather shocks adversely affect agricultural income, which in turn induces farmers to adapt. We add epidemic shocks along with the weather shocks as they indirectly affect the agricultural income and influence farmers' adaptation decisions. In the first model, we estimate the impact of weather and epidemic shocks on agricultural income. The first model posits the following ordinary least square estimation model.

$$Y_{ij} = \alpha + \beta W + \theta E + \varepsilon ij \qquad (1)$$

where Y is the logarithm of agricultural income of household i in union/village j, W is the exposure to climate related weather shocks that include flood, drought, cyclones, tidal waves, and toxic water. E is the index of epidemic shocks that include pestilence stricken, pest attack /livestock epidemic. We extend the first model by considering other controls (agricultural plot, agricultural soil) that may affect agricultural income. The extension of the first model is presented below.

$$Yij = \alpha + \beta W + \theta E + \delta P + \Phi S + \varepsilon ij \qquad (2)$$

where P is the vector of the size of agricultural plot/land (homestead, cultivable land, pasture, bush, derelict, and non-arable land), and S is the vector of the types of agricultural soil (loam, clay loam, sandy loam). Table 2.2 summarizes information on the weather and epidemic shocks along with the households' agricultural earnings, plot size, and soil types.

The average annual income of the surveyed households is about BDT 30,640 ($US 368), which is lower than the GDP per capita of Bangladesh in 2011 ($US 835.79). This indicates that the agricultural sector is one of the subsistence sectors of the country that supports a poor and vulnerable group of people. We consider two adverse shocks on agricultural income—weather shocks and epidemic shocks—in our study. The households were asked whether they experienced weather related shocks—flood, drought, cyclone, tidal waves, toxic water and epidemic shocks—pestilence stricken, pest attack/livestock epidemic in their locality in the last five years. Regarding weather shocks, majority of the households have experienced flood (about 55%) followed by drought (about 52%), cyclone (about 27%), tidal wave (about 7%), and toxic water (about 2%) in their locality. While weather shocks have a direct impact on the agricultural output and income, the epidemic shocks have an indirect impact on agricultural income through the emergence and re-emergence of diseases in livestock and poultry productivity. The majority of the households cited that they have experienced pestilence stricken (about 60%) in their locality compared to the pest attack/livestock epidemic (about 10%).

We hypothesize that the different agricultural plot sizes have a positive impact on agricultural income. According to the survey respondents, on average, households have around 163.48 decimals of cultivable land, 11.66 decimals of homestead plot, and less than 1 decimals of each of the following plot—pasture (0.2 decimals), bush (0.5 decimals), derelict (0.34 decimals), and non-arable land (0.61 decimals). We assume that the loam, clay loam, and sandy loam types of soil have negative association with agricultural output and income. It is observed that most of the agricultural plot is clay loam type (55%), followed by loam (32%), and sandy loam (30%) type.

2.4.2 The Impacts of Decrease in Agricultural Income and Other Factors on Adaptation Decisions

In this stage, we estimate the impact of a decrease in agricultural income indexed by climate related weather and epidemic shocks on the households' decision to adapt. we calculate the estimated coefficients for agricultural income from equation (1) and posit the probit regression to oversee the factors affecting adaptation decisions. This can be represented as:

$$P\ (A_{ij}) = \Psi\ (Y_{ij}, X_{ij}, Z_{ij}) + u_{ij} \qquad (3)$$

where Ψ is the cumulative distribution function. The probability of households' decision to take any adaptation option (A_{ij} =1) depends on the vector of the decrease in agricultural income (Y_{ij}), vector of household characteristics and other socio-economic controls (X_{ij}), and the vector of agricultural and technological extension (Z_{ij}). Table 2.3 shows the households' response to 22 different adaptation options that can happen simultaneously. We compute A_{ij} = 1 if the household made at least one change (out of 22) in its farming practices in response to climate change. As shown in Table 2.3, about 91 percent of households have adopted at least one change in farming practices in response to climate change. The vector of X_{ij} refers to the demographic and socio-economic characteristics of the households, such as the number of members in the household, age of the household's head, gender of the household's head, religion of the household's head, marital status, years of schooling of the household's head, agriculture as the primary and secondary occupation of the household, availability of electricity in the residence, total value of assets of the household except land. We also control for financial barriers (received of credit from formal and informal sources) and technological barrier (agricultural adaptation and method of tillage) to adaptation as we hypothesize that the relaxation of barriers will induce farmers decision to adapt. The descriptive statistics of these control variables are presented in Table 2.4.

The average household size found in our sample is 4.98, which is higher than the national average household size (4.35) of the country.[1] The average age of the household head was reported as 46 years, and most household heads have less than four years of education on average. Most of the respondents are male (94%), Muslim (88%), and married (94%). Approximately 76% of the household heads stated agriculture as their primary source of earnings, and about 45% of the household heads reported agriculture as their secondary source of earnings. In addition, 46% of the households have electricity in their home and about 48% of the households have borrowed credit from both formal and informal sources. Also, about 17% of the household heads have received information from the agricultural extension agent. These extension agents provide information on soil and water conservation, crop protection, crop utilization, and crop-livestock integration among others. In terms of the preparation of land for growing crops (tillage), the majority of the farmers used power tiller (79%), followed by animal (24%), and hand tool (6%).

According to Table 2.3, the top four preferred adaptation options of households are change in irrigation (64.25%), change in crop variety (58.13%), change in fertilizer (57.63%), and change in planting dates (37.63%). In our analysis, we estimate the impact of each factors on the top four adaptation options selected by the households. This leads us to identify which factors have stronger influence on households' decision to choose the specific adaptation options.

[1] See Bangladesh Population and Housing Census 2011. This can be publicly accessed at http://catalog.ihsn.org/index.php/catalog/4376

2.5 Results and Discussion

We used the least square estimation for the analysis of weather and epidemic shocks on agricultural income (see equation 1 and 2) and probit regression to see the impacts of decrease in agricultural income (indexed by weather and epidemic shocks) and other factors on the decision to adapt (see equation 3).

The estimated results of equation 1 are presented in Table 2.5. The least square estimation results of column (1) shows that among all the climate related weather shocks, drought, cyclone, and toxic water have significant negative impacts on agricultural income. The epidemic shocks—pestilence stricken and pest attack—also have significant negative associations with agricultural income. We consider AEZs fixed effects and union (village) fixed effects to catch spatial heterogeneity. This will allow for unobservable characteristics of the location of origin that are correlated with the explanatory variables and influence the decision to adapt. The results of fixed effects estimations are consistent with the base regression results. It is also noticeable that under union fixed effects, all the climate related weather shocks significantly reduce the agricultural income. Between the two epidemic shocks, pestilence stricken have stronger significant negative impacts on agricultural income compared to pest attack.

The estimated results of equation (2) are presented in Table 2.6. The results are consistent with the results of equation (1) and as expected the size of the agricultural plots—homestead, cultivable land—are found positively significant for agricultural income. All the three types of soil—loam, clay loam, sandy loam—decrease the agricultural income significantly.

we estimate the impacts of agricultural income (indexed by weather and epidemic shocks) and other factors on farmers' decisions to adapt. This is presented in Table 2.7. Findings of the study suggest that a one percentage point decrease in agricultural income through climatic and epidemic shocks induce households to adapt by almost 2 percentage points both in model (1) and (2). Among all the other demographic factors, household size, gender, years of education, and occupation (primary) are found influential factors for households' decision to adapt. In addition, those who have the advantage of having greater tangible assets are more prone to adapt than others.

Lack of access to credit is one of the major barriers encountered by farmers to adapt to the climate change (Enete and Amusa, 2010). In model (2) of Table 2.7, we test the hypothesis that the use of credit has a significant positive impact on adaptation decision. We have found a significant positive association with credit and farmers decision to adapt. It is also observed that the knowledge from agricultural extension agents on agricultural production, protection, and proper utilization of resources have significant positive impacts on adaptation decisions. Households who used power tiller as a tillage are more inclined to the decision to adapt than those who used hand tool or animal as tillage.

Based on the households' response to adaptation options (see Table 2.3), we have found that the change in irrigation, change in crop variety, change in the use of fertilizer, and the change in planting dates are four most preferred adaptation options for the households. Table 2.8 represents the impacts of each factors on each of these adaptation options.

We have found that the decrease in agricultural income due to the climate related weather and epidemic shocks influence households to change all the adaptation options except change in the planting dates. Among all the demographic and socio-economic factors household size, education, and agriculture as a primary occupation are found highly significant for almost all the selective adaptation options. It is also observed that the availability of credit and knowledge from agricultural extension agents on agricultural production, protection, and proper utilization of resources have significant positive impacts on all the selective adaptation options except the change in planting dates. Households who used power tiller as a tillage are more inclined to the decision to adapt than those who used hand tool or animal as tillage. This is found strongly significant for all four adaptation options. Thus, it can easily be inferred that the relaxation of financial and technological barriers will induce farmers to adapt more.

2.6 Conclusion

Unlike the previous studies that show the impacts of climatic shocks on farmers' adaptation decisions, we conduct a study on rural Bangladesh to see the impacts of weather and epidemic shocks on agricultural income and their influence on households' decisions to adapt. Findings of the study suggest that the decrease in agricultural income due to climatic and epidemic shocks will induce households to adapt. The adverse impacts of climate related weather and epidemic shocks on agricultural income suggest a number of adaptation options that can be effective to face the challenges of climate change in Bangladesh. I believe the study will assist policymakers in ranking the best possible adaptation options for the farmers and ways to promote them.

The deficit of financial support, limitations of gaining agricultural knowledge and technological support are the key constraints of households' capacity to adapt. Thus, we extend our analysis by relaxing the constraint of adaptation and investigate whether credit, agricultural extension, and technological support plays any significant role in encouraging farmers to adapt more effectively. It is found that the households are willing to adjust their crop variety, irrigation pattern, and use of fertilizer if they have the availability of credit, agricultural knowledge, and power tillage for technological support. In other words, the availability of credit increases the financial strength of farmers and their ability to meet costs associated with various adaptation options. The agricultural knowledge helps farmers to identify what changes of farming practices are needed at what time, and the advantage of technological support makes it easier for the households to employ the adaptation options that reduce the adverse impacts of climatic and epidemic shocks in agriculture.

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TABLES

Table 2.1 Distribution of Survey Respondents (in %) Across the Agroecological Zones

Name of AEZs	No. of Unions in each AEZs	Number of Households in each AEZs	Percentage
Barind Tract	4	80	10
Beel and haor basin	5	100	12.5
Floodplain	10	200	25
Himalayan piedmont plain	5	100	12.5
Modhupur Tract	4	80	10
Northern and Eastern Hills	5	100	12.5
Tidal Floodplain	7	140	17.5
Total	40	800	100

Source: Bangladesh Climate Change Adaptation Survey

Table 2.2 Households Responses on Climate and Epidemic Shocks, Agricultural Plot and Soil, and Agricultural Income

Variable	Definition	Mean	Standard Deviation
flood	If the household has experienced flood in his locality in the last 5 years (1 = yes, 0 = otherwise)	0.55	0.49
drought	If the household has experienced drought in his locality in the last 5 years (1 = yes, 0 = otherwise)	0.52	0.49
cyclone	If the household has experienced cyclone in his locality in the last 5 years (1 = yes, 0 = otherwise)	0.27	0.44
tidal wave	If the household has experienced tidal wave in his locality in the last 5 years (1 = yes, 0 = otherwise)	0.07	0.26
toxic water	If the household has experienced toxic water in his locality in the last 5 years (1 = yes, 0 = otherwise)	0.02	0.15
pestilence stricken	If the household has experienced pestilence stricken in his locality in the last 5 years (1 = yes, 0 = otherwise)	0.6	0.49
pest attack	If the household has experienced pest attack in his locality in the last 5 years (1 = yes, 0 = otherwise)	0.1	0.3
homestead	Size of agricultural plot (homestead) owned by the household (in decimal)	11.66	11.42
cultivable	Size of cultivable land owned by the household (hh)	163.48	306.45
pasture	Size of agricultural plot (pasture) owned by the hh	0.2	2.99
bush	Size of agricultural plot (bush) owned by the hh	0.5	2.19
derelict	Size of agricultural plot (derelict) owned by the hh	0.34	2.85
non-arable	Size of non-arable land owned by the household	0.61	5.87
loam	If the agricultural plot soil is 'loam' type (1 = yes, 0 = otherwise)	0.32	0.46
Clay loam	If the agricultural plot soil is 'clay loam' type (1 = yes, 0 = otherwise)	0.55	0.49
sandy loam	If the agricultural plot soil is 'sandy loam' type (1 = yes, 0 = otherwise)	0.30	0.46
agricultural income	Household's annual income from agricultural source (in Taka)	30640.52	148544.9

Notes: (1) All agricultural plot sizes are in decimals. (2) Agricultural income is measured in domestic currency (Taka) where $US 1 = 83.19 Taka

Table 2.3 Households Responses to Adaptation Options

Adaptation Options	Frequency	Percentage
Decision to adapt	725	90.63
Change crop variety	465	58.13
Change crop type	142	17.75
Increase amount of land under production	121	15.13
Change soil and water management technique	44	5.5
Change pattern of crop consumption	39	4.88
Mix crop and livestock production	28	3.5
Mix crop and fish farming production	24	3
Change field location	52	6.5
Build water harvesting scheme for domestic consumption	93	11.63
Build water harvesting scheme for crops	97	12.13
Build water harvesting scheme for livestock	7	0.88
Build diversion ditch	116	14.5
Plant trees for shading	17	2.13
Change irrigation/More Irrigation	514	64.25
Buy insurance	6	0.75
Change from crop to livestock production	7	0.88
Change from livestock to crop production	13	1.63
Seek off farm employment	121	15.13
Migrate to other location	19	2.38
Set up communal seed bank/food storage facilities	8	1
Change planting dates for Aus/Aman/Kharif/Boro/Rabi	301	37.63
Change fertilizer application in Aus/Aman/Kharif/Boro/Rabi	461	57.63

Source: Authors' calculation from Bangladesh Climate Change Adaptation Survey

Table 2.4 Summary Statistics of Survey Responses and the Variables of Interest

Variable	Definition	Mean	Standard Deviation
household size	Number of household members	4.98	2.19
age	Age of the household's head in years	45.52	13.69
male	If the household's head is male (1 = yes, 0 = otherwise)	0.94	0.23
muslim	If the religion of the household's head is muslim (1 = yes, 0 = otherwise)	0.88	0.31
married	If the household's head is married (1 = yes, 0 = otherwise)	0.94	0.23
years of education	years of schooling of household's head	3.5	4.15
primary occupation (agriculture)	If the primary occupation of the household's head is agriculture (1 = yes, 0 = otherwise)	0.76	0.42
secondary occupation	If the secondary occupation of the household's head is agriculture (1 = yes, 0 = otherwise)	0.45	0.49
electricity	If the households has electricity in their home (1 = yes, 0 = otherwise)	0.49	0.46
assets	Market value of households' assets (in log)	10.03	1.46
credit	If the household has received credit (1 = yes, 0 = otherwise)	0.48	0.49
agricultural extension	If the household's head received advice from extension agents (1 = yes, 0 = otherwise)	0.17	0.37
hand tool	If the household used human power as a method of tillage (1 = yes, 0 = otherwise)	0.06	0.23
animal	If the household used animal as a method of tillage (1 = yes, 0 = otherwise)	0.24	0.42
power tiller	If the household used power tiller as a method of tillage (1 = yes, 0 = otherwise)	0.79	0.4

Table 2.5 Impact of Weather and Epidemic Shocks on Agricultural Income

	Dependent Variable: Agricultural Income		
	(1)	(2)	(3)
	No Fixed Effects	AEZs Fixed Effects	Union Fixed Effects
Flood	-0.040 (0.130)	-0.112 (0.135)	-0.382 (0.210)*
drought	-0.282 (0.148)**	-0.558 (0.267)**	-0.987 (0.410)***
cyclone	-0.401 (0.150)***	-0.778 (0.286)***	-0.949 (0.306)***
tidal wave	-0.245 (0.301)	-0.381 (0.289)	-0.460 (0.421)
toxic water	-1.060 (0.414)***	-0.893 (0.406)**	-1.128 (0.372)***
pestilence stricken	-0.361 (0.210)**	-0.222 (0.152)	-0.386 (0.162)***
pest attack	-0.287 (0.174)*	-0.294 (0.181)*	-0.332 (0.176)*
constant	9.924 (0.177)***	10.570 (0.243)***	12.244 (0.927)***
observations	671	671	671
R^2	0.167	0.199	0.275

Note: Numbers in parentheses are the corresponding standard errors; *** Significant at 1% levels, ** Significant at 5% levels, * Significant at 10% levels.

Table 2.6 Impact of Weather and Epidemic Shocks on Agricultural Income (Control for Agricultural Plot Type and Soil Type)

	Dependent Variable: Agricultural Income		
	(1)	(2)	(3)
	No Fixed Effects	AEZs Fixed Effects	Union Fixed Effects
Flood	-0.179 (0.115)	-0.148 (0.379)	-0.223 (0.118)**
drought	-0.610 (0.133)***	-0.910 (0.370)***	-0.376 (0.143)***
cyclone	-0.620 (0.131)***	-0.769 (0.272)***	-0.287 (0.174)*
tidal wave	-0.363 (0.294)	-0.150 (0.361)	-0.528 (0.254)**
toxic water	-1.053 (0.359)***	-2.021 (1.003)**	-0.760 (0.354)**
pestilence stricken	-0.299 (0.142)**	-0.267 (0.364)	-0.494 (0.157)***
pest attack	-0.294 (0.181)*	-0.124 (0.181)	-0.265 (0.183)
homestead	0.392 (0.140)***	0.311 (0.124)***	0.530 (0.150)***
cultivable land	0.004 (0.001)***	0.005 (0.000)***	0.004 (0.000)***
pasture	-0.009 (0.006)	-0.008 (0.015)	-0.012 (0.015)
bush	-0.002 (0.018)	0.008 (0.023)	0.003 (0.023)
derelict	0.006 (0.009)	0.003 (0.016)	0.004 (0.016)
non arable land	0.004 (0.005)	0.001 (0.008)	0.005 (0.008)
loam	-0.005 (0.001)***	-0.005 (0.001)***	-0.005 (0.001)***
clay loam	-0.067 (0.036)*	-0.066 (0.031)**	-0.054 (0.032)*
sandy loam	-0.295 (0.060)***	-0.326 (0.028)***	-0.300 (0.029)***
constant	9.371 (0.184)***	10.222 (0.825)***	9.834 (0.221)***
observations	671	671	671
R^2	0.287	0.321	0.398

Note: Numbers in parentheses are the corresponding standard errors; *** Significant at 1% levels, ** Significant at 5% levels, * Significant at 10% levels.

Table 2.7 Factors Affecting Households Decision to Adapt (Probit Estimation)

	Dependent Variable: Decision to Adapt	
	(1)	(2)
ln agricultural income	-0.263 (0.114)**	-0.221 (0.135)***
household size	0.091 (0.050)*	0.129 (0.065)**
age	0.013 (0.006)**	0.018 (0.007)***
male	0.681 (0.308)**	0.806 (0.380)**
muslim	-0.160 (0.293)	-0.284 (0.368)
married	-0.519 (0.409)	-0.354 (0.473)
years of education	0.072 (0.041)*	0.067 (0.026)***
primary occupation (agriculture)	0.494 (0.220)**	0.649 (0.248)***
secondary occupation (agriculture)	0.258 (0.193)	0.300 (0.270)
electricity	0.542 (0.327)*	0.165 (0.205)
ln asset	0.170 (0.098)*	0.250 (0.145)*
credit		0.024 (0.013)*
agricultural extension		0.521 (0.271)**
hand tool		-0.325 (0.215)
animal		0.123 (0.267)
power tiller		0.274 (0.139)**
constant	-0.271 (0.859)	-0.607 (1.693)
observations	669	669
Pseudo R^2	0.233	0.416

Note: Numbers in parentheses are the corresponding standard errors; *** Significant at 1% levels, ** Significant at 5% levels, * Significant at 10% levels.

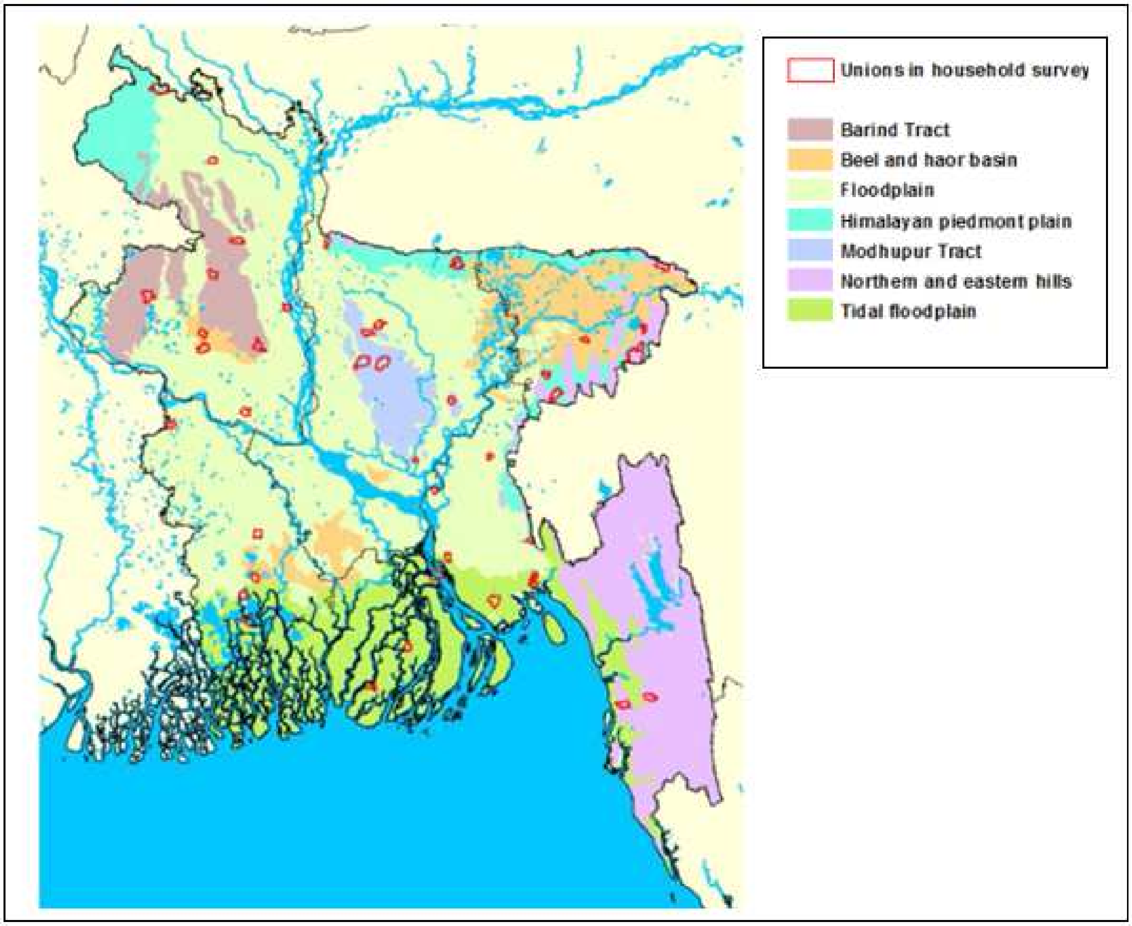
Table 2.8 Factors Affecting Households Decision to the Selective Adaptation Options

	Dependent Variable			
	(1) Δ Irrigation	(2) Δ Crop Variety	(3) Δ Fertilizer	(4) Δ Planting Dates
ln agricultural	-0.100**	-0.384**	-0.280**	-0.018
income	(0.037)	(0.180)	(0.121)	(0.043)
household	0.069**	0.554**	0.244*	0.027
size	(0.031)	(0.264)	(0.144)	(0.191)
male	0.111	0.309	0.183	0.409*
	(0.276)	(0.288)	(0.243)	(0.250)
muslim	-0.288	-0.065	-0.241	-0.006
	(0.202)	(0.166)	(0.189)	(0.026)
married	-0.129	-0.189	-0.018	-0.321
	(0.273)	(0.303)	(0.122)	(0.258)
years of	0.073*	0.033**	0.034**	0.137**
education	(0.039)	(0.017)	(0.015)	(0.067)
primary work	0.408**	0.263*	0.285*	0.537***
(agriculture)	(0.174)	(0.147)	(0.177)	(0.158)
secondary work	0.127	0.061	0.111	0.159
(agriculture)	(0.140)	(0.150)	(0.230)	(0.122)
electricity	0.179	0.033	0.123	0.454***
	(0.126)	(0.134)	(0.120)	(0.131)
ln asset	0.238*	0.212	0.084*	0.062
	(0.131)	(0.139)	(0.047)	(0.048)
credit	0.022**	0.007*	0.195*	0.126
	(0.011)	(0.004)	(0.108)	(0.109)
agricultural	0.670***	0.646***	0.243*	0.195
extension	(0.135)	(0.254)	(0.141)	(0.139)
hand tool	-0.541*	-0.352*	-0.160	-0.039
	(0.332)	(0.197)	(0.284)	(0.142)
animal	-0.135	-0.124	-0.147	-0.028
	(0.143)	(0.217)	(0.157)	(0.113)
power tiller	0.451***	0.697***	0.230*	0.279*
	(0.162)	(0.265)	(0.133)	(0.161)
constant	-1.301*	-2.982***	-1.445	-1.151*
	(0.741)	(0.742)	(0.612)	(0.639)
observations	664	664	664	664
Pseudo R^2	0.295	0.365	0.380	0.285

Note: Numbers in parentheses are the corresponding standard errors; *** Significant at 1% levels, ** Significant at 5% levels, * Significant at 10% level

FIGURE

Figure 2.1 Geo-coded Household Location Across the Agroecological Zones (AEZs)



Source: Thomas et al., (2013). IFPRI Discussion Paper No. 01281.

CHAPTER 3

HOUSEHOLD PREFERENCES FOR ADAPTATION: STATE VS. FEDERAL APPROACH FOR MANAGING COASTAL VULNERABILITY

3.1 Introduction

Hydro-climatic forces affect coastal areas in many ways. Coastal environments and communities are sensitive to sea level rise, warmer ocean temperatures, storm surges, severe rainfall events, flooding, landslides, ocean acidification, and ocean circulation. Often, densely populated communities in low-lying coastal areas are more vulnerable to natural disaster than those in inland areas (Bathi and Das, 2016; Barbier 2014). In the United States, more than 150 million people in 673 coastal counties are exposed to extreme weather events and climatic shocks (Ruth et al., 2007). During the last two decades, the coastal counties on the Atlantic and Gulf coasts have experienced intense hurricanes, including Irma, Harvey, Sandy, Wilma, Ivan, Katrina, Rita, Ike and many others. These hurricanes resulted in thousands of fatalities, injuries and illnesses, disruptions of public utility services, and financial losses through property damage and destruction of infrastructure.

Hurricane Sandy, classified as one of the costliest Atlantic hurricanes in US history, made landfall on October 29, 2012 (Manuel, 2013). Sandy was blamed for more than 200 deaths and an estimated monetary loss of US$ 78 billion in the United States (Kunz et al., 2013). According to Sullivan and Uccellini (2013), 24 states across the northeastern and mid-Atlantic region were severely affected by this deadly storm. The coast of central and northern New Jersey and New York City metropolitan area suffered most from this catastrophic cyclone. The governor's office of New Jersey and New York estimates that the total damages to the states are about $ 15.2 billion and $ 19 billion respectively (Blake et al., 2013). With these damages in mind, we have conducted a household survey in the specific hurricane Sandy affected counties to understand residents' preferences for an adaptation fund to manage coastal vulnerability.

Although disasters triggered by extreme weather events are disruptive to coastal communities and their economies, disaster preparedness provides great opportunities to take proactive actions that can significantly reduce the adverse effects of coastal vulnerability and the additional threats posed by climate change and sea level rise (Burkett, 2012). Available literature indicates that households, private sectors, and governments are three distinct units of an economy that can play a significant role to reduce vulnerabilities from current and future hazard events by increasing hazard awareness, improving community resilience, and restoring coastal environments (Ewing et al., 2010; Birkmann, 2007; Kent 2011; Godschalk 2003; Barbier 2014).

Adaptation in terms of proactive (ex-ante) mitigation policies can be more effective than reactive (ex-post) mitigation strategies (Letson et al., 2007). However, designing comprehensive ex-ante measures is challenging as it involves an assessment of how to generate and manage the fund at the state and federal level. Very few studies have explored ex-ante mechanisms to finance adaptation and promote resilience. With a few exceptions, Mozumder et al. (2014) found that more than one-fourth of homeowners would be willing to pay to finance a hurricane mitigation fund in Florida. The residents of New Orleans metropolitan area are willing to pay $301 for category 5 storm protection; this figure is $509 for the other U.S. citizens in the sample (Landry et al., 2011). The study by the Multihazard Mitigation Council (2005) showed that, on average, a dollar spent by the Federal Emergency Management Agency (FEMA) on hazard mitigation provides the nation with about $4 in future benefits.

Since the support for adaptation funds can have implications on the state or federal income taxes and households' budgets for goods and services, it is pertinent to know how much money households are willing to pay for the proposed adaptation funds managed by either state or federal agencies. Thus, the key objective of our paper is to analyze and compare households' preferences, in the form of their willingness to pay (WTP), between state and federally managed adaptation funds to minimize the adverse impacts of coastal hazards.

3.2 Factors Affecting Risk Mitigation Decision in Coastal Communities

Proactive mitigation strategies could decrease the loss of human life as well as the massive economic impacts of hurricanes. Peacock et al. (2005) argue that the first step in planning mitigation strategies is fully assessing existing hazard risks. Despite state and federal actions, households may reassess the risks on their own and practice mitigation measures accordingly. Whether individuals intend to take actions to mitigate risks is often based on their past experiences and expectations of future hurricanes.

Baker et al. (2012) conducted a survey on the behavior of 538 residents in suburban New York City, the coastal regions of New Jersey, Maryland, Delaware, and southeastern Virginia to determine households' perceived risk and preparatory actions towards hurricane Sandy. Their survey questions focused on the knowledge and information about the warning of the storm; threat perceptions; both short and long-term preparation actions; evacuation intentions; and experience of previous storms, among others. The study showed that those severely impacted by storms often engage in mitigation, while those who have experience with hurricanes without substantial losses may downplay the risks and forgo mitigation.

Socioeconomic and demographic characteristics such as income, age, and education can also affect mitigation decisions and risk assessment. Apart from these characteristics and personal experiences, another important factor of mitigation decisions is the insurance policy of the households that are in place to cover damages caused by hurricanes. Much of the attention surrounding hurricane mitigation decisions focuses on what households can do to protect their homes against the impacts of hurricanes (Ge et al., 2011; Peacock, 2005; Simmons and Wilmer, 2001; Young et al., 2012). A hurricane can cause massive damage to homes in a variety of ways: powerful winds can detach the roof, debris can break windows, garage doors can be torn down, and walls can be compromised or collapse. In such cases, households are more interested in installing window shutters to protect their home from the storm.

In attempting to assess the overall impacts of hurricane Sandy, special attention lies on understanding the level of public risk perception towards hurricanes and coastal vulnerabilities. With regards to extreme events, the perception of risk plays a crucial role in the decision-making process. Risk is essentially an assessment of the level of hazard a certain event presents to a decision-maker (Dash and Gladwin 2007; Riad and Norris 1998; Peters and Slovic 1996; Whitehead et al., 2000). The definition and assessment of risk inherently incorporates subjectivity (Slovic and Weber, 2002). As such, risk is a concept that people contend with when dealing with uncertainty and possible dangers in life (Slovic, 2001). In the context of natural hazards such as hurricanes and predispositions to coastal vulnerability, this perception of risk is often a primary factor in prompting people to take actions to reduce these risks (Dash and Gladwin 2007; Riad and Norris 1998; Peters and Slovic 1996). Thus, the most widely used factors that drive adaptation behaviors to mitigate risks are socioeconomic and cognitive variables, experience, and perceived responsibilities (Koerth et al. 2017; Mozumder et al. 2014; Paul and Routray, 2011; Terpstra 2011; Kievik and Gutteling 2011).

In this paper, we not only pay attention to all these explanatory factors but also focus on households' intention to generate adaptation funds at the state and federal level to understand how effective financing these funds is in taking preventive measures. In addition, we also give insights into whether short run (5 years) or long run (10 years) adaptation funds are more preferable for the households at the state and federal levels.

3.3 Fund for Adaptation: State VS. Federal Approach

Historically, environmental regulations were primarily designed and managed by the state and local governments in the United States (Adler, 2007; Vogel et al., 2012; Revesz, 2001). However, after the emergence of the National Environmental Policy Act (NEPA) in 1969, the federal government's role has increased significantly (Goulder and Stavins, 2011). The current notion of environmental federalism is not limited to environmental pollution and regulation, but also deals with the risks of natural disaster and adaptive actions. Yet the setting of environmental standards still has some striking anomalies (Oates, 2001). For instance, it is not clear why home insurance policies are regulated by the state agencies, while flood insurance policies are managed by the federal agencies. It is a matter of argument that the state agency may not be trusted with the responsibility for setting environmental standards as they can prioritize economic development over the interests of the environment (Oates, 2001). However, states with coastal areas have decades-long experience in addressing multiple environmental stresses. They are often on the front lines in responding to natural disasters, especially with a focus on aiding vulnerable communities (Rosenzweig and Solecki, 2014).

While dealing with the impacts of natural disaster on the coastal areas of the United States, policy analysts mostly focus on the response and recovery strategies. For instance, state and local governments are the first line of emergency response in disasters. They boast fire, police, emergency medical services, and emergency management agencies as a response to disaster. At the federal level, the response and recovery are mostly associated with the funding facilities. Federal assistance, measured as a proportion of hurricane damage, has grown significantly over the last three decades to help communities recover from severe disasters. Since 1989, FEMA has spent more than 13 billion dollars to implement long-term hazard mitigation projects in which 76% of total mitigation grant funding has been allocated for hurricane, storm, and flood related disasters (Davlasheridze et al., 2017). On the other hand, states have to have an approved State Hazard Mitigation Plans (SHMPs) to receive federal disaster mitigation funding from FEMA (Babcock, 2013).

Though the analysis of Sandy's impacts emphasized the need for fast response and recovery, the priority should be taking adaptive measures before the hurricane hits. Forming an adaptation fund beforehand will allow the state and federal agencies to take number of actions that can reduce the impacts of disaster. For example, flood resistant buildings can withstand the damage of floods; residential and community safe rooms can shield people from wind and debris; and homes can be elevated to reduce flood damage. These steps build resiliency against disasters and can reduce the need for costly response and recovery efforts. The most essential thing needed for implementing this is to mobilize sufficient funds at the state and federal level.

Given this backdrop, the key question is, who is likely to contribute to the proposed adaptation fund at the state and federal level and how much will they contribute? Though there is no straightforward answer to that question, it can be inferred that society should bear the responsibility of investing in adaptation (Farber, 2007). More precisely, the homeowners who are the beneficiaries of the mitigation policy have a reason to pay for it. Besides, the fund can also be collected through state or federal taxes as it benefits the entire community. We hypothesize that the household preferences for an adaptation fund are sensitive to how it is managed (state vs. federal) and the associated time range. For instance, households may prefer a state adaptation fund in the short term to receive immediate benefits of food, clothing, and temporary shelter etc. On the contrary, a federal adaptation fund may be preferred in the long run to restore economic activity, and rebuild community facilities, infrastructure, and family housing for the successful recovery from future hazards.

3.4 Survey Design and Sampling Procedure

3.4.1 Study Area

An online survey was developed to investigate households' preferences between state and federally managed adaptation funds to minimize the adverse impacts of coastal hazards. The GfK group (formerly knowledge networks) conducted the survey between

July 12 and July 22, 2013 on behalf of the researchers of Florida International University (FIU). GfK uses their unique panel (KnowledgePanel®) to respond to the survey. GfK's KnowledgePanel® is a probability-based panel in which all members have equal probability of selection. The survey sample consisted of representative adults who live in the specific hurricane Sandy affected counties in New Jersey, New York, Connecticut, Maryland, Massachusetts, Virginia, Delaware, Pennsylvania, Rhode Island, and West Virginia. The panel sample selection methodology used for this study also corrects for nonresponse and noncoverage biases in the panel. Out of 3276 participants, 2028 (61.9%) completed the survey. GfK's KnowledgePanel® administered the response rate for the sample used in this survey. This response rate is the percent of cases that qualified for the survey from the total number of participants that completed the survey. With the qualified response rate of 59.76%, a total of 1212 usable responses were received through this probability based representative survey. The proportion of respondents from each state is shown in Table 3.1. This shows that the majority of responders are from NY, NJ, MD, and PA respectively. Among them, more than 50% of the respondents are from NY and NJ.

3.4.2 Survey Methods and Sample Selection

Finding a hypothetical valuation that provides unbiased value estimates for public goods and services is a challenging task (Cummings and Taylor, 1999). Contingent valuation (CV) methods are effective in this regard and are widely used in the stated preference economics literature to obtain estimates of marketed, non-marketed, and environmental goods (Landry et al., 2011; Petrolia and Kim, 2009; Petrolia et al., 2014; Ivehammar, 2009). Furthermore, this is a handy method to evaluate preferences for public policies or projects that have not been implemented yet.

This induced us to use dichotomous CV methods to investigate preferences or willingness to pay (WTP) for adaptation funds. The questionnaires designed in our studies have a "referendum-style" structure that is common in the split-sample CV studies to determine the support for adaptation funds at the state and federal levels. While answering these stated preference CV questions, the respondent ought to believe that his or her response could potentially influence decision making, and should be aware of the outcome of the decision making (Carson and Grooves, 2007; Carson et al., 2004)

The split-sample CV methods are designed to separate the full sample into two or more sub-samples so that we can get the estimator for each sub-sample independently (Petrolia et al., 2014; Habb and McConnell, 2002). Another advantage of using the split-sample is to avoid both anchoring and ordering bias in a sample survey study. During decision making, anchoring bias occurs when individuals use an initial piece of information to make subsequent judgments and ordering bias arises when responses are affected by the *order* of answer choices. The use of split-sample rules out both anchoring and ordering bias and makes respondents state their preferences as accurately as possible on SAF and FAF.

The split-sample tests that are done in CV studies are planned for policy purposes where policy makers are interested in two or more outcome variables (Carson et al., 2001).

In our case, we split the full sample (1212) into two subsamples (606 each) and randomly ask the households about their willingness to pay for SAF irrespective of their choice of FAF and vice versa. In addition, we used the full sample to determine the combined adaptation fund (CAF), which is the support for any of the proposed adaptation funds (state/federal). Results of this stated preference study may be useful to policy makers to determine whether the fund should be raised through the state or federal income taxes in the future.

3.4.3 Survey Questions on SAF and FAF

Our split-sample survey questions are designed to determine two interrelated things of the study: first, to figure out the households' WTP for the proposed SAF and FAF, and second, to know whether households are in favor of a shorter time frame of 5 years, or the longer time frame of 10 years for payment through state/federal taxes.

We randomly select half of the total respondents (606) and ask the referendum-voting question on SAF as follows.

"Suppose that a referendum will be held for a proposed "SAF". This fund will be managed at the state level and will mobilize resources statewide to support proactive measures to minimize the adverse effects of hurricanes and related events such as costal restoration, flood protection and improved transportation. If this proposal is approved, an increase of ($100/$200/$300/$400/$500) will be charged in your state income taxes in each of the next (5/10 years). It is also notable that such increase in income taxes implies a decrease in your budget for goods and services such as food, health care, etc. Would you vote in favor of (Yes) or against (No) the proposed SAF?"

The survey response to this question is presented in Table 3.2. For each dollar amount, more respondents said "no" to the proposed SAF, leading to an overall 64.36% "no" response rate. The other 35.64% of respondents indicate that they would vote "yes" for the proposed SAF. The same response rate and breakdown of the "yes/no" responses applies to identify the time preference for the payments through state taxes. The survey response to this part is shown in the left panel of Figure 3.1. The respondents favored the longer payment time frame of 10 years (112 favorable responses) over the shorter payment time frame of 5 years (104 favorable responses).

We asked the similar referendum-voting question on FAF to the other half of the respondents as follows.

"Suppose that a referendum will be held for a proposed "FAF". This fund will be managed at the federal level and will mobilize resources nationwide to support proactive measures to minimize the adverse effects of hurricanes and related events such as costal restoration, flood protection and improved transportation. If this proposal is approved, an increase of ($100/$200/$300/$400/$500) will be charged in your federal income taxes in each of the next (5/10 years). It is also notable that such increase in income taxes implies a decrease in your budget for goods and services such as food, health care, etc. Would you vote in favor of (Yes) or against (No) the proposed FAF?"

The survey response to this question is presented in Table 3.3. For each dollar amount, more respondents said "no" to the proposed FAF, leading to an overall 64.69% "no". The other 35.31% of respondents indicate that they would vote "yes" for the proposed FAF. The same breakdown of the "yes/no" responses applies to identify the time preference for the payments through federal taxes. The survey response to this part is shown in the right panel of Figure 3.1. The respondents favored the shorter payment time frame of 5 years (120 favorable responses) over the longer payment time frame of 10 years (94 favorable responses).

3.5 Empirical Framework and Variables of Interest

We design the empirical framework to determine the marginal effects of the explanatory factors on the support for proposed state and federal adaptation funds and to figure out the WTP of the households for these programs. This induces us to apply dichotomous CV methods by imposing payments (bid prices) that will be acceptable to the respondents if they want to support the state or federal fund. The willingness to pay for the proposed hurricane mitigation fund (state/federal) is assumed to follow a log-linear form

$$\ln WTP = X\beta + \varepsilon \qquad (1)$$

where WTP for adaptation funds is a function of the vector of explanatory variables (X) that include perceived risk, temporal variations, and other household characteristics. β is vector of coefficients to be estimated, and ε is the stochastic error term. The dichotomous approach used in this study does not allow us to directly observe lnWTP. This can be observed indirectly, given that households are expected to provide a favorable answer to the dichotomous CV question only if their lnWTP is greater than or equal to the lnBID presented in the contingent scenario (Mozumder et al., 2014; Lopez; 2012). In that case, the probability of observing a positive response given the values of the explanatory variables is given by:

$$P\ (Y = 1|x) = P\ (\ln WTP > \ln BID)$$

$$= P\ (X\beta + \varepsilon > \ln BID)$$

$$= P\ (\varepsilon > \ln BID - X\beta)$$

Assuming that $\varepsilon \sim N\ (0,\sigma^2)$, we have

$$P\ (Y = 1|x) = P\ (\vartheta > \frac{\ln BID - X'\beta}{\sigma})$$

$$= 1 - \phi\ (\frac{\ln BID - X'\beta}{\sigma})$$

$$P\ (Y = 1|x) = \phi\ (\frac{X'\beta}{\sigma} - \ln BID\ \frac{1}{\sigma}) \qquad (2)$$

where $\vartheta \sim N\ (0,1)$ and $\phi\ (\cdot)$ is the standard cumulative normal. This is similar to the traditional logit model. Thus, equation (2) can be estimated by using the maximum likelihood estimation (MLE) method to solve for β and σ. The other option is to directly use the discrete choice logistic command and estimate the following.

$$P(Y=1|X) = \alpha X + \delta \ln bid + e \quad (3)$$

By doing so, we obtain the estimates for equation (3) as:

$\hat{\alpha} = \frac{\hat{\beta}}{\hat{\sigma}}$ (the vector of coefficients associated to each one of the explanatory variables),

$\hat{\delta} = -\frac{1}{\hat{\sigma}}$ (the coefficient for the variable capturing the amount of the bid).

The ultimate objective pursued in our CV study is to estimate WTP along with the confidence intervals for the state and federal funds. The median WTP can be computed by using the coefficients of equation (3) as follows:

$$WTP = e^{(-\bar{x}\hat{\alpha}/\hat{\sigma})} \quad (4)$$

Since WTP measures are non-linear functions of estimated parameters, procedures such as delta method are inappropriate as they yield symmetric confidence interval. Thus, we used Krinsky and Robb 95% confidence interval to measure median WTP as a better estimator (Creel and Loomis 1991; Jeanty 2007; Haab and McConnell 2002; Park et al., 1991).

The definition and descriptive statistics of explanatory and outcome variables used to estimate equation (3) are shown in Table 3.4. From the descriptive statistics, we found that about 35.6% support SAF and 35.3% support FAF. It is also observed that about 52% of those who prefer to support SAF are ready to make their payments through state income taxes for the next 10 years as opposed to the next 5 years. On the other hand, about 56% of those who prefer to support FAF are ready to make their payments through federal income taxes for the next 5 years as opposed to the next 10 years. This means that the respondents who are in favor of SAF prefer to make their contributions over a comparatively long run (10-year state tax) basis, while those who are in favor of FAF prefer to make their contributions on a short run (5-year federal tax) basis.

We expect a positive association between evacuation and adaptation funding (state/federal). People who evacuated during Sandy had firsthand experience of vulnerability. They are more likely to realize the need for building an adaptation fund for protecting their house, improving the transportation facilities to evacuate, and other risk reducing measures. In our study, we have found only 7% people were evacuated during hurricane Sandy. The reason behind the low evacuation rate was that most respondents (more than 87%) were not informed about the evacuation notice.

Insurance may have an ambiguous effect on implementing adaptation measures. One can hypothesize that the relation between insurance and support for an adaptation fund is likely to be negative because those who have paid for insurance premiums and are covered by an insurance policy may not feel the urge to contribute to the fund for adaptation. Since most of the respondents (59%) in our study have insurance policies to cover damage caused by hurricane Sandy, they may prefer to contribute less to the SAF and FAF compared to those who had no insurance policy to cover the damage. On the contrary, potential benefits/credits on the insurance policy may stimulate respondents to undertake the mitigation measure and encourage them to pay for the fund (Botzen et al., 2009).

The explanatory factor, window protection, is included to represent preparedness to cope with hurricane events. This is expected to be positively correlated with the support for a fund as it can help mitigate hurricane related hazards. In addition, those who are interested in increasing their safety through protecting their windows are likely to be more willing to pay for the proposed fund. The binary indicators expectation and concern depict perceived hurricane risks, which are expected to have a positive effect on the household's willingness to pay for the proposed (state/federal) adaptation fund as a risk reduction strategy.

Socioeconomic variables such as income, age, education, and household size may have an impact on adaptation behavior and willingness to pay. We hypothesize a positive association between income and support for fund. Since the cost of adaptation is a barrier, households with higher incomes are more likely to pay for the SAF and FAF. Age can have a bidirectional effect on willingness to pay for an adaptation fund (Koerth, 2016). Older people living in coastal areas may have more knowledge and experience of hurricanes than others. This will lead to a positive association between age of the respondent and support for the fund. On the other hand, older households may rate the benefits of adaptation lower than younger households due to their residual lifespan (Ge et al., 2011). Respondents with a higher education level are more likely to support adaptation measures (Richert et al., 2017; Poussin et al., 2014). Thus, we hypothesize a positive association between higher education and willingness to pay for adaptation fund. We do not make any prior hypothesis on household size as it may affect the willingness to pay in either a positive or negative way.

3.6 Results and Discussion

Based on our split-sample survey design, we run the discrete choice logit model (equation 3) for two outcome variables, i.e., support for SAF and support for FAF. The geo-coded location of respondents in support of the proposed SAF and FAF is shown in Figure 3.2. We also consider a third outcome variable as CAF; that is, the combination of the first two outcome variables. More precisely, CAF is the support for any of the adaptation funds (state/federal). We run two different discrete choice logit models (Model 1 and Model 2) for each of these three outcome variables. In Model 1, we only consider the cognitive and perceived risk related explanatory variables, whereas in Model 2 we include socioeconomic variables along with the cognitive and perceived risk related explanatory variables. Thus, Model 2 can be considered as the full model of our study. Table 3.5 and Table 3.6 show the marginal effects of these estimated logit specifications of WTP models for three outcome variables.

We present both models to show the considerable degree of robustness in terms of estimated marginal effects and WTP estimates. The Akaike Information Criterion (AIC) is used to compare models across different samples. All else being equal, the model with the smaller AIC (Model 2) is the better fitting model. In contrast, the Bayesian Information Criterion (BIC) favors a more parsimonious model specification (Model 1) over the full model (Model 2). While comparing two models on the same data, Pseudo R^2 would be higher (Model 2) for the model with the greater log likelihood. Since the sign and estimated coefficients of Model 2 (full model) are similar to Model 1, and both the value of AIC and Pseudo R^2 tend to support the model with household characteristics, we emphasize our discussion on the results of Model 2.

In Model 2, the estimated coefficient on the bid parameter is negative and significant for all three outcome variables. This implies that an increase in the bid amount would decrease the probability of respondents' support for the proposed SAF and FAF by approximately 47% points and 26% points respectively. This means the respondents are more sensitive to the bid for the SAF than FAF. The estimated coefficient for the duration of federal income tax is negatively significant for the FAF. This implies that respondents who are in favor of FAF are more willing to pay through federal income taxes for the long run (10 years) compared to the short run (5 years). On the other hand, the estimated coefficient for the duration of state income tax is not significant for SAF. This reveals that the respondent prefers FAF for the long run mitigation policy, whereas for the SAF, they have no specific time preference. The long run mitigation policies for a federal fund are also supported by some other studies (Benson and Clay 2003; MMC 2005; Hunt 2016).

The estimated coefficient on concern is positively significant for both SAF and FAF. This suggests that the households who are more concerned about the impacts of hurricanes are willing to pay more for the adaptation fund. It is also notable that the estimated coefficient of concern is higher for the SAF compared to the FAF. The estimated coefficient of insurance is found negatively significant for SAF but insignificant for FAF. This implies that households who are already insured for the hurricane related damages are less interested in paying for the SAF. Other cognitive and perceived risk related explanatory variables (evacuation, window protection) are found to be insignificant for both SAF and FAF.

Socioeconomic factors have significant effects on households' WTP. Though the sign of the coefficients for income, age, education, and household size are similar for both SAF and FAF, their levels of significance are different. For instance, age and household size are found negatively significant for the state adaptation fund but insignificant for the federal adaptation fund. On the other hand, income and education are found positively significant for the FAF but insignificant for the SAF.

We also test for the multicollinearity to make sure independent variables are not linear combinations of each other. According to the general rule, variance inflation factor (VIF) exceeding 4 requires further investigation, while VIF exceeding 10 is a sign of serious multicollinearity that needs to be corrected. The mean VIF of the models in our study is less than 2, which means there is no major concern of multicollinearity. Based on the estimated coefficients of Model 1 and 2, we construct Krinsky and Robb 95% confidence interval of median WTP for all three outcome variables. This is shown in Table 3.7 and depicted in Figure 3.3 for the convenience of understanding.

According to the WTP estimates (Table 3.7), households are willing to pay more for the SAF than FAF in both models. Specifically, in Model 2 (full model) households are willing to pay $ 68.37 for the SAF compared to $ 27.35 for the FAF. One argument in favor of higher WTP for SAF is that households may have considered federal government is likely to play a more active in post disaster management than pre-disaster management. Thus, while they are willing to pay for the proposed adaptation fund, they believe that the fund would be better utilized at the state level than at the federal level. In addition, the adaptation program managed by the federal government may need to pass through various levels of subnational fiscal and regulatory policy and may be subject to more bureaucratic scrutiny (Shobe and Burtraw, 2012). Thus, implementing effective policy for risk mitigation can be costlier and more time consuming at the federal level compared to the state level.

Several earlier studies have supported decentralization over centralized actions of the federal governments to mitigate hurricane or flood related disaster (Skidmore and Toya, 2013; Goodspeed, 2013; Escaleras and Register, 2013). Several factors are worth mentioning in this regard. First, local knowledge plays an important role for household level adaptation decisions and may positively affect state-managed adaptation programs

(Adger et al., 2009). In addition, state governments are often in a better position to know what infrastructure investments are needed in a locality before and after a natural disaster (Goodspeed, 2013). The issue of free riding can also be taken into consideration. Whenever actions are taken by the federal government, some states may free ride on others and may not contribute the share that reflects their state-specific risk exposures, and household preference for adaptation may be impacted by that. All these factors are likely to contribute to lower WTP for FAF.

3.7 Conclusion

In this paper, we analyze households' participation in the implementation of proactive adaptation measures to mitigate coastal vulnerability. Given that hurricane is a natural phenomena and we cannot control its characterstics (e.g., intensity, time left for landfall, storm surge etc.), we proposed a fund to manage coastal vulnerability. By using the split-sample for a proposed State Adaptation Fund (SAF) and Federal Adaptation Fund (FAF), we apply the discrete choice logistic model and show that households are willing to pay more for a State Adaptation Fund (SAF) compare to a Federal Adaptation Fund (FAP). It can also be inferred that households consider state agencies more suitable than federal agencies in managing extreme weather-related disaster risks. On the other hand, federal agencies play an important role in disbursing funds for disaster-management risk.

Williams (2012) has used an analytical approach to evaluate the efficiency of state and federal actions on environmental policy. One of the major findings of his paper is that the state and federal taxes for implementing environmental policy yield more efficient outcomes than federal command and control policy. Moreover, if the states are more likely to supplement the national tax with their own taxes, this will lead to a more efficient outcome than a national tax alone. This suggests that there is a need of an optimal mix of responsibility between state and federal governments in promoting adaptation and disaster management activities. More generally, households may consider contributing to both state and federal funds to manage coastal vulnerability. In closing, we believe that this study provides some insights for policymakers to realize whether adapation policies to reduce climate change and coastal hazards risk should be managed at the state or federal level or a combination of both. Given that the United States has a significant number of populations living in coastal areas that are exposed to increasing levels of vulnerabilities, we hope that the analysis will be useful for future planning purposes.

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TABLES

Table 3.1 Distribution of Survey Respondents (in Percentage) Across States

Name of the State	Percentage of Survey Respondents	Cumulative Percentage
Connecticut	6.87	6.87
Delaware	2.74	9.60
Massachusetts	3.95	13.56
Maryland	10.26	23.82
New Jersey	25.91	49.73
New York	33.45	83.18
Pennsylvania	10.10	93.27
Rhode Island	2.73	96.00
Virginia and West Virginia	4.00	100.00

Table 3.2 Willingness To Pay (WTP) for State Adaptation Fund (SAF)

State	Bid Amount					Total
Fund	100	200	300	400	500	
0	55.00	62.10	70.00	69.23	65.57	64.36
1	45.00	37.90	30.00	30.77	34.43	35.64

Table 3.3 Willingness To Pay (WTP) for Federal Adaptation Fund (FAF)

Federal	Bid Amount					Total
Fund	$100	$200	$300	$400	$500	
0	61.48	63.56	57.03	73.11	68.91	64.69
1	38.52	36.44	42.97	26.89	31.09	35.31

Table 3.4 Definition of Variables of Interest and Descriptive Statistics

Variable	Definition	Mean	Standard Deviation
SAF	If the respondent is in favor of the SAF (1 = yes, 0 = otherwise)	0.356	0.479
FAF	If the respondent is in favor of the FAF (1 = yes, 0 = otherwise)	0.353	0.478
CAF	If the respondent is in favor of either SAF or FAF (1= yes, 0 = otherwise)	0.359	0.481
lnstate bid	Natural log of the annual contribution to the SAF	5.567	0.571
lnfederal bid	Natural log of the annual contribution to the FAF	5.561	0.567
lnbid	Natural log of the annual contribution to any of the SAF/FAF	5.564	0.568
state tax time	If the respondent is in favor of the 5 years state taxes for SAF (1= yes, 0 = otherwise; 10 years)	0.485	0.501
federal tax time	If the respondent is in favor of the 5 years federal taxes for FAF (1= yes, 0 = otherwise; 10 years)	0.561	0.497
tax time	If the respondent is in favor of 5 years state/federal taxes for CAF (1= yes, 0 = otherwise; 10 years)	0.521	0.499
evacuation	If the respondent evacuated when hurricane Sandy hit (1= yes, 0 = otherwise)	0.076	0.265
Insurance	If the respondent has an insurance policy to cover damages caused by Sandy (1= yes, 0 = otherwise)	0.590	0.265
window protection	If the respondent had window protection during Sandy (1= yes, 0 = otherwise)	0.055	0.227
expectation	If the respondent thinks that his home will be affected by hurricane in the next 10 years	0.754	0.511
concern	If the respondent is concerned about the impacts of intense hurricane (1= yes, 0 = otherwise)	0.512	0.501
income	Household’s income group (1= less than 5000; 2 = 5,000-9,999; …….19 = 90,000+)	13.152	4.155
age	age of respondent (in years)	52.91	15.43
education	respondent’s years of education (in number)	11.371	1.640
hhsize	number of household members	2.49	1.285

Table 3.5 Marginal Effects from Estimated Logit (Model 1)

Variable	State Adaptation Fund (SAF)	Federal Adaptation Fund (FAF)	Combined Adaptation Fund (CAF)
lnstate bid	- 0.434 (0.156)***	-	-
lnfederal bid	-	- 0.247 (0.160)	-
lnbid	-	-	- 0.324 (0.108)***
state tax time	- 0.151 (0.178)	-	-
federal tax time	-	- 0.359 (0.188)**	-
tax time	-	-	- 0.215 (0.125)*
evacuation	0.478 (0.329)	0.075 (0.262)	0.352 (0.228)
insurance	- 0.300 (0.179)*	- 0.209 (0.199)	-0.241 (0.126)**
window protection	0.584 (0.415)	0.358 (0.393)	0.448 (0.269)
expectation	0.144 (0.211)	0.379 (0.233)*	0.278 (0.153)*
concern	0.814 (0.188)***	0.392 (0.193)**	0.540 (0.129)***
constant	1.456 (0.872)*	0.625 (0.911)	0.918 (0.615)
observations	596	582	1178
Pseudo R^2	0.047	0.023	0.030
AIC	759.947	675	1510.692
BIC	795.082	709	1551.271

Note: Numbers in parentheses are the corresponding standard errors; *** Significant at 1% levels, ** Significant at 5% levels, * Significant at 10% levels.

Table 3.6 Marginal Effects from Estimated Logit (Model 2)

Variable	State Adaptation Fund (SAF)	Federal Adaptation Fund (FAF)	Combined Adaptation Fund (CAF)
lnstate bid	- 0.473 (0.161)***	-	-
lnfederal bid	-	- 0.263 (0.163) *	-
lnbid	-	-	- 0.327 (0.110)***
state tax time	- 0.121 (0.181)	-	-
federal tax time	-	- 0.367 (0.193)**	-
tax time	-	-	- 0.220 (0.126)*
evacuation	0.467 (0.357)	0.117 (0.265)	0.330 (0.240)
insurance	- 0.307 (0.186)*	- 0.285 (0.215)	- 0.260 (0.126)**
window protection	0.621 (0.416)	0.429 (0.416)	0.502 (0.281)*
expectation	0.154 (0.218)	0.312 (0.238)	0.257 (0.155)*
concern	0.828 (0.195)***	0.435 (0.196)**	0.546 (0.131)***
income	0.014 (0.027)	0.058 (0.029)**	0.027 (0.018)
age	- 0.012 (0.006)*	- 0.008 (0.007)	- 0.008 (0.004)*
education	0.088 (0.068)	0.134 (0.071)**	0.102 (0.048)**
household size	- 0.298 (0.097)***	- 0. 112 (0.087)	- 0.153 (0.597)***
constant	1.815 (1.221)	- 0.851 (1.311)	0.242 (0.853)
observations	596	582	1178
Pseudo R^2	0.071	0.046	0.043
AIC	746.870	668.243	1495.925
BIC	799.552	719.150	1556.784

Note: Numbers in parentheses are the corresponding standard errors; *** Significant at 1% levels, ** Significant at 5% levels, * Significant at 10% levels.

Table 3.7 Krinsky and Robb 95% Confidence Intervals of Median Willingness To Pay (WTP) for Model 1 and Model 2

Model	Variable	Median WTP	Lower Bound	Upper Bound	ASL*
	State Fund	63.82	2.47	122.01	0.000
1	Federal Fund	25.50	0.23	59.67	0.008
	Fund (Combined)	40.72	1.17	88.79	0.008
	State Fund	63.82	2.47	122.01	0.000
2	Federal Fund	25.50	0.23	59.67	0.008
	Fund (Combined)	40.72	1.17	88.79	0.008

Notes: *Achieved Significance Level (ASL) is for testing H_0: WTP<=0 vs. H_1: WTP>0.

FIGURES

Figure 3.1 Average Willingness To Pay (WTP) for the Proposed State Adaptation Fund (SAF) and Federal Adaptation Fund (FAF) for Next 5 and 10 Years

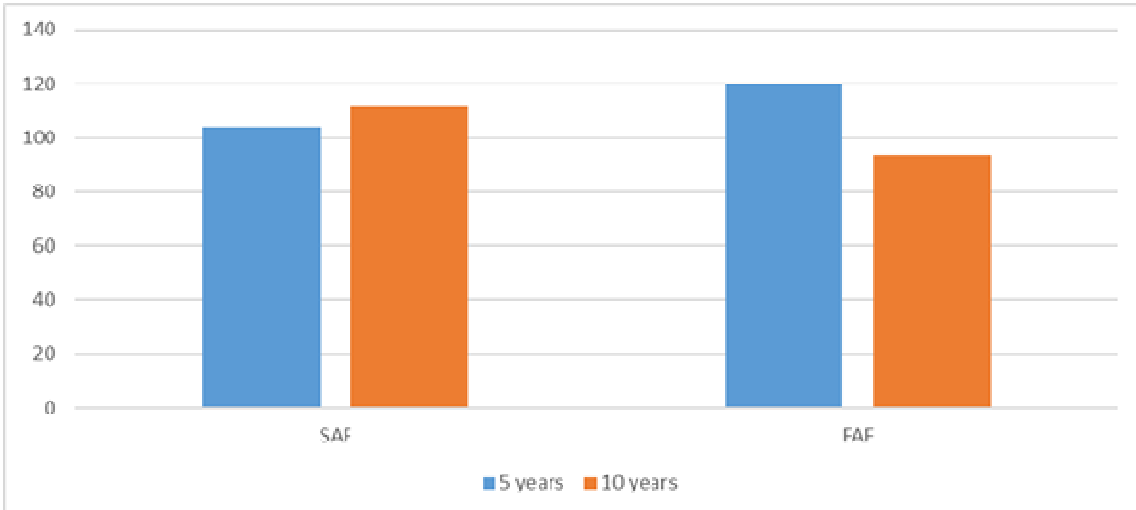


Figure 3.2 Geo-coded Household Location and Their Preference for the Proposed State Adaptation Fund (SAF) and Federal Adaptation Fund (FAF)

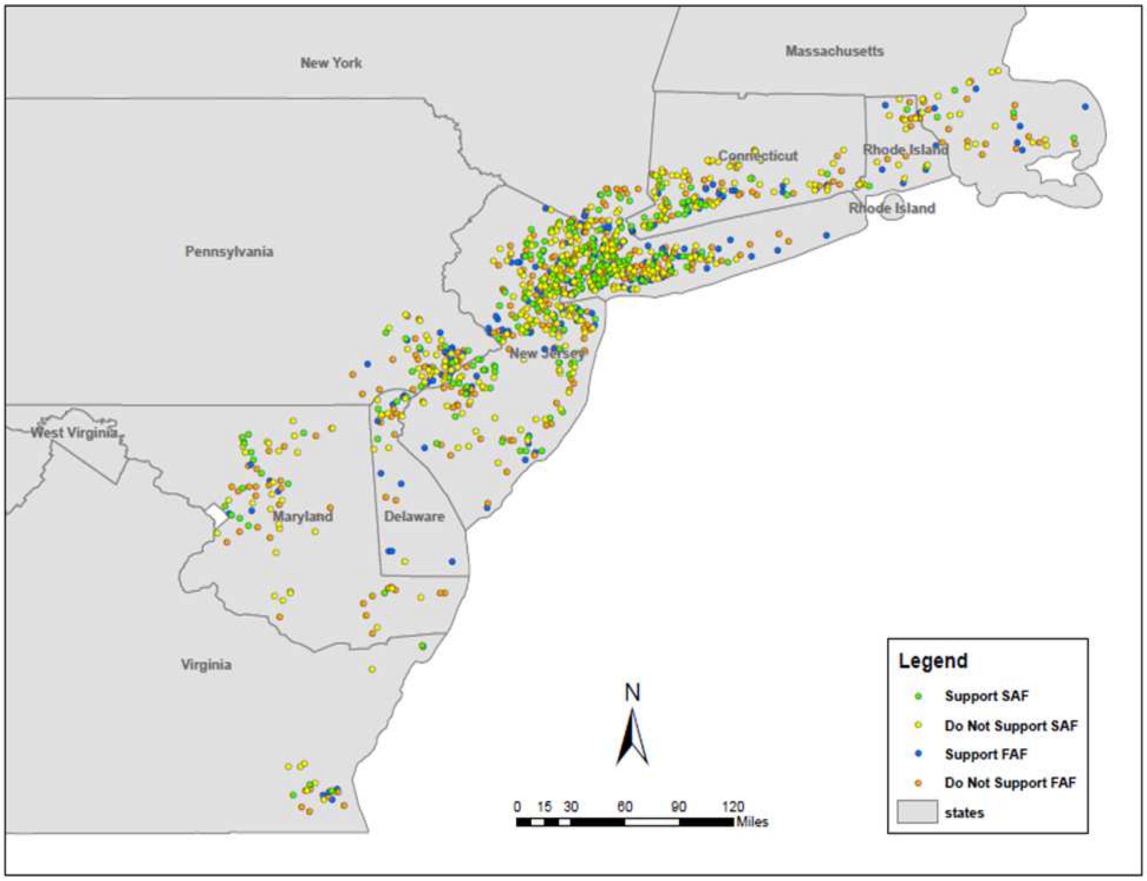
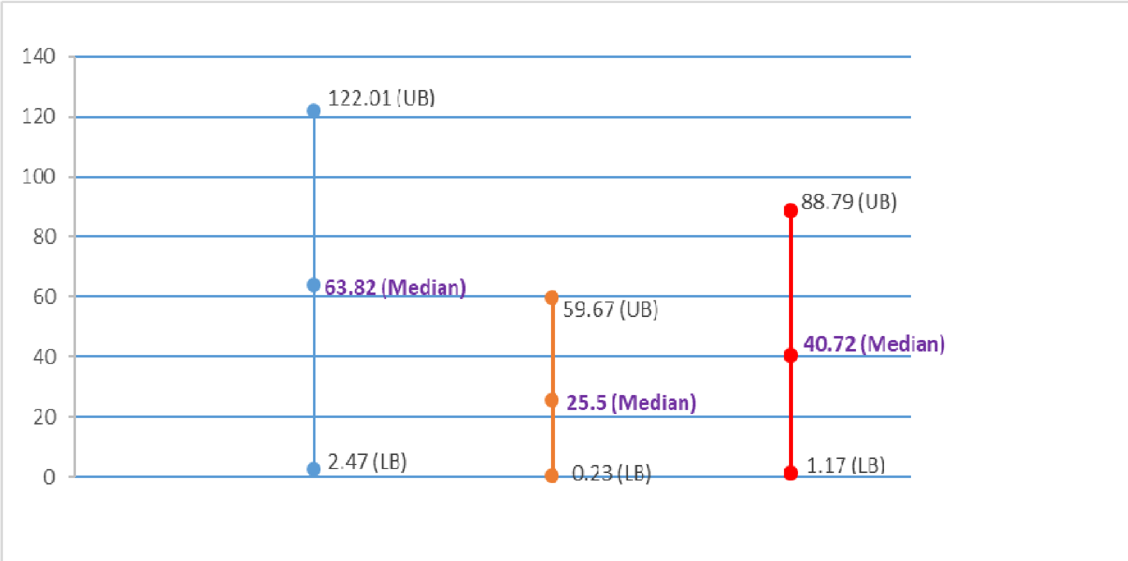
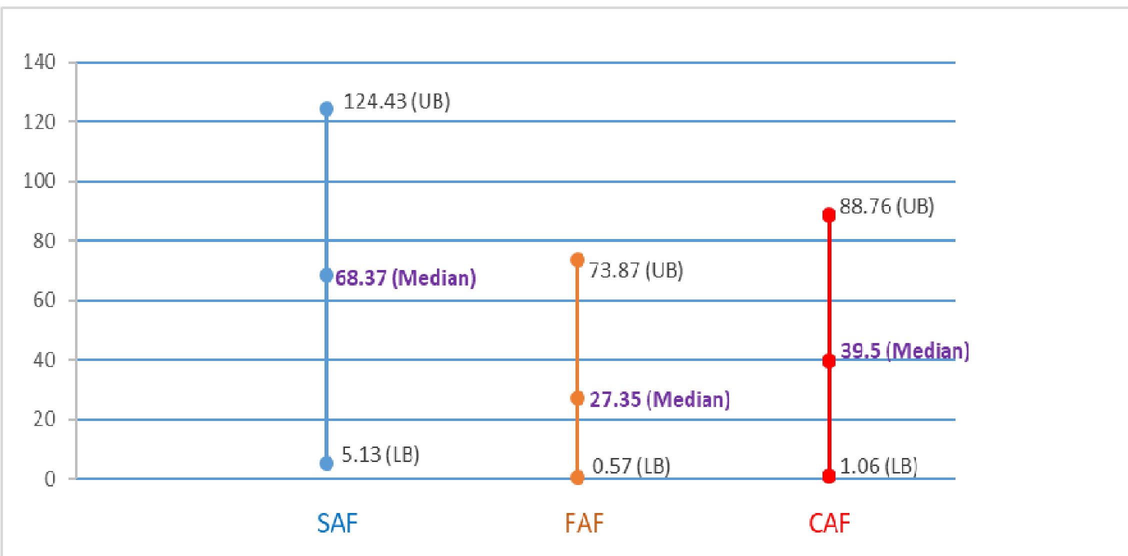


Figure 3.3 Median Willingness To Pay (WTP) Estimates with Lower and Upper Bounds from Model 1 and 2



Notes: LB and UB stand for lower bound and upper bound of WTP estimates for Model 1.



Notes: LB and UB stand for lower bound and upper bound of WTP estimates for Model 2.

CHAPTER 4

CONCLUSION

4.1 Summary and Contribution of the Dissertation

In general, weather is considered as the short-term variation of rainfall or precipitation whereas climate is the long-term average of the weather. The common link between extreme weather events and climatic shocks are the deviation of short term or long-term changes of weather. In other words, climatic shocks are the frequency of extreme weather events that include severe rainfall, flooding, cyclone, drought, river erosion, sea level rise, salinity, tidal wave among others.

Climate change poses a serious challenge to the people of developing and developed countries. However, the magnitude of vulnerability varies in terms of geographical location, living and economic condition of the households, infrastructure among others. That is why it is not feasible to implement a uniform adaptation strategy to manage extreme weather events and climatic shocks for both developing and developed countries. This motivates me to investigate the country specific adaptation strategies to cope with natural hazards.

It is evident from the scientific literature that Bangladesh is amongst the developing countries most affected by climate change. People living in the coastal communities, subsistence farmers, and the very poor have the lowest capacity to cope with the natural disaster. Therefore, I use the data from Bangladesh for pursuing the adaptation research for the first and second chapters of my dissertation.

In the first chapter, I conduct a study on the coastal communities of Bangladesh to identify whether internal migration can be considered as an effective coping instrument to transient and/or permanent environmental shocks. Findings of the study suggest that migration is an effective coping mechanism only if the households migrate to the nearest metropolitan city to survive permanent environmental shocks.

The second chapter of my dissertation focuses on the households of Bangladesh whose main source of income comes from the agricultural sector. These subsistence farmers are challenged by several factors including—weather and epidemic shocks, lack of earnings and financial support, illiteracy and insufficient knowledge on adaptation strategies, lack of support from the public and private sectors among others. The findings of the study suggest that farmers are ready to choose several agricultural adaptation options to minimize the loss of agricultural income driven by climatic shocks. It is also evident that farmers who obtain more credit from formal and/or informal sources, are more willing to adapt.

Despite of the fact that the developed countries have better instruments to cope with natural hazards than the developing countries, they are still in need of implementing proactive mitigation strategies to manage extreme weather events and climatic shocks. With this motive in mind, in chapter three I explore the adaptation strategy to manage coastal vulnerability in United States. Since developed countries have greater scope of generating funds for adaptation, I attempted to investigate whether these funds can be generated at the state or at the federal level. Given that home insurance in the United States is managed at the state level and flood insurance is managed at the federal level, it is relevant to know whether households are willing to pay for the state adaptation fund or for the federal adaptation fund to manage coastal vulnerability. The findings of my study suggest that households consider state agencies more suitable than federal agencies in managing extreme weather-related disaster risks and are thus ready to pay more for the state adaptation fund.

4.2 Policy Implications and Scope for Further Research:

In three different chapters of my dissertation, I attempted to exhibit how internal migration, agricultural adaptation, and fund for adaptation can be used as a coping instrument for managing extreme weather events and climatic shocks. I believe that this study provides some useful insights for policymakers to realize which adaptation strategies are more effective and for which country. It is also evident from the study that the role of local, state, federal government, and private sectors is crucial to climate change response strategies by disbursing financial support (credit, relief), and education (knowledge on climate change and adaptation options) to those who are vulnerable to disaster shocks.

For further adaptation research, I want to investigate the extent to which the livestock sector is impacted by the environmental and epidemic shocks and analyze the effectiveness of different adaptation strategies to cope with risk as it relates to livestock productivity in the context of developing and developed countries.

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