THE ECONOMICS OF NON-COMMUNICABLE DISEASES IN RURAL BANGLADESH

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Abstract

Background: In Matlab, Bangladesh, a rural sub-district with ongoing demographic surveillance, an epidemiological transition is well under way with an emerging burden of disease attributed to non-communicable diseases (NCD). In this setting there is a need to understand NCDs in terms of socioeconomic determinants and economic impacts to individuals and households, which helps inform the decision to develop NCD-related public policies. This work addresses these issues by characterizing the education gradient in mortality over a period of 24 years and by evaluating the household-level economic impacts after an adult NCD death and subsequent coping strategies.

Methods: Paper #1 uses data from the routine Matlab surveillance system for the populations in 1982, 1996 and 2005, looking prospectively at both NCDs and infectious disease mortality over a five year follow-up period. Cox proportional hazard models are used for multivariate analysis to assess the education gradient in mortality for each broad cause of death category and to what extent components of wealth, occupation and marital status contribute to this gradient. In papers #2 and #3, all of the adult NCD deaths in 2010 in Matlab were identified and directly matched to a comparison group of households with no deaths. A regression standardization approach is used in Paper #2 to obtain a marginal estimate of the relative risk of a household being poor after an NCD death in terms of an asset-based wealth index, self-rated economic condition and land ownership. Paper #3 examines the coping strategies that households use after an NCD death. Logistic regression is then used to look at household and individual-level characteristics related to coping and an econometric difference-in-difference (DiD) approach is used to examine changes in household composition.

Results: Paper #1 finds a larger education gradient for females for both NCD and infectious disease mortality when the data is pooled for all three time periods. For both males and females, a larger gradient is also found for infectious diseases. Marital status of an individual explains more of the education gradient in mortality than occupational status or household wealth. Paper #2 shows that there is a 14-19% increased risk of a household being poor two years after an adult NCD death, depending on which measure of economic status is used. Individual characteristics of a male death, prime age death or death of a married household member leads to a higher risk of a household being poor. In Paper #3, the results for coping enriches this picture further. The most common coping strategy among households after the death was the reduction of spending on basic household items. A prime age death is positively associated with the most number of coping strategies, four, and there is evidence that poorer households have more limited coping options. The DiD results for household composition show that households moderately replace human capital in terms of recruiting new adults to the household and that households are more likely to recruit adult females after a prime age death.

Conclusion: The rising NCD burden in low income countries means that more understanding of the economic impacts of these diseases is needed. Using census data in the demographic surveillance system in rural Matlab, Bangladesh, this dissertation explores the individuals and household economic impacts associated with NCD deaths. An NCD death has the potential to impose severe economic consequences for households, impacting household wealth and propagating a poverty trap where poor household are not able to make gains in terms of economic mobility. Health shocks from NCDs lead to coping strategies that may have long term negative consequences for

households. This appears to be especially true when the death is to a prime, working-age household member.

Policy Recommendation: This work emphasizes the need for more intense prevention efforts for NCDs in rural Bangladesh. In Matlab, where this study is based, there have been intensive efforts to reduce maternal and childhood mortality that has been documented as a global success story. This work shows that there are important distributional and efficiency concerns related to NCD health that should motivate more public intervention. In terms of equity, there are higher rates of mortality among the least educated and health gains can be made with continuing progress in rural education and access to social psychological resources. As well, there may be longer term costs to household members, in terms of a poverty trap, when there is an NCD death. Better access to financial protection resources and preventive care is needed. This is especially true for households that are at risk of having a premature adult death. The review of the economic impacts from NCDs that are provided from this work provide an argument for developing more NCD-related policies in rural Bangladesh.

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Role in the Study

This study is part of a larger initiative by the NHLBI and United Health to fund centers of excellence for NCD research. Through this effort, a partnership with Johns Hopkins School of Public Health and icddr,b Center for Control of Chronic Disease (CCCD) was facilitated. The partnership fostered a two-phase grant to look at the economic consequences of NCDs. Phase I explores the historical inequality in NCD mortality in Matlab and Phase II develops a survey to measure the economic impacts and coping strategies. I have served as a Research Assistant from 2011 to 2014 on this project in Baltimore, MD and in Dhaka, Bangladesh. For Phase I, I have provided technical assistance and writing support to the study team. For Phase II, I have participated in developing the data collection instrument, piloting and field testing the instrument, training data entry staff, analysis of the data and drafting of the final manuscripts.

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List of terms and abbreviations

ATT – Average treatment effect on the treated

COPD – Chronic obstructive pulmonary disease

DALY – Disability adjusted life year

DiD – Difference in difference

GBD – Global burden of disease

GDP – Gross domestic product

HR – Hazard ratio

ICD – International classification of disease

Icddr,b – International Center for Diarrhoeal Disease Research in Bangladesh

IV – Instrumental variable

OLS – Ordinary least squares

MDG – Millennium development goal

MFI – Microfinance institution

NCD – Non-communicable disease

RDD – Regression discontinuity design

RR – Relative risk

TMLE – Targeted Maximum Likelihood Estimation

WHO – World Health Organization

Chapter 1. Introduction

1.1 Study Rationale and Background Literature

1.1.1 The Non-Communicable Disease Burden Globally and in Bangladesh

Worldwide there is an interest in developing health systems to meet the emerging burden of NCDs. In terms of overall burden, NCDs are the dominant cause of disease in high income countries and most low and middle-income countries as well. Global health research and international aid, however, have historically been targeted to addressing the burden of disease from maternal and childhood related illnesses. The Millennium Development Goals (MDG) have set global targets for reducing the rates of maternal and childhood illness and there have been intense efforts globally to invest in programs addressing HIV/AIDs, malaria and tuberculosis. The global efforts to address NCDs are just beginning to take shape. In September of 2011, the United Nations held its first high level meeting on NCD prevention and control (1). As a result of this meeting, the Secretary General laid out a 5 step plan for addressing NCD management and prevention by engaging all sectors of society and by learning lessons from the ongoing efforts to tackle diseases such as HIV/AIDS and Tuberculosis.

Low and middle-income countries represent a large share of the total global burden of NCDs, accounting for 80% of the cardiovascular disease and diabetes deaths, 90% of the chronic obstructive pulmonary disease (COPD) deaths and more than two thirds of the malignant neoplasm deaths worldwide (2). In South East Asia, a World Bank report concluded that the burden of disability adjusted life years (DALY) from NCDs in that

region is already greater than that of communicable diseases, maternal and child health conditions and HIV/AIDS combined (2). In the country of Bangladesh, the Global Burden of Disease (GBD) reports that from 1990 to 2010 there was a 244% increase in years of life lost (YLL) attributed to ischemic heart disease and a 133% increase in the YLLs from diabetes and no infectious diseases increased by more than 22% (3). Coupled with the World Health Organization's (WHO) 2010 STEPS survey for NCD related risk factors, which showed alarmingly high levels of risk factor prevalence with 99% of adults reporting having at least one risk NCD risk factor (4).

One snapshot of Bangladesh comes from looking at Matlab, a rural area with demographic surveillance that has been ongoing for several decades. Here, there has been a large decline in the burden from infectious diseases that has been countered by a large increase in the burden from NCDs (5). NCDs now account for nearly 80% of the burden in mortality in Matlab (6). Yet, Matlab is a poor rural area with an informal agrarian economy and low levels of education. The situation in Matlab and Bangladesh should dispel the myth that NCDs in low income countries are a "disease of the rich". The burden of NCDs affects all levels of Bangladeshi society.

1.1.2 The Costly Emerging Burden and the Case for Public Policies

The increasing awareness of the emerging burden from NCDs worldwide means understanding the relationship between economic status and NCDs needs to be better understood. In more general terms, there is a well-known bi-directional relationship between health and wealth. This has led to research that attempts to disentangle this relationship in order to make effective health and development policies. At the

macroeconomic level, a well-known positive relationship exists between a country's income and its level of health. This was famously noted by Samuel Preston with his "Preston Curve" in a work in 1975 looking at gross domestic product (GDP) and life expectancy (7). The trend of the rising burden of NCDs in many countries worldwide means that the role or NCDs in this relationship will only become more important over time. A report published for the 2010 World Economic Forum found that the growth in NCDs over the next 20 years will cost $ 47 trillion, representing three quarters of the world GDP in 2010 (8).

Understanding more fully the economic consequences of NCDs may provide more justification for public policy to tackle the burden. There are three traditional reasons why government intervention may be needed: efficiency, equity and stability (9). Here, efficiency refers to the functioning of markets, equity refers to distributional considerations and stability refers to the minimizing the peaks and troughs of the business-cycle. This dissertation is only concerned with the equity and efficiency arguments.

There may be an equity argument for public policy interventions to address NCDs if there are inequalities around socioeconomic status and age. For infectious diseases, this argument has been made very clear since there are strong linkages between being poor and having higher levels of infectious disease, and for infectious diseases affecting the young, specifically those under five years, more strongly. NCDs, have traditionally been considered diseases that affect those who are older and who are not poor. There is strong evidence, though, that this notion is misleading. Previous studies that have looked at

aggregate burdens across countries, disaggregated by region and income group, show that in all regions of the world except Sub-Saharan Africa, NCDs are the leading contributor to disease burden and that its contribution in relation to infectious diseases is getting larger over time (10). It should be noted, however, that the rising NCD burden is in the context of the overall disease burden and that given the trends of population aging and transitioning country demographics, the global NCD burden may actually be getting smaller when age-standardized rates are used. In addition, the burden of NCDs falls heavily on those who are under age 60 at more than twice the prevalence, in terms of overall deaths, in low and middle-income countries as for high income countries, 29% compared to 13% according to a 2010 WHO report (11).

In terms of efficiency, the case has been made for maternal and infectious diseases that there is justification for public intervention because of externalities, or costs that are incurred outside of the primary actor (12). For NCDs, the rationale is less clear. In a review of the efficiency argument for public policy intervention for NCDs, Suhrcke and colleagues lay out a framework to explain where market inefficiencies may exist (13). Using several examples from the tobacco and nutrition literature as empirical examples, they identify inefficiencies in terms of the costs and rational behavior. In terms of costs, they state that most of the costs that are incurred from NCDs are private, which traditionally includes costs to household members. There are examples, however, where intra-household costs are considered to be external costs and thus provide more justification for public policy (14). In developing countries, there may be an even stronger case for classifying intra-household costs as external due to larger household sizes and reduced bargaining power within the household, especially for women and

children (13). There is also an argument that actors may not be fully rational because of the inefficiencies such as asymmetric or insufficient information about NCD risks and that actors may have time-inconsistent preferences that prevent them from acting rationally in the present. If these inefficiencies exist, then individuals behave too myopically, and there may be a justification for government involvement. Proposed interventions to correct market inefficiencies could be higher taxes, information campaigns and subsidization of prevention, which will likely be underprovided in a market setting (15).

In Bangladesh, there is already some evidence that there are large costs imposed by NCDs and that there may be equity and efficiency reasons for establishing public policies to tackle them. A Lancet study from 2007 found that Bangladesh will lose a substantial $1.14 billion in GDP from 2006 to 2015 due to heart disease, stroke and diabetes (16). In other studies, using representative survey data for the entire country have found that NCDs will push 4.61% of households into poverty annually due to out of pocket expenditures (17). It has also already been shown that the NCD burden in terms of risk factor prevalence is more likely to affect the poor (18). The lack of current national surveillance and public health services for NCDs will pose a significant challenge for the country of Bangladesh in the future. There are current policy efforts to establish a framework for moving forward to address health systems requirements of NCDs (19). The large economic impacts of improved NCD health make the case for these efforts more compelling.

1.1.3 The Study Setting – Matlab, Bangladesh

The rural area of Matlab, Bangladesh, represents a unique opportunity to study the relationship between socioeconomic status and NCDs. The long-running demographic surveillance site that collects vital statistics information for the entire population of close to a quarter of a million people has been functioning for several decades. Cause of death data has been collected throughout and in the past decade a verbal autopsy system has been used for assigning causes of death to international classification of disease version 10 (ICD-10) coding. Many studies in low-income countries looking at the health and wealth relationship in the past do not have access to this type of objective health data and used self-rated health instead, which may suffer from reporting bias from the economic status of the respondent (20, 21). The surveillance system in Matlab also collects periodic socioeconomic status information, which permits an understanding of differentials in health outcomes according to economic standing at approximate 10 year cross-sections. It should also be noted, however, that while trends in reduced maternal and child health indicators in Matlab have been replicated in other parts of Bangladesh, Matlab is an area with disproportionate levels of programming and surveillance where maternal and child health services are provided freely. Caution when generalizing research findings from Matlab to other areas of the country and world has been noted in previous research.

1.2 Conceptual frameworks

1.2.1 Socioeconomic Gradients and the Relationship between Education and Mortality

To further understand the bi-directional relationship between health and wealth, there have been several proposed frameworks. One element of this relationship looks at explaining the consistent positive relationship between socioeconomic status and health. Three primary indicators of socioeconomic status are considered to be wealth (or income), occupation and education, and all three have been examined for their association with health outcomes. A consistent finding in the literature is that those who are worse off are more likely to have worse health. In developed countries, seminal work has been from the Whitehall II study in the UK, finding worse mortality outcomes for those that are lower in the social hierarchy according to occupational status (22). For conclusive results showing the income and education gradients in mortality in the US, work was done by Lynch and colleagues and by Kitagawa and Hauser (23, 24). In low and middle-income countries, a similar relationship between socioeconomic status and health is found. One study by Caldwell in the 1970's, for example, shows a positive relationship between education and child survival in Nigeria (25). Barros and colleagues also review the literature for socioeconomic disparities that are seen in child mortality in low and middle income countries, with evidence found in the Demographic and Health Surveys (DHS) and UNICEF Multiple Indicator Cluster Survey (MICS) (26).

Economists and health researchers have developed frameworks that look at the production of health as a function of inputs at multiple levels, such as for individuals or

for households. The idea of a health production function has originally proposed by Grossman and has since been a mainstay for health economics research (27). There is even a nod to this type of thinking in a framework for the production of child health according to determinants at various levels, including the education of parents (28). The relationship between education and health is complex. Researchers have been interested in the causal relationship between the two and using quasi-experimental studies in developed countries, have found mixed results for the strength of the causal pathway in either direction. There is, however, a strong correlation between education and health that is important (29, 30).

Another understanding of the relationship between education and health has been through the development of frameworks to identify the mechanisms through which education affects health. For clarity, these will be referred to as the "components" of the education gradient throughout the dissertation. These frameworks have been developed in several social science disciplines such as economics, sociology and demography (31-35). While there are several different categorizations of these components, ones that are commonly found include: socioeconomic status, social psychological resources and health behaviors. These components may help explain the economic gradient in health at multiple levels, such as at individual or household level (36). In recent economics literature there has also been an increasing focus on further components of the gradient which may include cognitive abilities, risk-aversion tastes and more comprehensive understandings of social networks (37, 38).

A diagram for the conceptual framework that is used in this work is shown in **Figure 1-1.** The figure shows a bar that reaches a positive value in a two-dimensional plane. This is representative of the positive association between education and health, which is also called the education gradient in health. In this framework, the education gradient should only be considered a cross-sectional association. As an example, one could think of this as the positive association between years of education and life expectancy. The figure also shows that several other boxes make up the education gradient. These boxes are the components of the gradient, which represent factors that may be associated with the education and health relationship that also partly explain the education gradient. The components themselves may also independently be associated with health and are thus not fully represented by the education and health gradient. Understanding of the gradient in this manner has been found in several key works that look at the education gradient and its components (35, 37, 39). We have not been able to find any visual representation of this framework and analysis approach in the literature and thus believe that **Figure 1-1** is the first visualization of the education gradient components approach.

1.2.2 The Economic Consequences of Poor Health

A second set of frameworks examines the economic consequences of health. This topic focuses on the economic impacts as a consequence of poor health. These frameworks, however, do not completely remove the concept of *a priori* socioeconomic status because they also account for the fact that the impacts of health shocks may be different by initial economic condition. In the US, seminal work by Smith showed that adverse health could lead to a worsening economic condition (40). Studies that look at the economic impacts

of adverse health events have termed these events “health shocks”, which is a subset of broader economic shocks, which may be due to individual level adverse events (idiosyncratic) or broader level adverse events (covariate). Research on health shocks have proposed that these are idiosyncratic events with exogenous properties that may be used for understanding the causal impact of health on wealth (20, 21, 41).

To understand how adverse health events effect economic outcomes, there have been two frameworks proposed. One of these was proposed by Russell, which establishes that poor health can impact household wealth through direct and indirect costs (42). A similar framework, published two years after Russell’s was proposed by McIntyre and colleagues (43). This framework included the concept of direct and indirect costs but also described specific coping mechanisms that households use in response to these costs (43). Employing the McIntyre framework in research in Bangladesh has previously been done as well (44). A modified version of the McIntyre framework was used to look at coping for this dissertation (see Chapter 4). Coping strategies are divided into three main categories: financial, demographic and behavioral, and ten individual coping strategies are divided among the three categories. The modified framework is seen in **Figure 1-2.**

1.3 Study Objectives

The goal of this dissertation is to evaluate microeconomic aspects of NCDs in a rural, low income area of Bangladesh with a long-running surveillance system. The work will characterize the education gradient for NCDs and infectious diseases in this area and look at the components of the education gradient such as income, occupation and marital

status. To look at the economic impacts of an adverse health event from an NCD, this work will also use a matched cohort study and a newly developed statistical estimator to attempt and measure the marginal relationship between an NCD death and being poor. Lastly, the risk of being poor because of a health event likely occurs because of channels of influence that cause a household to incur health expenditure and lose production capacity. The third focus of this work will examine which coping strategies are used after an NCD death and whether or not there are changes to household composition, defined as the total number of household members as well as the total number of members according to gender and age (male or female; child or adult). The specific research objectives and sub-objectives are listed as follows:

1. To explore the education gradient from adult mortality in Matlab, Bangladesh.
    a. Characterize the education gradient in mortality for adult NCD and infectious disease deaths.
    b. To explore the components of the education gradient and to what extent factors related to wealth, occupation and marital status explain the gradient.
2. To evaluate the economic impact on households from a health shock from an NCD death in Matlab, Bangladesh.
    a. To assess whether an NCD health shock leads to a higher risk of being poor two years after the death according to three different measures of economic status.
    b. To examine the individual-level characteristics of the deceased that are associated with a higher risk of being poor after an adult NCD death.

3. To evaluate the coping strategies that a household uses after a health shock from an adult NCD death in Matlab, Bangladesh.
    a. To identify which coping strategies households use after an adult NCD death.
    b. To explore what individual and household-level characteristics are determinants for using certain coping strategies.

In the first objective, the hypothesis is that there will be an education gradient in NCD mortality. The component of wealth is hypothesized to contribute the most to the gradient in education, however, given the informal economy and overall low levels of wealth in Matlab, there may be large roles for non-monetary components of the education gradient.

For objective #2, the hypothesis is that a death to a prime age adult member of the household from NCD will lead to a higher risk of a household reporting being poor in the two year period after the death. Households with a death to prime age member, male member, head of the household or member with a higher level of education will be at the highest risk of being poor.

Objective #3 adds to the picture the spectrum of coping strategies that households use after a death. The hypothesis in this analysis is that households will engage in several types of activities to smooth consumption after the shock from a death. Those households where the death represents a more severe economic impact, such as the death to a prime age member may attempt to replace the lost household member. Coping strategies may have the largest negative impacts for poorer households if they are not able to smooth consumption after a death and thus contribute to a cycle of poor health and poverty.

The three objectives of this work have to do with understanding the economics related to the NCD burden in adults in low and middle-income countries in terms of the impacts at the household level and how households may experience differing impacts based on the characteristics surrounding the death and the household's level of resources. The organization of the rest of the thesis document is detailed in the following section.

1.4 Organization of the dissertation

The remainder of this dissertation is organized as follows:

- Chapter 2: Explores the first objective looking at the education gradient in mortality for infectious diseases and NCDs in Matlab over a 24 year period using demographic surveillance data and periodic socioeconomic status census data. The contribution of each of three components of this gradient are evaluated according to sex and cause of death.
- Chapter 3: Explores the wealth impact of having a shock from an NCD death in Matlab. This is done with a new survey and matched-cohort study. A marginal estimate of the risk of being poor is developed using a regression standardized estimator specifically for matched cohort designs.
- Chapter 4: Explores the economic impact from an NCD death through the coping mechanisms that households use after the death. Individual and household-level determinants of coping are explored and a difference-in-difference analysis is used to examine coping in terms of human capital replacement.
- Chapter 5: Concludes the thesis and offers final policy messages.

The main tables and figures for each paper appear at the end of each chapter. Additional tables and figures are included in the last sections of the document in the appendices.

1.5 Figures for Chapter 1

Figure 1-1 Conceptual Framework for the Education Gradient in Health

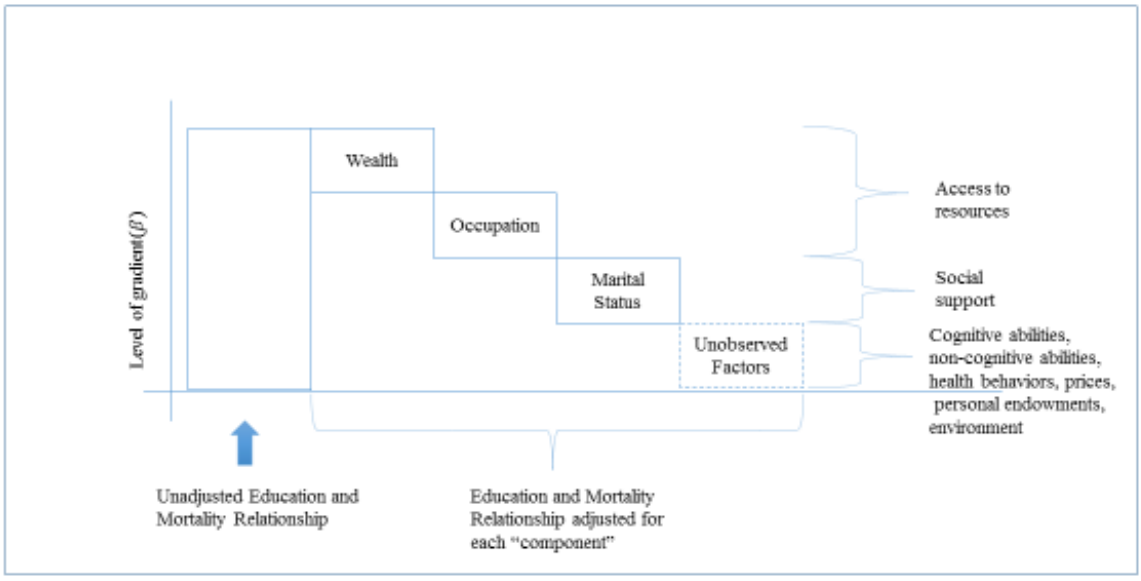
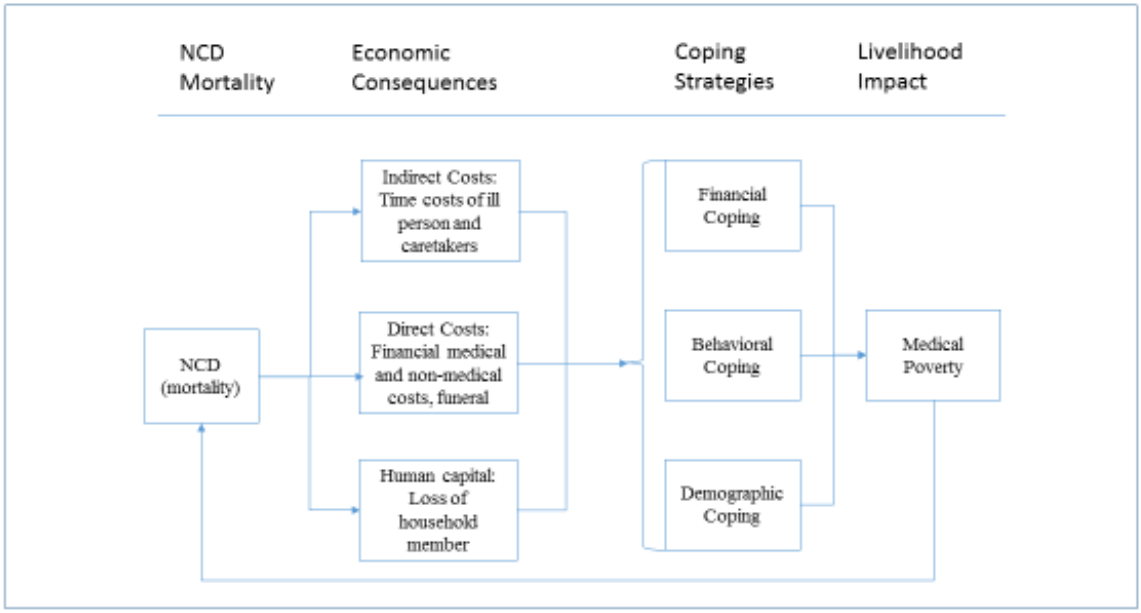


Figure 1-2 Conceptual Framework for the Economic Consequences of Poor Health



Chapter 2. The Education Gradient in Adult Non-Communicable Disease and Infectious Disease Mortality: Are there Relevant Differences?

2.1 Abstract

This study attempts to gain understanding of the education gradient in adult mortality in a low and middle-income country where there is a changing burden of disease from one dominated by infectious diseases to one dominated by non-communicable diseases (NCD). The education gradient in adult mortality, which is the positive association between years of schooling and survival, is identified in Matlab, a rural area of Bangladesh that has seen improvements in female education during the years 1982 to 2005. This work also explores the components of the education gradient in mortality for both sexes and for deaths from both NCDs and infectious diseases. Cox proportional hazards regression is used to examine the education gradient in NCD and infectious disease mortality for three prospective five year periods beginning in 1982, 1996 and 2005 in Matlab. Component variables of wealth, occupation and marital status are individually added to the base model to assess how much they contribute to the observed education gradient in mortality. For females, an extra year of education significantly reduces mortality from NCD by 7% and infectious disease by 12% (hazard ratios of 0.97 and 0.88). For males, an extra year of education provides a reduction in NCD and infectious disease mortality of 2% and 8% (hazard ratios of 0.98 and 0.92). These gradients mean that if everyone in Matlab were to achieve a level of primary education, close to 2,600 deaths would be averted in the time period of this study. For the components of the education gradient, marital status explains the highest portion for both

infectious disease and NCD mortality, followed by wealth and then occupation. These three components account for a larger portion of the gradient in males than females, but females show the steepest education gradients in mortality overall. With calls for more services for the prevention and treatment of NCDs in low income settings, there is a role for education in addressing the NCD burden. In Matlab, an increase in the levels of rural female education is associated with the saving of many lives, but the levels of education remain very low and education for men has been stagnant for several decades. Continued investment in education will prevent deaths and become more important for NCDs, in absolute terms, as the burden from NCDs rises. Policies should consider how access to social-psychological resources in addition to economic resources are improved through education, when attempting to identify those who are vulnerable to mortality and poor health. This study in rural Bangladesh provides a model for understanding the education gradient in health for low-income countries with changing disease patterns.

2.2 Introduction

This study attempts to gain understanding of the education gradient in health in low and middle-income countries where there is a changing burden of disease from one dominated by infectious diseases to one dominated by non-communicable diseases (NCD). The "education gradient" is the consistent positive relationship between education and health, which has been shown to reliably exist in many settings (23, 32, 37). This relationship has been well-studied for different outcomes of health in high income countries but less work has been done in low and middle-income countries, especially for adult health. Much of the education gradient work that has been done in

low and middle-income country settings deals with issues in child health and HIV/AIDS, with less emphasis on issues related to adult NCD health (45, 46).

In the past decades, Bangladesh has been steadily developing economically, which is seen by a consistent upward trend in the country's per capita gross domestic product (GDP) (**Figure 2-1**) (47). Additionally, the country has had a declining poverty rate nationally and for the rural population (**Figure 2-2)** (48). The country has also begun to address the issue of low education by making investments in rural female education (49). Since the mid 1990's, there have been successful efforts to increase school attendance for females and data from one rural area shows a near doubling of the years of education that females complete from 1982 to 2005 (**Figure 2-3).** In contrast, rural male education levels have remained stagnant, so any increase in overall levels of education needs to account for the differences by sex.

Along with economic development, Bangladesh is also undergoing an epidemiologic transition, with improvements in infectious disease mortality and an increasing portion of the burden of disease coming from NCDs (**Figure 2-4)**. Gaining an understanding of the education gradient for Bangladesh is important to evaluate how investments in health services and education may contribute to improved health overall. In the rural area of Matlab, many years of investments in child health, maternal health and family planning services and environmental improvements have led to a rapid decline in the burden from infectious diseases and a corresponding increase in the burden from NCDs (5). **Figure 2-5 and 2-6** show the mortality rates in Matlab for both infectious diseases and NCDs for

the whole population by level of education, classified as either high or low. The figures show a clear health benefit to education for lowering mortality rates for each disease category, regardless of whether the overall disease rates are increasing or decreasing.

The Matlab *upazila (*sub-district) is located in the state of Chandpur and has a population of a quarter of a million people. Since 1966, it has been a site for demographic surveillance and public health programming (even before the establishment of the modern country itself). Led by the nonprofit organization, the International Center for Diarrhoeal Disease Research in Bangladesh (icddr,b), the area has implemented programs addressing issues of cholera, access to clean water and family planning. Both the icddr,b and the Bangladeshi government currently operate hospitals that provide free maternal and child health services to the Matlab population.

The well-established positive relationship between education and health provides justification for investments in education as a health improving strategy (50). In the social sciences literature, there have been attempts to examine the causal effects of education on health using quasi-experimental approaches with education modeled exogenously, meaning it is assumed that one's education does not depend on one's health (30, 51, 52). These studies have identified settings where econometric designs such as regression discontinuity and instrumental variables estimation can be used to obtain the exogenous effect of education on improved health.

In the absence of the right conditions for making causal conclusions, there have also been attempts to understand the components of the education gradient, which may shed light on the mechanisms explaining the positive education and health relationship. The

components of the gradient are defined as the mechanisms through which education affects health. Previous work has identified these components and established frameworks to examine how each one contributes to the positive education and health relationship (32, 35, 37, 53). The main components typically include: economic resources, social-psychological resources, prices, cognitive abilities, personal endowments, health behavior, environmental factors and tastes (33, 35, 37). This research in Matlab, lacking an exogenous measure of education, adopts this second approach to explore the components of the observed education gradient in mortality.

The aim of this study is to identify the education gradient in mortality in a rural, low income country setting in Bangladesh and to explore the contribution of three components of this gradient, wealth, occupation and marital status. The education gradient is evaluated in adult mortality by sex and by broad category of cause of death: infectious disease and NCD. By comparing the two categories of diseases, the work sheds light on unobserved components of the education gradient as well, which may help to design better policies. For example, does education have a larger effect for those affected by NCDs or infectious diseases and should education interventions be targeted to those with who are vulnerable in terms of economic resources or social-psychological resources. This research is especially relevant given the emerging burden from NCDs in Matlab and other countries that are undergoing an epidemiologic transition.

2.3 Literature Review

2.3.1 Education and mortality relationship in LMICs and Bangladesh

Since the seminal work of Kitagawa and Hauser in 1979 looking at mortality differentials in the United States by level of education, there have been many studies to further understand the education and mortality relationship (23). Using country data from the US and Western Europe, researchers have addressed questions related to the education and mortality relationship according to age, sex, race and other sub groups where the relationship may be important for understanding socioeconomic status and health (52, 54, 55).

In low and middle-income countries, however, there has been much less research looking at the education gradient in mortality. This may be due to the lack of data for these settings or that the levels of education remain very low. Suppressed levels of education in low and middle-income countries have been hypothesized to reduce the relationship between education and health, yet researchers still see gradients when looking at issues such as HIV/AIDS mortality, parental education gradients in child mortality and child education gradients in child mortality gradients(25, 51, 56-59). In recent years, as NCDs have emerged as a global health issue, there have also been more studies looking at education gradients for adult health in low and middle-income countries that specifically looking at non-communicable diseases (46).

The long-running surveillance site in Matlab, Bangladesh has been collecting information on mortality and education since the 1970s and previous researchers have used this data to look at the differences in mortality by education. Using Matlab data from 1974-1977,

one study found an education gradient in mortality in Matlab when dividing education into three categories: none, primary and secondary, according to the education of the head of the household or the highest education of anyone in the household. In each case the mortality rate ratio of the lowest educated to highest educated ranged from 1.9 to close to 3 (60). Utilizing the same Matlab data up to the year 1996 to study the survival of adult females, another study used a binary education variable and found that women with any years of education had a 1.6 times survival advantage over those with no formal education (61). A more recent estimate using Matlab data in the years 1996 and 2005 came to a similar conclusion, finding that literate adults were 1.46-1.61 times more likely than illiterate adults to survive in the subsequent three year period (62).

2.3.2 Causal literature on the education and health relationship

In the field of Economics, some of the initial ideas relating education to health were put forward by Gary Becker (63). These were further developed by Grossman's use of education in the health production function and subsequent review looking at the non-market outcomes of education (50). An important point is that education, or knowledge capital, may be endogenous to health. This means that there may be reverse causality where health leads to better schooling or there may be an omitted variable that explains both education and health (64). One popular explanation for the third variable hypothesis was proposed by Fuchs, postulating that time preference may be the omitted third variable explaining both education and health (65).

There are several quasi-experimental research techniques that may be able to account for some of the endogeneity when evaluating the causal effect of education on health. These

include: using lagged health variables, using the differences in health of twins or sibling, using instrumental variables or using regression discontinuity that examines the effect of education around a discrete cut-point or policy change (30, 50). While these techniques have been used more frequently in developed country settings, they are beginning to be used in developing country settings as more and better data becomes available (30, 51, 52).

One important conclusion from the causal literature on the education and mortality relationship is an understanding of the size of the effect. That is, how much health, in terms or better survival, does one extra year of schooling buy. This is difficult to discern given the variety of study populations, research designs and methods for measuring education and mortality. Regardless, the results reported that there is generally a less than 10% reduction in five or ten year mortality in adults for each extra year of schooling. For example, for US data, one study finds a 3.6% reduction in ten year mortality for an extra year of education and another finds a 7 to 9% reduction in five year mortality for each additional year of education (39). For lower and middle-income countries, there was no quasi-experimental results found for adult mortality, however, using instrumental variables in Indonesia, one study finds a near 12% reduction in the total number of children who die for each additional year of parental education (51). Clearly there is variation in the gradient depending on the characteristics of the mortality cause, time period, age and region of interest and an understanding of the education gradient in mortality for adults in low and middle-income countries is warranted.

2.3.3 What are the components of the gradient

In addition to understanding the causal effect of education for health, it has also been important to understand the components that make up the gradient. While not causal in nature, this research provides insights into why the education gradient exists, and this understanding may be used to design better policies for health improvement (66).

In the sociology literature, Ross and Wu set a framework of explanatory categories of work and economic conditions, social-psychosocial resources and health lifestyle (35). Economics frameworks understand the education gradient in similar terms though they add economic constraints of income, prices and access that may explain the gradient (33). Additionally, there has been an addition of cognitive ability and non-cognitive abilities (such as ability to act) that have been explored as well (37, 38, 67).

2.3.3.1 Wealth & Occupation

The first component that is usually mentioned in most frameworks is that of economic resources. This may be measured with a variable for income (or wealth). The component for economic resources usually explains a large portion of the gradient, and in empirical research, has been shown to be the most important component of the gradient (37).

Lower education is associated with lower income and vice versa for higher education (68). Cutler explains that income can effect health through two channels: more income can buy more health-improving goods such as healthcare or health insurance and more income can increase consumption, which leads to a higher utility for living to older ages.

In this sense, income can be thought to be an indicator of command over and access to resources (37).

Income is usually thought to explain a large portion of the education gradient in health. In a review of several datasets for the effect of economic resources on the education gradient in the use of prevention, Cutler finds that economic resources overall explain 20% of the gradient and it could even explain as much as 32%, depending on the dataset that is used (37).

Occupational status may also play an important role. One study that combines work and economic conditions found that up to 59% of the gradient in self-rated health can be explained (35). Measuring economic resources through occupation is not new and has been famously done in the Whitehall II study to look at social gradients in mortality (22). In addition to the relationship with income, lower education may lead to a worse occupation status which may then impact mortality (68, 69).

2.3.3.2 Marital status

In addition to the variables for economic resources, a variable for social, or social-psychological support is also thought to explain part of the education gradient. Marital status has been used as a proxy for such types of support and has been found to be an important type of informal support that may work in addition to formal support mechanisms (e.g. workplace programs) (35, 70). The effect of marital status is thought to be related to higher levels education and more stable marriages are thought to be an

important “non-pecuniary” impacts of more schooling (71). In the reverse direction, marital may also be a critical determinant of mortality as well (72).

In one study in the United States, variables for marital status, income, household size and rural/urban status, when combined, were found to explain between 20-50% of the education gradient in mortality (39). In Bangladesh, marital status has also been previously found to be an important determinant of mortality (35, 73). Although, we are cautious about interpreting marital status as an accurate proxy for social support given that marital status in rural Bangladesh is also determined by different cultural practices than it is in other developed countries.

2.3.3.3 Other Components of the Gradient

Prices are thought to influence the education and health relationship if those with more education are economically better off and more price elastic. That is, those with more education may be more likely to reduce unhealthy behaviors that have a cost (37). The evidence for this component is weaker, however, and there have also been studies showing that the less educated are more price elastic (74). Prices, however, in Matlab are thought to be held relatively constant for the entire population and thus are considered to not have the variation necessary for examination.

Cognitive abilities are another element that may contribute to the education and health gradient. Those that have higher abilities may be more efficient at producing health (50). The data requirements to look at cognitive ability are certainly more intense and less work has looked at this component; however Goldman and Smith find a strong effect of

cognitive ability by including an intelligence score in their model with years of schooling (75).

The previous two components of the gradient, prices and cognitive ability, are not evaluated in this work due to data limitations, but prices are assumed to play a minimal role in the education gradient. Cognitive ability is more problematic, given that it may explain a potentially large part of the gradient, and may be an important element that cannot be accounted for (31). In addition to these two components, there are elements of personal endowments and environmental conditions that could also explain the gradient.

2.3.4 The Education gradient by infectious and non-communicable disease

Since there is only data available for the three components of wealth, occupation and marital status, the exploration of the education gradient by broader cause of death category, NCD and infectious disease, is undertaken to shed further light some of the unmeasured components. In essence, there may be some important characteristics of NCDs and infectious diseases themselves that could lead to a better understanding of the gradient and its components.

There has been no previous work, to the best of our knowledge, which dichotomizes cause of death according to these categories when exploring the education gradient in health. Perhaps the closes attempt at this was done by Montez and colleagues who divided causes of death into those that had behavioral determinants (such as smoking causing chronic lung disease) and non-behavioral components. This classification

roughly followed a stratification by NCD and infectious diseases where the behavioral-related causes equate to the NCD category. The results of this study find that diseases with behavioral components explain more of the education gradient in males than for females, though the authors do note the limitations of making conclusions about the component of behavior simply by the cause of death (70).

Other previous work has also highlighted the education gradient in terms of the behavioral risk factors that lead to increased NCD burden. One study looking at smoking concluded that a steeper education gradient (greater difference in health outcomes) may be found when knowledge about risk factors emerges because education leads to a more efficient use of knowledge (45, 50). For developed countries, there have also been studies concluding that the education gradient for chronic diseases will be larger because the more educated are better able to manage complex prevention and treatment for chronic conditions (76). This conclusion has been made with other health interventions such as the use of more information intensive strategies for contraception (77). An important point, however, is that the access to information is found to be very important for an education gradient in health to emerge (45). For NCDs in Matlab, where there is very little access to information about NCDs and related risk factors, there may be a narrowing gradient (smaller relative difference) in NCD mortality, as mortality rates rise.

On the other hand, they may also have a steep education gradient in infectious disease mortality in a setting such as Matlab. While infectious disease mortality is rapidly declining, from a relative perspective, the gradient could be getting larger. There has been some evidence that large-scale public health programs, such as the one in Matlab are

inequality-enhancing (78, 79). Although services are generally focused on the infectious disease burden, the poorest are the least likely to receive services even in a situation where services are provided freely. There has been some evidence for this in high income countries where universal access does not reduce inequalities (80).

To summarize, most research on the education gradient in mortality has been conducted in developed countries, though there is indication of a gradient existing in developing countries as well. In the causal literature, quasi-experimental designs have found that investments in education will lead to significant improvements in health. This effect may work through several components related to economic condition, social-psychological resources, prices, cognitive ability and other factors. Of these, economic condition and cognitive ability have been found to play a large role in explaining the gradient but so has social-psychological resources, measured by marital status. No studies have examined the education gradient in mortality according to broad cause of death categories such as NCD and infectious disease, but there has been some work in developed countries showing that the gradient in NCD mortality will be significant because of education's relationship with health behaviors and efficient use of information. This study attempts to fill this gap in the literature by evaluating the education gradient in mortality gradient in a rural, low income area, looking at components related to economic and social-psychological resources as well as broad categories for cause of death.

2.4 Data

2.4.1 General data

This study uses census data with individual identification numbers to link death certificate information with socioeconomic and household characteristics in Matlab. Data from the Matlab surveillance system is used for the population in 1982, 1996 and 2005. These three time points are when wealth surveys were conducted in Matlab and provide a cross-sectional picture of socioeconomic status at those times. The follow up time for mortality information is limited to five years. Longer follow up periods would not capture significant changes in variables such as household wealth and marital status that are changing in time and may affect conclusions about the relationship between education and mortality. This approach is consistent with previous examinations of socioeconomic status and mortality in Matlab and other settings (60-62).

The study population includes all those who are alive, aged 15 years or older at the beginning of each year in Matlab in 1982, 1996 and 2005, following them for outmigration and death. Using an age cut-off of 15 years ensures that the majority of the selected population has completed education. This is a common cut-off for research looking at effects of adult education in developing countries, and lower than the usual cut-off for developed countries, which is usually 20 to 35 years old (34, 81).

2.4.2 Primary Dependent Variable - Mortality

Mortality was coded as a binary variable for whether someone experienced a death in the follow up period or not. Deaths were broken down into broad disease categories for NCD

and infectious disease according to the death classification scheme used by the surveillance program in that year. The NCD category did not include any injuries, both intentional and unintentional and all causes of death from maternal and reproductive causes for females were excluded.

Notably, for each of the three periods, a different cause of death classification system was used. In 1982, the cause of death was documented by the interviewer at the time of collecting the information about the death. By 1996, the surveillance team used verbal autopsy methods for classifying death into 98 separate causes. In 2005, the verbal autopsy system was refined to classify cause of death according to the International classification of disease version 10 (ICD-10). The categorization of the causes into two broad categories is an attempt to reconcile these differences in assigning specific causes of death in each period. This approach has been used previously when describing cause of death information for Matlab (5, 62).

2.4.3 Primary Independent Variable - Education

Education was measured as a continuous variable for the years of education completed, ranging from zero to sixteen, for the deceased individual. For sensitivity analyses, a categorical education variable based on the years of education completed with categories for no education, 1-5 years completed, 6-10 years completed and 11 or more years completed was used (82). These categories are consistent with the education system in rural Bangladesh. Additionally, this analysis only uses a measure of year of formal schooling completed. Children in Matlab may attend religious schools for all or part of

their education, but consistent with previous work in Matlab, we separate formal schooling from religious schooling (73).

2.4.4 Further Independent Variables - Exogenous Controls

Each of the models specified in equations 1-5 include a set of control variables. These variables are: age, religion, household size, birth cohort and census year. These variables are not influenced by years of formal education and are considered exogenous to the education and health relationship.

Individual age is included as a continuous variable and age is also examined as a categorical variable to control for birth cohort effects. Following previous work in Matlab, we use age groups of 15-40, 40-59 and 60+ to describe groups of young, middle-aged and older adults (6, 62). A further categorical variable is included for religion, whether someone is Muslim, and dummies are generated for the three time periods of interest in order to account for long-term trends. A similar dummy-variable approach has been used previously to examine long-term mortality trends in Matlab (61).

2.4.5 Components of the Education Gradient

This study looks at three components of the education gradient. The first two are wealth and occupation, which are an indicator of one's economic resources. The third component is marital status, which has been proposed as a measure of social-psychological resources in developed country settings and which may play a role in developing country settings as well. Other components of the gradient such as prices, health lifestyle, cognitive abilities and non-cognitive abilities are either assumed to be

constant or unobserved. In our data, wealth is measured at the household level and occupation and marital status are individual-level measures.

2.4.5.1 Wealth

Wealth was measured with an ordinal quintile scale with a one representing being very poor and a five representing being very rich. The quintile was calculated by the surveillance system for each household in the base years using principal component analysis (PCA) for a list of durable household items as well as characteristics that included land ownership, home building materials and type of latrine and water source utilized (83). The socioeconomic status instruments were standardized for the years 1996 and 2005, but was slightly different for the year 1982, primarily using a smaller list of durable assets. However, given the large number of assets listed for each year and the degree of overlap in assets used, this measure is considered to be a consistent measure of wealth for each time period.

2.4.5.2 Occupation

Occupational status was classified into seven main groupings based on a review of the main economic activities in the region and previous literature (84). The occupational categories capture key classifications made by a previous study in rural Bangladesh and by the Bangladesh Bureau of Statistics (84, 85). The surveillance system in Matlab used different occupational groupings for the year 1982 than it did for 1996 and 2005 so such a standardization was necessary. In contrast to previous studies, this research includes a category for homemaker or housewife to be able to assess the effect of this dominant female occupation on female mortality (58, 86). A category for being a student is also

included despite its clear endogeneity with the effect of education. This has been done in previous studies in Bangladesh, and it is assumed that given the overall low levels of education in the area that most of the gradient for education comes from those with lower levels of education who are not likely to still be students (84).

2.4.5.3 Marital Status

Marital status includes three categories including: single/never married, married and widowed/divorced. This categorization has been previously used for research in Matlab, though it may fail to capture the effects of individuals who marry multiple times and experience variable states of marital status over time. In this analysis, the most recent listing of marital status of an individual is used prior to a mortality event or censoring due to outmigration.

2.4.6 Data limitations

As mentioned above, there may be an issue with the classification of deaths into broad categories because the process for assigning causes of death in Matlab varied dramatically from 1982 to 2005. Collapsing the causes into broad categories of death is an attempt to account for this. The errors in assigning cause of death are less severe in this study if such errors only occur within categories. This has been proposed as a likely scenario by previous work in Matlab (5). There may still be problems; however, since in each year individuals with various levels of medical expertise were tasked with assigning the causes of death.

There may also be an issue with the large number of unknown deaths that are found in the earliest time period, 1982. For this early period there were 404 unknown male deaths and 376 unknown female deaths. Looking at the average age of death from unknown causes showed that in males, these fell near the "young NCD" deaths with a mean of 59 years. This, for example, is the same as the mean age for the known Cancer deaths. This same pattern was seen for unknown female deaths, with the mean age of unknown death being around 53 years, which is close to the 54 year old mean for female cancer deaths. Next, when looking at the gradients for just the unknown causes, in males, the gradient was closer to the NCDs (education coefficient = -0.03). For females, this was opposite, with the gradient for the unknowns being quite large and closer to the infectious disease estimate (education coefficient = -0.24, unadjusted). Further work may be needed to determine how these unknown deaths may bias the results.

Another limitation is the measurement of the variable for education. Using only year of education completed does not provide any indication of the quality of education. A further limitation of the education variable may be that low levels of education overall hinders uncovering the true relationship between education and health (58). This study assumes that education is linear in health, but there may be important differences in this relationship at different education levels. This relationship has been explored in studies in the (34, 87). In Matlab, there are very few individuals at the highest educational levels, and many people with zero years, meaning that much of the health benefits from education are a result of completing just a few years of education. This is further explored by collapsing education into a binary variable for any years of schooling and into a categorical variable for the different schooling levels (none, primary, secondary, post-

secondary). The results are not shown but are consistent with those presented for year of education completed.

Using wealth is one of the strengths of this analysis since income may be subject to short-term fluctuations, unrelated to education (31). The use of an asset-based wealth quintile is also a standard measure of wealth in developing countries when income and consumption data are not available (88).There may also be limitations to using asset- based wealth; however, as the PCA based quintile may mask important heterogeneity of wealth levels and access to resources between household members. This is especially worrisome for females, given their lower status in Matlab society.

The variable for occupation could also have drawbacks. The variable for occupation (one's primary economic activity) in the Matlab surveillance system is coupled with that for employment status (whether one is working) so the effect of having an occupation in of itself may be confounded. Employment status would be a better variable to use if it was available, since if one is not working, this may be due to ill health prior to imminent death (35, 69).

2.5 Econometric framework

The association for the effect of education on adult, chronic disease death was analyzed using a multivariate cox proportional hazard regression model separately for each sex and each major broad category of cause of death, NCD and infectious disease. The equation is specified as follows:

$$log\ h_i(t) = \alpha(t) + \beta_1 Edu_i + \beta_2 X_i \qquad (1)$$

Where $h_i(t)$ is the hazard function for individual i at time t, $\alpha(t)$ is the baseline hazard, Edu_i is year of education for individual i, the main independent variable of interest, and β_1 is the coefficient on year of education, which represents the education gradient. X_i represents assumed independent variables of interest of age, religion, household size, birth cohort, and census year.

The models employed right-censoring and used the Efron method to account for tied data. Survival time is calculated from the time of the base year census and age is included in the model to derive the age-adjusted hazard of mortality (34, 89, 90). All standard errors are clustered at the household level.

To examined the relationship of education with the hazard of mortality, four specifications of the model were run: with education as the only independent variable (not shown), as a reduced form model with education and exogenous controls (equation 1), as a reduced form plus each of the components added individually (equations 2-4) and as a reduced form plus all of the components added at once (equation 5) (39). The exogenous controls for the reduced form model include variables for age, religion, household size, birth cohort and census year. The explanatory power of the component variables of wealth, occupation and marital status were then assessed in models 2, 3 and 4 below, with β_3 representing the coefficient on the component variable:

$$log\ h_i(t) = \alpha(t) + \beta_1 Edu_i + \beta_2 X_i + \beta_3 Wealth_i \quad (2)$$

$$log\ h_i(t) = \alpha(t) + \beta_1 Edu_i + \beta_2 X_i + \beta_3 Occup_i \quad (3)$$

$$log\ h_i(t) = \alpha(t) + \beta_1 Edu_i + \beta_2 X_i + \beta_3 Marr_i \quad (4)$$

The final model that included all independent variables at the same time is given by the following equation:

$$log\ h_i(t) = \alpha(t) + \beta_1 Edu_i + \beta_2 X_i + \beta_3 Wealth_i + \beta_4 Occup_i + \beta_5 Marr_i \qquad (5)$$

To understand the degree to which the education gradient in mortality is explained by the three explanatory variables of interest, we used an approach where the percent reduction in the coefficient on education was calculated with the addition of the variable of interest individually to the base model. For example, for the addition of wealth in equation 2, the percent explanation of the education gradient was calculated as: $[(\beta_1^{Model\ 1} - \beta_1^{Model\ 2})/\beta_1^{Model\ 1}] * 100]$, where $\beta_1^{Model\ 1}$ is the coefficient on the variable for education for model 1. This was then repeated for models 3, 4 and 5, each time using model 1 as a reference. This method has been employed by others when evaluating the degree to which an added variable explains the relationship between the primary dependent and independent variables of interest (34, 35, 37, 41).

As the education gradient in mortality is represented by a rate ratio, it represents a relative effect and a further step is needed to understand the absolute effects of the education gradient (32, 33, 91). After the cox proportional hazard models were estimated, the expected number of deaths, as a predicted value, were obtained assuming a scenario where everyone in the population of Matlab completed primary education, which was 5 years. These deaths were then subtracted from the observed number of deaths in the pooled data to obtain an estimate of the deaths that could be averted if everyone completed this basic level of education.

2.6 Results

Descriptive information for the entire study population stratified by sex is provided in **Table 2-1**. The table provides information pooled for all three years.

2.6.1 The link between Education and the Components of the Gradient

Initially, ordinary least squares regression was used to examine the general relationship between year of education and variables for marital status, occupation and wealth. These models were set up according to the following specification:

$$Z_i = \beta_0 + \alpha Edu_i + \beta_k X_k + \epsilon_i \quad (6)$$

In equation 6, Z_i represents the component of interest, either wealth, occupation or marital status. The variable Edu_i represents the year of education for individual i with α being the coefficient for the relationship between a change in year of education with a change in the component. The vector X_k represents independent control variables at the individual and household level and β_k is a vector of their corresponding coefficients. The control variables are: age, religion household size, birth cohort and census year. This preliminary analysis provides an estimate of R^2 to describe how the observed variation in wealth, occupation and marital status is explained by education.

Equation 6 was run for the pooled dataset and separately for males and females with results shown in **Table 2-2**. Models were also run for each of the time periods individually and there were no large changes in the R^2 values or explanatory rank of the coefficients by year. For both sexes, education is significantly positively associated with

wealth, occupation and marital status and the largest coefficient on education is seen when wealth is the dependent variable. Examining the R^2 values, education explains the most variation in wealth, (R^2 0.20 for males and 0.22 for females). Education explains slightly less of the variation in marital status, with an R^2 value of 0.18 for both sexes. Education explains the least amount of variation in occupation, with an R^2 value of 0.04 and 0.05 for males and females.

2.6.2 Overall education gradient in mortality

The results for the overall education gradient in mortality for both sexes and causes of death for the pooled data is shown in **Table 2-3.** The gradient in education is measured by the coefficient on the variable for year of education from the reduced form equation 1 (again: $log\ h_i(t) = \alpha(t) + \beta_1 Edu_i + \beta_2 X_i$).

For females, the gradient in both causes is significant and shows an extra year of education is positively associated with a decline in mortality (hazard ratio less than one). For female NCD mortality, an extra year of education is associated with a 7% reduction (HR = 0.93) and for infectious disease mortality and an extra year of education is associated with a 12% reduction (HR = 0.88) in mortality. In absolute terms, this education gradient would result in 689 averted female NCD deaths and 1,275 averted female infectious disease deaths if every female in Matlab had a primary level of education. This represents 21% and 55% of the NCD and infectious disease deaths that were observed over the time period.

In males, the gradient in both cause of death categories also shows a positive relationship with health and both are significant. Male NCD mortality is reduced by 2% (HR = 0.98) for every year of education completed and male infectious disease mortality is reduced by 8% (HR = 0.92) for every year of education completed. This means that if every male in Matlab had a primary level of education, 167 NCD deaths and 505 infectious disease deaths would be averted, representing 4% and 20% of the observed deaths from these causes in the time period.

The steepest education gradients, which is a relative effect, and the largest number of deaths averted, the absolute effect, are both seen in infectious disease mortality. By sex, the largest relative and absolute effects are seen for females.

2.6.3 Components in the education gradient

Table 2-4 gives the results when adding the three components of wealth, occupation and marital status to the reduced form base model for female mortality. When adding all three of these components, the education gradient is reduced by 59% in NCD mortality and by 27% in infectious disease mortality and remains significant for both causes of death. With all three components accounted for, an extra year of education provides a 3% reduction in NCD mortality (HR = 0.97) for females and a 9% reduction in infectious disease mortality (HR = 0.93) for females. This equates to 361 total NCD deaths averted and 732 total infectious disease deaths averted over the time period, which represents 11% and 31% of the total observed deaths.

When adding the components to the reduced form base model individually, wealth reduces the education gradient in NCD mortality by 14% and the gradient in infectious disease mortality by 11%. Occupation showed a minimal effect, reducing the education gradient in NCDs by 1% and by less than 1% for infectious diseases (denoted NA). Marital status reduced the education gradient by the largest amount in female NCD and infectious disease mortality reducing the gradient by 52% in the former and 16% in the latter.

In **Table 2-5,** the results are shown when adding the three components of wealth, occupation and marital status to the model for male mortality. For NCD and infectious disease mortality, when adding all three of the components, the education gradient is completely reduced in male NCD mortality (100% reduction) and no longer significant. In infectious disease mortality, the education gradient is 49% reduced when all three components are added. In these models, completing an extra year of education provides no mortality benefit for male NCD mortality (HR = 1.00) and a 4% reduction in infectious disease mortality (HR = 0.96). This equates to 261 averted infectious disease deaths in the time period, 11% of the observed deaths, and no averted deaths from NCDs.

Table 2-5 also shows the amount that each component individually explains the education gradient in male mortality. For NCD mortality, wealth explains 48% of the gradient while wealth only explains 20% of it in infectious disease mortality. Occupation explains 19% of the gradient in NCDs and a similar amount, 21%, in infectious diseases.

Adding marital status results in the entire gradient being explained in NCDs mortality and 21% of the education gradient in infectious disease mortality.[1]

In all, the three components explain a large portion of the education gradient in NCD mortality, explaining 59% of the gradient for females and the entire gradient for males. The three components explain less of the gradient in infectious disease mortality, 27% for females and 49% for males. Marital status explains the most for any sex and cause, but shows and especially large effect for NCD mortality. Wealth and occupation still explain a large part of the gradient for male mortality, but for females these components explain much less.

2.7 Discussion

This study identified the education gradient in mortality for the rural, low income area of Matlab, Bangladesh and explored how the components of the education gradient in mortality differ by sex and cause of death category. The education gradient in mortality was examined for three prospective five year periods beginning in 1982, 1996 and 2005. Component variables of wealth, occupation and marital status were individually added to the base model to assess how much they contribute to the education gradient.

The education gradient overall shows that there is a range of a 2 to 12% reduction in mortality per year of schooling completed in both sexes depending on whether NCDs or

[1] To test this further, we also run models restricting the age of the sample to different cut points. When removing those who are aged older than 65, marital status explains 80% of the gradient in male NCD mortality. This may be a result of a steeper education gradient seen for the restricted group if the "age-as-leveler" theory holds in the Matlab population 92. Dupre ME. Educational differences in age-related patterns of disease: reconsidering the cumulative disadvantage and age-as-leveler hypotheses. Journal of health and social behavior. 2007;48(1):1-15. Epub 2007/05/05..

infectious diseases are being looked at. The gradient is steeper for females, meaning that an extra year of education completed confers a larger reduction in mortality. By simulating a situation where all females achieve a level of primary education, the result show that the relationship between education and mortality would avert 21% of the NCD deaths and 55% of the infectious disease deaths that were observed. The steeper gradients seen in females is interesting given that in settings such as the US and Western Europe, the opposite is typically seen (55, 70). This is consistent with theories of gender bias in patriarchal societies such as Matlab; however, and other studies in the area have also noted the importance of female education, even testing it for effects on the mortality outcomes of male spouses (73).

Males would see a lower absolute number of deaths averted, 4% of NCD deaths and 20% of the infectious disease deaths, though this still represents a saving of nearly 700 lives. From these conclusions, it is encouraging to see that the average level of female education has been increasing in Matlab over the past several decades. The average level of education for males appears to be stagnant or slightly declining, which means that efforts to promote education for the entire region should be undertaken.

When looking at the components of the education gradient in mortality, it is interesting that marital status explains more of the gradient than wealth but this could result from it being endogenous in a rural low-income setting such as Matlab. Marital status is especially important for the education gradient in NCD mortality; however, it is also the most important component for the gradient in infectious disease mortality. This could highlight the importance of social-psychological resources to improve overall health or

the endogeneity of marital status or both. The component of wealth still plays a large role in explaining the education gradient, though it accounts for a much larger portion in males that it does for females. This is similarly the case for occupation and shows the lack of work and economic opportunities for females in rural Bangladesh.

There are also interesting differences in the education gradients between NCD and infectious disease mortality, which may be worth exploring further. Steeper overall gradients are seen for infectious disease mortality than for NCD mortality, which shows that there may be more knowledge about infectious disease prevention in the area resulting in a larger gap between the educated and uneducated. The three components of the education gradient that are explored in this analysis are also seen to play a more important role in the education gradient in NCD mortality than for infectious disease mortality. This may indicate that access to resources, both economic and social, are more important for preventing NCD mortality than for preventing infectious disease mortality. Previous work has shown that the introduction of more informational interventions leads to steeper education gradients in health (45).

2.7.1 Policy implications

With calls for increased investment in the prevention and treatment of NCDs, there is a potential that the education gradient in NCD mortality will get steeper, if access to information and health technologies follow the same patterns seen in previously. This should not undermine the conclusion that improved health services are needed for the rising NCD burden. Investments in education will only provide more benefits in terms of better NCD health outcomes and such investments have the potential to be inequality

reducing. Development efforts have focused on the achievement of basic levels of education, particularly targeting vulnerable populations such as females whose literacy rates have historically been extremely low (93).

The relative gradient in infectious diseases is steeper than the gradient in NCDs, but the increasing NCD rates means that more absolute benefits from NCD prevention will be realized from investments in education. This is even more important with increasing an burden of NCD mortality in the future (5). Improvements in overall education will be important for combating this rising burden. The results from the analysis of the components of the gradient show that there is a need for focusing policy towards further economic development and social support mechanisms to combat the burden from NCDs.

The education and mortality relationship in Matlab is also important because of the role of education in rural Bangladeshi society. The improvements in female education are notable and show the importance of recent efforts to increase education among rural females in the country (94). The contrast with the trend in male education levels is also interesting as those reporting any education for males is decreasing while those reporting any education for females in increasing.

The strong relationship between education and health seen in this study has a number of policy implications for Matlab, Bangladesh. The differences in mortality explained by education, wealth, age, religion, occupation and marital status may inform programs and interventions that target education, economic development or highly vulnerable groups to improve the health systems in poor areas that see shifts in epidemiologic burden due to aging populations and a high prevalence of NCD-related risk factors. There is consensus

that these changes are occurring in many low and middle-income countries so an understanding of they relate to the education gradient in health will be important (66).

2.7.2 Limitations

One limitation of this work is that the data only allows the inclusion of three components of the education gradient. Further clues about the components of the gradient are offered by dividing the causes of death into broader disease categories, however this should not be a substitute for better data on these components. Such components that have been reported to play significant roles in the education gradient are cognitive and non-cognitive abilities (37, 38). These may be playing a role in the gradient that is not observed. There is also a large number of observed unknown causes of death in the earliest time period, 1982, which were excluded from the analysis. This has been noted in previous work and could influence the conclusions about main effects of the gradient and the differences that are observed between the two cause of death categories. We have shown that these unknown causes have low mean ages of death and education gradients similar to the education gradient in NCDs in males and similar to the education gradient in infectious diseases in females. Further analysis using more robust imputation strategies should be used in future work to examine whether the main findings change when these unknown causes are re-distributed.

A second limitation is the lack of any measurement of schooling quality. Since this is not available, the estimates here are taken as an average of the schooling quality in the Matlab area. Variation in schooling quality, however, is also likely not a large issue because of a homogenous schooling system in the area. A final limitation of this work is

the lack of evaluating whether there are any peer effects that contribute to the education gradient. This is something that may be explored further with multi-level modeling the Matlab data as there are various levels such as household, bari (group or households) and village where peer effects may exist and contribute to the education gradient.

2.7.3 Future Research

The finding that the education gradient in NCD mortality is smaller than that for infectious disease mortality may be an important point for future research. Previous work has found that social gradients in mortality have increased with rising NCD burden (31, 95). A possible explanation may be that the narrowing gradient is due to an aging-related rapid rise in the absolute burden from NCDs, leading to a convergence in the mortality burden among all strata of society. This study ran models interacting the variable for census year with the education gradient to explore how it changes. While preliminary, there is indication of a narrowing education gradient in NCD mortality over time (**Appendix).**

Other studies in Bangladesh have found that education is associated with lower levels of disease risk factors and higher levels of health services utilization(18). Understanding the role of peer effects may also be important in a rural setting such as Matlab and looking beyond individual-level education to education of partners, households, baris and villages may also be important (32). Already, research in Matlab has shown important results for the effects of spousal education on mortality and found that spousal education is more important for males, than it is for females (73). This is an interesting result, given the lower status of women in Bangladeshi society as a whole and future work into the role of

marital status in the education gradient in rural, low-income areas of Bangladesh may be warranted.

2.8 Conclusion

In conclusion, this work finds that the gains made in female education in rural Bangladesh in the past decades are associated with a significant number of averted adult female deaths from both NCD and infectious disease causes. The low level of female education, on average, and continued investment in primary education for females will provide more health benefits. Investments in male education will also provide health benefits, and it is worrisome that average levels of male education have been stagnant in the area for several decades. The education gradient is found to be larger in infectious disease mortality than NCD mortality and, given the historically higher mortality rates from infectious diseases, improved education is associated with a larger number of averted infectious disease deaths. With declining rates of infectious disease mortality and a rising burden of NCD mortality, improved education will be associated with larger numbers of averted NCD deaths, in both sexes in the future.

The finding that marital status explains a large portion of the education gradient in mortality shows the important interaction of social processes in the education and health relationship for overall health in this area. The fact that it explains more of the gradient than wealth means that economic development through mechanisms such as cash transfers may not be as effective as interventions that focus on social development and that target based on social characteristics.

2.9 Tables for Chapter 2

Table 2-1. Descriptive Information for Study Population

Variable	Text Description	Males Estimate (Std. Dev.)	Females Estimate (Std. Dev.)
Primary Independent Variable			
Education Year (mean)	Continuous number of total years of schooling completed	3.63 (4.18)	2.75 (3.64)
Missing education (%)		0.02	0.03
Control Variables			
Age (mean)	Continuous variable for age at the end of each base year (1982, 1996 and 2005), calculated according to date of birth	36.70 (17.10)	35.95 (16.60)
Muslim (%)	Binary variable for whether or not one is Musliim	0.86	0.87
Household size (mean)	Continuous variable for household size at a given time	6.16 (2.57)	5.95 (2.57)
Birth Cohort (%)	Categorical variable for whether one was in the group of people in a given age group at a given time		
15-39		0.62	0.65
40-59		0.25	0.24
60+		0.12	0.11
Component Variables			
Wealth Quintile (%)	Categorical variable for the asset-based wealth quintile that one's household is in at a given time. Quintile 1 = poorest and Quintile 5 = richest.		
Q1		0.14	0.15
Q2		0.17	0.17
Q3		0.19	0.18
Q4		0.21	0.21
Q5		0.22	0.21
Missing		0.08	0.08
Occupational Status (%)	Categorical classification of the primary work activity of an individual.		
Not working		0.04	0.01
Student		0.04	0.03
Household work		0.00	0.87
Skilled Agriculture		0.32	0.00
Unskilled labor		0.14	0.01
Manuf. / Skilled labor / Service		0.21	0.01
Business		0.11	0.00
Others		0.02	0.03
Missing		0.12	0.04
Marital status (%)	Categorical variable for the marital status in a given base year (1982,1996 and 2005) for an individual.		
Never married		0.30	0.12
Currently married		0.55	0.60
Widow/Divorce)		0.15	0.28
Missing		--	--
Population and Deaths			
Total Population - Pooled	The total populaiton of a given sex above age 15 in Matlab at a given time.	201,301	220,695
Population - 1982		56,734	59,168
Population - 1996		68,748	73,408
Population - 2005		75,819	88,119
Non-communicable disease - pooled	A count of the total deaths from non-communicable diseases for a five year follow up period of the Matlabl population in 1982, 1996 and 2005.	4,405	3,235
Non-communicable disease - 1982		814	592
Non-communicable disease - 1996		1,405	901
Non-communicable disease - 2005		2,186	1,742
Infectious disease - pooled	A count of the total deaths from infectious diseases for a five year follow up period of the Matlabl population in 1982, 1996 and 2005.	2,483	2,329
Infectious disease - 1982		1,481	1,312
Infectious disease - 1996		650	718
Infectious disease - 2005		352	299

Note: All descriptive information was stratified by sex. Within each sex, the information was pooled by census year and looked at for each year individually. The mean and standard deviation were reported for each continuous variable and the proportion in each group and the standard error were reported for each categorical variable.

Table 2-2. OLS Regressions on the components of Wealth, Marital Status and Occupation

Parameter	Male			Female		
	Wealth	Occupation	Marital status	Wealth	Occupation	Marital status
Coeff on Education	0.11***	0.01***	0.01***	0.15***	0.02***	0.01***
Standard Error	0.00	0.00	0.00	0.00	0.00	0.00
R^2	0.20	0.05	0.18	0.22	0.04	0.18
N	186,264	186,264	186,264	203,266	203,266	203,266

Note: Significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Data here is pooled for all three time periods. All equations run with the ordinary least squares model: $Z_i = \beta_0 + \alpha Edu_i + \beta_k X_k + \epsilon_i$ with controls for age, religion, household size, birth cohort and census year. Wealth is measured by the quintile from 1 to 5. Marital status is coded as binary for either being in the married or unmarried category (single/divorced/widowed). Occupation is coded as binary for being employed or not. Having an occupation of housework is considered the same as no occupation. Detailed models shown in Appendix Table C-1.

Table 2-3. Cox Proportional Hazards Regression for the Education Gradient in Mortality in Matlab, Bangladesh

Parameter	NCD		Infectious Disease	
	Male	Female	Male	Female
Hazard Ratio	0.98***	0.93***	0.92***	0.88***
Confidence Interval	(0.97-0.99)	(0.91-0.95)	(0.91-0.94)	(0.85-0.91)
R^2	0.053	0.041	0.035	0.030
N	186,264	203,266	186,264	203,266

Note: Significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Data here is pooled for all three time periods. All equations run with the cox proportional hazards model: $log\ h_i(t) = \alpha(t) + \beta_1 Edu_i + \beta_2 X_i$ with exogenous controls for age, religion, household size, birth cohort and census year. Detailed models shown in Appendix C-2 to C-55

Table 2-4. Explanatory contribution of components to the education gradient in NCD or infectious disease mortality in females

Model	Parameter	NCD	% Gradient	Infectious Disease	% Gradient
Base Model	**Hazard Ratio**	0.93***	--	0.88***	--
	Confidence Interval	(0.914-0.954)		(0.851-0.910)	
	R^2	0.041		0.030	
	N	203266		203266	
Add Wealth	**Hazard Ratio**	0.94***	14%	0.89***	11%
	Confidence Interval	(0.923-0.963)		(0.863-0.922)	
	R^2	0.041		0.030	
	N	203266		203266	
Add Occupation	**Hazard Ratio**	0.93***	1%	0.88***	NA
	Confidence Interval	(0.914-0.955)		(0.850-0.909)	
	R^2	0.041		0.031	
	N	203266		203266	
Add Marital Status	**Hazard Ratio**	0.97***	52%	0.90***	16%
	Confidence Interval	(0.947-0.989)		(0.868-0.928)	
	R^2	0.051		0.035	
	N	203266		203266	
Add Wealth + Occupation + Marital Status	**Hazard Ratio**	0.97***	59%	0.91***	27%
	Confidence Interval	(0.950-0.995)		(0.881-0.941)	
	R^2	0.051		0.036	
	N	203266		203266	

Note: Significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Data here is pooled for all three time periods. All equations run with the cox proportional hazards model: $log\ h_i(t) = \alpha(t) + \beta_1 Edu_i + \beta_2 X_i + \beta_3 Z_i$ where Z_i represents either wealth, occupation or marital status. All models include exogenous controls for age, religion, household size, birth cohort and census year. The % of the Gradient explained is calculated with the formula: $[(\beta_1^{Model\ 1} - \beta_1^{Model\ 2})/\beta_1^{Model\ 1}] * 100$, where model 1 is the base model and model 2 is the subsequent models with the individual component added or with all three added together. Detailed models shown in Appendix C-4 and C-5.

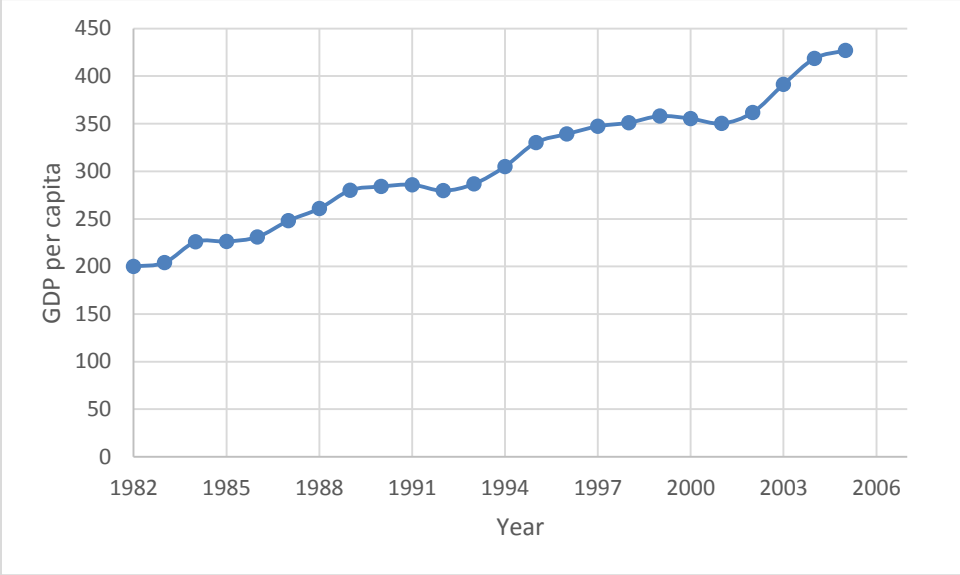
Table 2-5. Explanatory contribution of the components to the education gradient in NCD or infectious disease mortality in males

Model	Parameter	NCD	% Gradient	Infectious Disease	% Gradient
Base Model	**Hazard Ratio**	0.98***	--	0.92***	--
	Confidence Interval	(0.972-0.987)		(0.911-0.936)	
	R^2	0.053		0.035	
	N	186264		186264	
Add Wealth	**Hazard Ratio**	0.99***	48%	0.94***	20%
	Confidence Interval	(0.979-0.999)		(0.925-0.951)	
	R^2	0.053		0.035	
	N	186264		186264	
Add Occupation	**Hazard Ratio**	0.98***	19%	0.94***	21%
	Confidence Interval	(0.974-0.993)		(0.923-0.949)	
	R^2	0.053		0.035	
	N	186264		186264	
Add Marital Status	**Hazard Ratio**	1.00	NA	0.94***	21%
	Confidence Interval	(0.995-1.011)		(0.926-0.952)	
	R^2	0.107		0.049	
	N	186264		186264	
Add Wealth + Occupation + Marital Status	**Hazard Ratio**	1.00	NA	0.96***	49%
	Confidence Interval	(0.985-1.024)		(0.947-0.973)	
	R^2	0.107		0.050	
	N	186264		186264	

Note: Significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Data here is pooled for all three time periods. All equations run with the cox proportional hazards model: $\log h_i(t) = \alpha(t) + \beta_1 Edu_i + \beta_2 X_i + \beta_3 Z_i$ where Z_i represents either wealth, occupation or marital status. All models include exogenous controls for age, religion, household size, birth cohort and census year. The % of the Gradient explained is calculated with the formula: $[(\beta_1^{Model\ 1} - \beta_1^{Model\ 2})/\beta_1^{Model\ 1}] * 100$, where model 1 is the base model and model 2 is the subsequent models with the individual component added or with all three added together. Detailed models shown in Appendix C-2 and C-3.

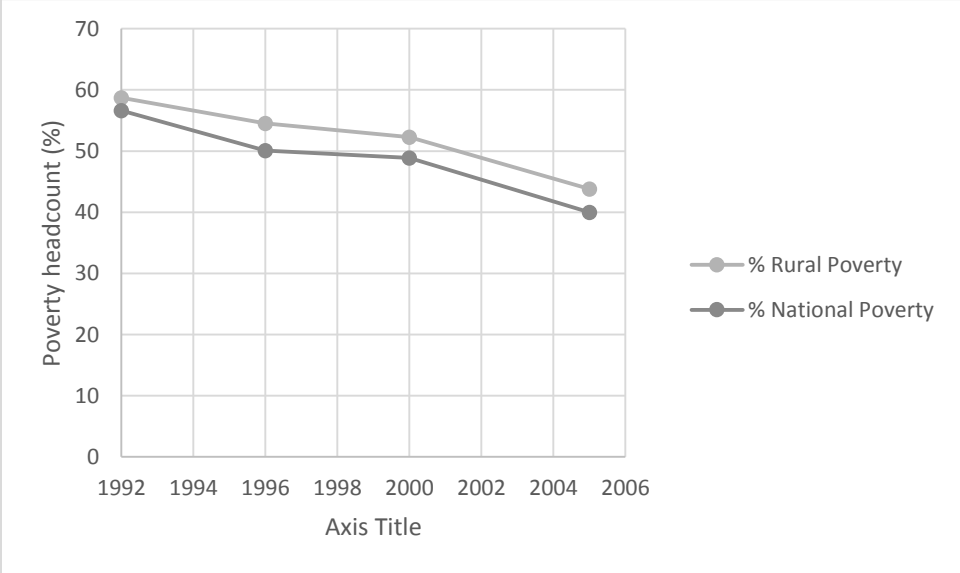
2.10 Figures for Chapter 2

Figure 2-1. GDP per Capita (US$) for Bangladesh



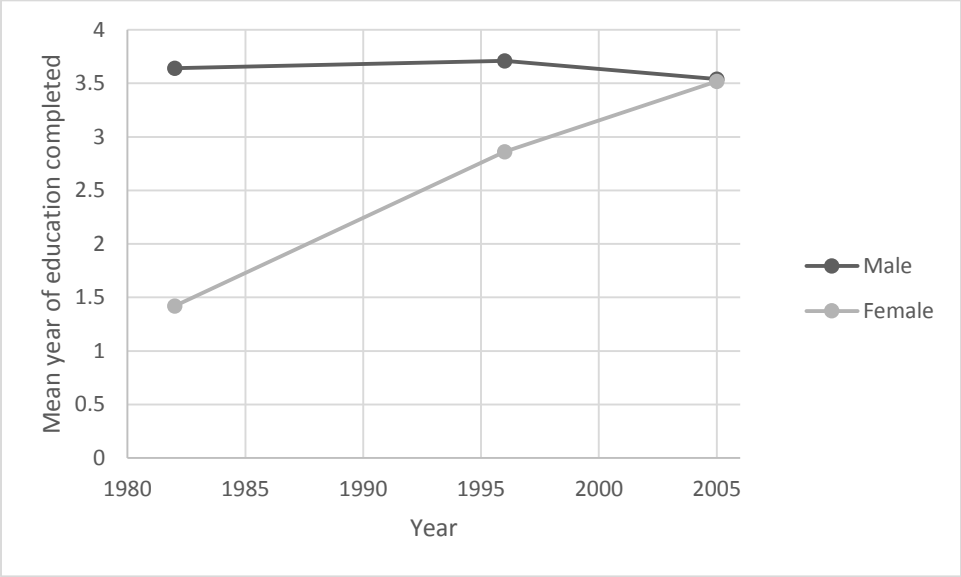
Note: GDP – Gross Domestic Product per capita, measured in US$ using current prices. Reference: IMF World Economic Outlook (47).

Figure 2-2. Percentage of the Population of Bangladesh in Poverty



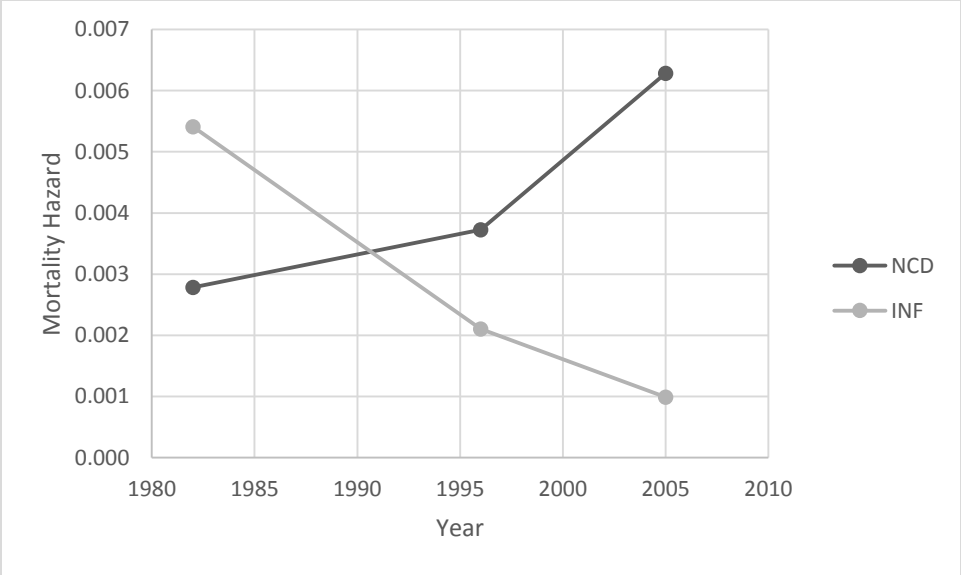
Note: 1992 is the earliest year for which poverty headcount estimates are available. % Rural poverty is equal to the poverty headcount ratio at the rural poverty line (% of rural population). % National Poverty is equal to the poverty headcount ratio at the national poverty line (% of population). Reference: World Bank Poverty and Inequality Database (48).

Figure 2-3. Mean Years of Education Completed by Sex in Matlab, Bangladesh



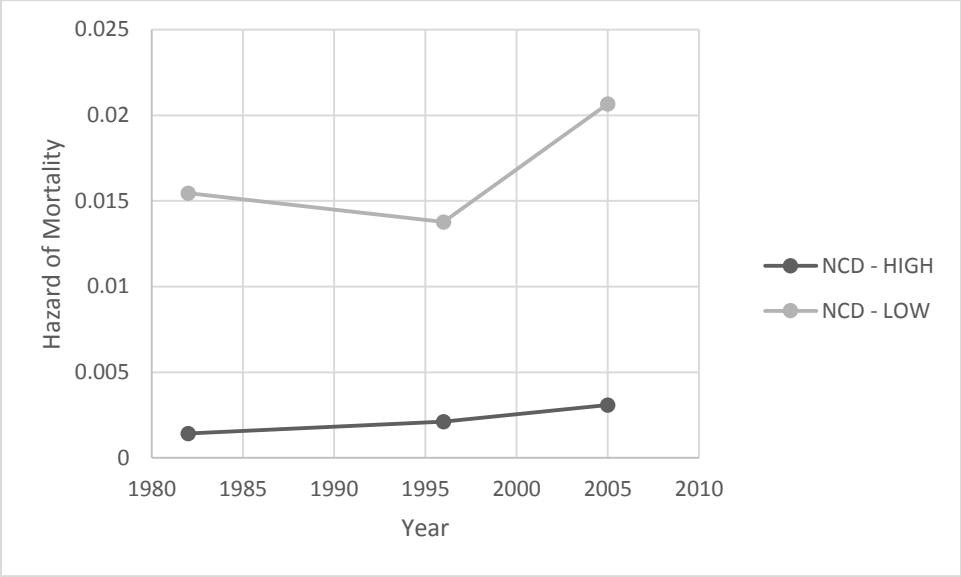
Note: Observations are the mean of the continuous year of education for males and females at three time points: 1982, 1996 and 2005.

Figure 2-4. Mortality from Non-communicable and Infectious Diseases in Matlab, Bangladesh



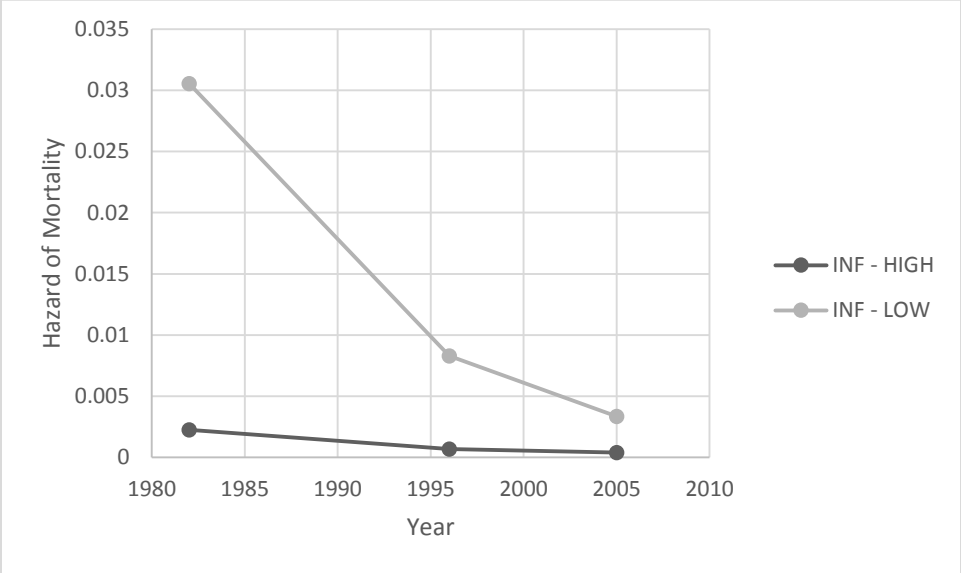
Note: Mortality hazard calculated as the number of deaths from a given cause (NCD or infectious divided by the total person years contributed over the 5-year follow up for each of the timepoints 1982, 1996 and 2005.

Figure 2-5. Non-communicable Disease Mortality by Education for Matlab, Bangladesh



Note: High education is more than 5 years completed and low education is 5 or less years of education completed.

Figure 2-6. Infectious Disease Mortality by Education for Matlab, Bangladesh



Note: High education is more than 5 years completed and low education is 5 or less years of education completed.

Chapter 3. The Household Economic Impact of a Non-Communicable Disease Death in Matlab, Bangladesh: An Empirical Application of Regression Standardization

3.1 Abstract

Adverse health events may negatively impact the economic condition of a household. In low and middle-income countries with a growing portion of their disease burdens coming from non-communicable diseases (NCD), the consequences of poor health from NCDs have not been fully explored. This work evaluates the risk of being poor for households with an adult NCD death. A cohort study is conducted in a rural area of Bangladesh, and a marginal estimator using regression standardization, is used to estimate the economic impacts of a death. Three different measures of economic outcomes are explored: an asset-based index, self-rated household economic condition and total household landholding. The results show that households with an adult NCD death had a significantly higher marginal risk of being poor up to two years after the death that ranged from 14-19%. This effect was significant for all three outcomes of economic condition. Comparing the regression standardized results to those using traditional contingency tables and multivariate regression found similar results. The regression also showed that a death to a prime, working-age (ages 15-59) household member leads to a significantly higher risk of being poor when using an asset index or self-rated economic condition. This work emphasizes the need for more intense prevention efforts for NCDs and for better financial protection from health shocks in rural Bangladesh. The finding of a significant economic impact for households experiencing NCD deaths means that programs to address the burden of NCDs and policies that provide for better access to care and risk-pooling for households will aid the economic development in rural

Bangladesh. Future work should disentangle further the mechanisms through which economic impacts from an NCD death shock occur.

3.2 Introduction

There is a strong positive association between health and wealth. This relationship was made explicit at a country level with the work of Samuel Preston in 1975 who looked at the relationship between life expectancy and per capita gross domestic product (GDP) (Preston 1975). At the microeconomic level there are attempts to understand the health and wealth relationship as bi-directional. In the direction of wealth to health, research has focused on the effect of more economic resources leading to better health outcomes. Alternatively, economic research to understand the relationship in the opposite direction, from health to wealth, establishes a framework for wealth impacts through increased health expenditure, changes to labor participation, changes to human capital and changes in the marginal utility of consumption (40).

One approach for assessing the effects of health on wealth at the micro level has been to look at "health shocks", defined as an unanticipated event that leads to economic losses and constrained opportunities for households (21, 96). Health shocks, when assumed to be exogenous, have also been used as tools for economists for solving the endogeneity problem between health and wealth. For a shock from a death to a household member, increased health expenditures and losses of human capital are detrimental to a household's overall economic condition (97). In low and middle-income countries this may be especially true since there is limited access to social protection and risk-pooling mechanisms (98). In terms of shocks from adult mortality, the economic impacts have

been looked at for communicable diseases such as HIV/AIDS and found that there are significant costs to individuals and households in terms of reduced consumption and human capital (97, 99). Others have found economic impacts on children when there is an adult death (100). There have also been studies that look at non-mortality health shocks such as self-reported morbidity and the associated economic impacts (101). Overall, the evidence supports that health shocks have a negative economic impact on households through increased medical expenditure and reduced human capital. In contrast, in some settings, there have also been studies showing no effects or even improved economic outcomes after health shocks, showing the complexity of the issue. The impact of health shocks from NCD mortality have not been studied as well but there is evidence that they have the potential to be even more severe than those from other causes of disease (20). NCDs are also predicted to play a role in the understanding of socioeconomic mobility and poverty traps. Recent research has examined NCD-related poverty issues in low-income countries and found that there are important interactions with NCDs and poverty (102, 103).

NCDs are a growing portion of the disease burden in low and middle-income countries and particularly troubling is the premature mortality from NCDs. A 2010 report by the World Health Organization (WHO) found that 29% of NCD deaths were in people younger than 60 years old in low and middle-income countries, whereas this same statistic was 13% for high income countries (11). In Bangladesh, non-communicable diseases (NCD) represent the leading cause of mortality and there has been a large growth in the proportion of deaths from NCDs over time (3). In the rural area of Matlab, Bangladesh, a demographic surveillance site with ongoing cause of death monitoring,

there have been age-adjusted increases in the mortality rates from NCD specific causes (5).

Examining the economic impact to households from NCD deaths may be an issue given the bi-directional relationship between health and wealth. For this reason, NCD health shocks in terms of adult mortality are used in a matched cohort study design in the Matlab demographic surveillance area. An extension of standardization methods, using a regression standardization approach, was developed recently for matched cohort analysis is used to provide a marginal effect (104). The regression standardization method is implemented with a parametric model and with a machine learning function to address the well-known limitations of parametric models. More specifically, the major limitation of parametric models is the assumption made about the underlying data distribution. In practice it is very unlikely that one can correctly specify the functional form of the parametric regression. These concerns have been discussed widely in the statistics and epidemiology literature (105-108). This approach of combining machine learning and effect estimation has been shown to be more robust to model misspecification than traditional, parametric approaches (108). Here, this approach is used to provide a policy-relevant estimate, a marginal estimate of the effect among the exposed, for mitigating the risk of poverty for those experiencing adult NCD health shocks.

The objective of this study is to evaluate whether households in rural Bangladesh experiencing mortality shocks from NCDs have a higher risk of being poor two years after death. This is done with the use of a regression standardized marginal estimator and a novel machine learning standardized estimator in Matlab, Bangladesh, a rural area with

demographic surveillance. These results are compared with traditional analyses approaches using contingency tables and multivariate regression. As a sub-objective the economic impacts from NCD death are evaluated for whether they differ by individual characteristics such as prime age (working age) status, sex, marital status and position in the household.

3.3 Literature Review

3.3.1 The Economic Consequences of Poor Health

In aggregate, the positive relationship between health and wealth shows that countries with a lower GDP have worse health, in terms of life expectancy, and that higher national income is related to better life expectancy (7). The existence of a positive relationship leads to a question of the directionality of the relationship between health and wealth. At the aggregate level, there have been attempts to look at the effect of increasing income on health, and also the reverse effect, how better health leads to more wealth or income.

There have also been attempts to explore this relationship at the micro level of the individual and the household. In low income countries, shocks from health events have been reported to be an important for the economic situation of the household (21). These micro-level economic impacts were explored by Gertler and Gruber who found that households in Indonesia may not be able to fully smooth consumption (adjust for economic losses) after health shocks (20).

There are two frameworks that have been used to look at the economic impacts from health shocks (42, 43). Such mortality shocks result in the loss of human capital for

households and may result in the loss of income earning potential as well. Often, the most devastating impacts of mortality shocks have been to households experiencing deaths of prime working-age adult members (97, 109).

Other studies in developing countries that have looked at the impact of adult health shocks have been in settings of high HIV/AIDs prevalence. This work has taken place in with datasets from Tanzania, Kenya, Mozambique and Zambia and are primarily concerned with death from adult, economically productive household members (97, 99, 109-111). These studies find differences in the effects on households from prime-age mortality based on the age and gender composition of the households, the initial wealth and the labor and agricultural characteristics of the community. Outside of the HIV/AIDS literature, other analyses have been conducted looking at the impacts of health shocks on household wealth outcomes in low income country settings (112, 113).

The importance of understanding the effects of prime age, or economically active, adults depends on whether the person that died was a net consumer or net producer for the household. It also depends on whether the earning activities of the household are changed, called income coping, and whether the composition structure of the household is changed, called demographic coping (109, 111). The issue of coping is examined in the next framework.

3.3.2 Economic Consequences of Non-communicable disease

The growing burden from NCDs has the potential to have large economic consequences. Recent work estimates the global output loss from NCDs such as CVD, chronic

respiratory disease, cancer, diabetes and mental health be near $47 trillion (8). At the microeconomic level, other studies have shown households experiencing NCDs may have worse economic outcomes than those with poor health from communicable diseases. This was seen in the data originally with self-reported health (20). Analyses have also shown that households with chronic illness, *ex post*, are more likely to be in the lower two socioeconomic quintiles (lower 40% of the wealth distribution) (114).

At the household level, the economic impact from an NCD may be realized through higher out of pocket expenditures (OOP). This has been seen in research in Russia and Ukraine where there are formalized systems for financial risk pooling (115, 116). One study in South Asia found a similar result, with larger OOP health expenditure in for households with angina in India (96).

Another explanation for the economic impact from NCDs comes from the effect on labor supply. In studies looking at health shocks from illness episodes, not deaths, the effect on labor income was found to be a reduction of nearly 5% for NCD illness with no significant loss for households with a communicable disease illness (115). In terms of labor participation, two studies in South Asia have found that household labor decreases overall by about 2-3% compared to a control group when there is an NCD (117, 118). The reduced labor participation is also seen in studies of the impact of a death, which reduces labor participation through the reduction of human capital of a household (99). When examining labor participation, however, there is also a possibility that the non-sick members of the household will increase labor participation and earn more income to cope with the health event or death.

While OOP medical expenditure and labor outcome have been found to be worse for households with NCDs, another measure of general economic impact is non-medical expenditure. For this outcome, studies that have looked at NCDs have found more mixed results (96). While one study in India found a small decline in non-medical expenditure for households with heart disease, another study looking at angina in multiple South Asian countries did not find any reduction in non-medical expenditure (96, 117). One explanation for this may be that NCD health events take place in older age groups where households have time to adjust finances and can even anticipate the onset of a death. In these settings, some households, from an economic standpoint, may even be better off following a death of an older household member that is a net-consumer.

3.3.3 Accounting for Endogeneity between Health and Wealth

Understanding the relationship of NCD deaths with household economic condition in Bangladesh presents some methodological challenges. The endogenous relationship between health and wealth means that cross-sectional associations will not provide a causal indication of the level of economic impact that could be realized that would come from a reduction of the NCD burden. Shocks are usually considered to be idiosyncratic and exogenous, and because of these properties, could provide some conclusion about the causal relationship between health and wealth (119). A recent review, has shown that when measuring the effects of health shocks, there is a heterogeneity of methodologies to account for endogeneity, economic outcomes used and types of health events used (96). Some studies have constructed a counterfactual comparison group with matching through direct matching approaches and through propensity score matching approaches to account for the endogeneity between health and wealth (116, 118). These approaches, as well as

implementation of fixed effects in regression help account for time invariant unobservable factors that may confound the results. Further work has also used instrumental variables estimation, which also accounts for time variant unobservable effects, but which may pose more burden on the researcher to identify a valid instrument (115).

This study does not make final causal conclusions about the impact of health on wealth because there may be other unobservable confounders that are not identified here. This study does however use an epidemiologic study design, a matched cohort study, and a novel estimator to account for all of the measured confounding and to provide a marginal estimate. There is also a chance that the addition of an instrumental variable estimation approach to address unobserved confounding would change these results, which would further strengthen any causal conclusions. This study is one of the first in the health economics literature to use a matched cohort design and regression standardization to obtain a marginal effect in combination with a super learner machine learning algorithm. There have been other examples of these approaches in the biostatistics and epidemiology literature (104, 120).

3.4 Data

The data for this study come from two different sources. One is the ongoing health and demographic surveillance conducted by the International Center for Diarrhoeal Disease Research in Bangladesh (icddr,b). This surveillance is a yearly census of all vital events for the Matlab population. As a part of this surveillance, there is a periodic

socioeconomic status census, approximately every ten years, which collects information on the ownership of household assets.

A strength of using this surveillance data is the ability to select households with NCD deaths from administrative census data. Having census data for deaths that includes cause of death information means we can identify all households that had NCD deaths in 2010. This is a unique situation for a rural, poor population in a developing country. Other surveys of health-related impact suffer from endogeneity bias due to self-rated shocks where upward bias is possible if a household member is more likely to remember a shock because it is severe (112). In addition to collecting information on deaths, data for specific causes of death by ICD-10 coding allows for accurate identification of the causes of death. Previous studies in low-resource settings where cause of death information is not available have had to use proxy variables such as age of death to determine the cause (111).

Using mortality as the primary independent variable provides an objective measure, subject to less bias than a subjective health rating. Using self-rated health may be insufficient if notions of well-being differ systematically in different cultures. For this reason, self- assessed functional status or objective health measures are found to be better (121).

The second source of data for this study is a survey that was designed to evaluate the household economic impact of NCD mortality. This survey was collected for the study population in Matlab in the year 2012 and is found in the **Appendix 7.1**. Separate modules in the survey collected information on the socioeconomic and demographic

characteristic of the household, information about the NCD death in 2010 and subsequent household coping strategies.

The study population consists of all adult deaths, defined as 15 years or older, from NCDs that were recorded in the routine surveillance for Matlab in the calendar year 2010. Using a lower age of 15 is justified for a rural, low income setting such as Matlab where most people complete education and enter the work force by this age (56). There were 909 adult NCD deaths in Matlab in 2010 identified by routine surveillance. Of these 909, 856 of the households were surveyed in 2012, meaning that there was a 6% attrition rate for the study. The group of households where these deaths occurred is referred to as the "NCD group" for the remainder of this study.

Each individual in the NCD group was matched to another individual in a household with no deaths in the year 2010. The group of households with this individual is referred to as the "comparison group". The direct matching procedure was based on the age, sex and village of the deceased individual. Deceased individuals and comparison individuals were matched exactly on sex and within 5 years on age. Comparison individuals residing in the same or nearest village meeting these criteria were selected. Three matching households were identified for each individual in the NCD group, of which, up to two were interviewed. A diagram showing the study design is shown in **Figure 3-1**.

3.4.1 Primary Dependent Variables for Economic Impact

This study used three measures of economic status: an asset-based wealth index, self-reported economic condition and the total amount of land that a household owns. These

were collected in the 2012 survey. Each of these measures was assessed in 2012, when the interview was conducted for both of the groups. **Table 3-1** provides a definition for each one of these outcomes.

The three different measures provide a picture of the economic status of the households from different lenses. The asset-based index using durable household items has been used in Matlab for decades and provides a validated estimate for the distribution of wealth based on these items. The latent wealth variable, however, may also be captured with the self-rated economic condition measure, which takes into account non-asset components of wealth and subjective perceptions of wealth as well. Further testing is done with a measurement of total landholding, which is common for areas of rural Bangladesh such as Matlab with an agrarian economy. This measure, however, also suffers from limitations when there shifting importance of agriculture in the economy. A matrix of pros and cons for each measure is listed in **Figure 3-2.**

3.4.1.1 Asset-based wealth index

An asset index was calculated as a measure for wealth, which is typically done in the absence of data on income or consumption (88). The index was calculated with a principal component analysis (PCA) of 26 durable household goods collected in the survey in 2012. PCA is a common method for transforming a list of assets into an index that measures wealth when information for prices is not available. PCA, however, provides a cross-sectional snapshot of the economic condition of an area and may not be ideal when understanding longitudinal changes in socioeconomic status is needed (122).

The cross-sectional nature of PCA presents problems for looking at asset scores over multiple time periods. When PCA weights (the eigenvalues derived from PCA) are used for more than one time period, the weights can be applied either to the pooled sample or to the baseline sample with an assumption that the relationship between asset ownership and wealth is constant (123). Following this suggestion, for our study, one option would be to use the PCA weights from the 2005 socioeconomic status surveillance census to the survey data from 2012. Another suggested solution to this issue is to use a modified version of PCA called polychoric principal component analysis (PPCA) that has been proposed as a better approach to measure asset-based wealth over multiple time periods (122). PPCA better accounts for differences across time because it provides a weight for asset ownership as well as non-ownership with a negatively signed weight.

PPCA was run for the list of assets collected in Matlab in 2005 and the weights were applied to the same listing of assets which was collected for the 2012 NCD economics survey. Being poor was defined as being in the bottom 40% of the wealth distribution, which is the lowest two wealth quintiles.

The limitations of asset-based wealth measurement have been well-documented. A primary limitation for this measurement is that a lack of prices prohibits assigning a monetary value to the assets. The quality and length of time that the household has held the assets are also not measured. Studies on the relationship of asset indices with detailed surveys of consumption in India have found poor correlation (124).

3.4.1.2 Self-rated economic condition

The second measure of economic condition was household self-rated economic condition according to a 5-step subjective ladder. These types of subjective ladders of socioeconomic status have been called Macarthur scales and have been used as alternatives to objective socioeconomic status measures or when understanding perceived economic status. Similar self-rating scales have been used in prior work looking at the economic impact from health shocks in low income country settings (112) (21, 125).

The survey asked surviving respondents to assess the household economic condition in 2012 at the time of the interview, approximately two years after the NCD death. Household representatives were asked to mark their economic condition onto a 5-step ladder with steps representing: 1 – very poor, 2 – poor, 3 – not poor or rich, 4 – rich and 5 – very rich. (126). When identifying interview respondents, measures were taken to ensure that individual could speak about the general economic condition of the household.

Households that marked that they were in the first two rungs of the ladder were considered poor. An example of the survey question for self-rated economic condition is shown in **t**he full questionnaire in the **Appendix 7-1.**

For self-rated economic outcome, there may be bias resulting from using recall data from up to two years in the past. The households could either forget about the significance of a death or exaggerate the impacts as being too severe. Attempts to minimize this bias for

this study came from constructing disease timelines and using natural events (e.g. the annual wet season) as reference points.

3.4.1.3 Landholding

The third measure of economic condition is a measure of total household landholding. This comprised both residential land and agricultural land. The use of landholding as an indicator of wealth status has been used previously in rural areas that have a high level of agricultural activity. This study used a threshold of 50 decimals (dm) of landholding to determine poor status. A decimal is a measure of land area that is only used in certain parts of India and Bangladesh. It is equal to 1/100 acre or 40.46m^2. Previous work in rural Bangladesh has validated this threshold as an indicator of poverty (127).

A limitation of using the measurement for landholding as a measurement for wealth is that it only captures wealth through this single dimension. With the growth of businesses and increasing education in the rural areas of Bangladesh, opportunities for non-agricultural income generation are likely becoming more prevalent. Further, there is no indication of the quality of the land that is owned or income generated from external sources such as remittances or safety net transfers. Households may also be incentivized to underreport landholdings if they think that sharing that information would lead to higher taxation. Regardless of these limitations, there is indication that land is still a central component of a household's assets in rural Bangladesh and that owning no land may be a good indicator of destitution.

3.4.1.4 Relation between the three economic outcomes

An overall description of the pros and cons of each of the economic outcomes is provided in **Figure 3-2.** Descriptive information is shown for the three economic outcomes of interest in **Table 3-1.** At the time that the survey was administered in 2012, the percentage of the population classified as poor differed depending on which measure is used. Using the asset index, 22% of the study population was classified as poor in at follow up. This is 42% when the self-rated economic condition and 63% according to the threshold of owning 50dm of total land. The correlation between the different measures is also shown in **Table 3-1.** The largest correlation is between the asset index and the self-rated condition, which has a Spearman rank coefficient of 0.39. The asset index and total landholding show the lowest amount of correlation, with a coefficient of 0.26. Comparing the correlation of self-rated economic condition and landholding also shows low amounts of correlation, with a Spearman coefficient of 0.32.

3.4.2 Primary Independent Variable – Non-Communicable Disease Mortality

The 909 adult deaths from NCDs were identified by International Classification of Disease version 10 (ICD-10) codes that are assigned by the surveillance team in Matlab through a dual physician review verbal autopsy. Deaths from injuries including unintentional injury such as accident and drowning, and intentional injury such as suicide and homicide were excluded (128). The final NCD deaths included deaths from: cancer, COPD, diabetes, cardiovascular disease (including hypertensive disorders, ischemic heart disease and stroke), blood disorders, metabolic disease, mental disorders, neurological

disease as well as other respiratory and digestive diseases. An illustration of the total numbers of deaths in each category is shown in **Figure 3-3.**

3.4.3 Further Independent Variables

The covariates used for stratification and in the multivariate analysis were collected through the routine surveillance for Matlab. These were obtained from the demographic surveillance system for the year 2009, the year prior to the NCD death. For the deceased individual, data were obtained for age, sex, household position, marital status and education. Data were also obtained for household-level characteristics such as religion and household size. The variable for household size may be an indicator of the total resources available to the household (129). All of the independent variables are assumed to be exogenous to the relationship of an NCD death on a household's economic condition.

Descriptive statistics for the independent variables are seen in **Table 3-2.** The distribution of variables that were used for matching: age, sex and village show that there is balance among the groups. The mean age is around 68 years and 21% of each group is considered prime age. Additionally, 45% of each group is female and the individuals in the NCD group also come from 135 different villages while those from the comparison group come from 145 villages.

The other individual-level variables show that a large proportion of the study population has no education and about a quarter have completed some primary education, up to 5 years of formal schooling. Only 15% has completed more than 6 years of formal

schooling. For marital status, 62% of the study population is married and 36% are widowed. A small percentage report being either unmarried or divorced, 2% and 1% respectively.

Position within the household was measured as a binary variable for whether one was the household head or spouse of the household head. This is the only independent variable which shows a significant difference between groups. 67% of the NCD group and 73% of the comparison group are either household heads or spouses of the household head. The percentage of households self-reporting their economic condition as poor prior to the death is also shown. Here, 44% of the NCD households and 43% of the comparison households self-report as poor either before the death in the former or in 2009 for the latter. By this measure, the households do not appear to be different in economic status at baseline.

Household-level independent variables were included for total household size and religion. These did not differ between groups. The mean household size was around 6.2 persons and 86% of the population was Muslim.

3.5 Analytical Framework

3.5.1 Study Design

This study uses a matched cohort design with exposure-driven sampling, the exposure of interest being an adult death from an NCD (130). Matched cohort designs are relatively rare compared to other designs, but it is used here because of the availability of

surveillance information for all households in Matlab and the ability to identify all deaths for a given time period by cause. The matching procedure establishes a comparison group that potentially balances confounding variables related to the household's economic status at baseline (131). Using a matched cohort design also means that adjustment can be done for the variables used for matching. The longitudinal nature of the cohort design also means that household and individual characteristics are removed that could affect the economic impact of an NCD death (131).

The differences between descriptive characteristics for the NCD group and the comparison group at baseline are first assessed. There is ambiguity in the literature about whether accounting for matched variables in a matched cohort analysis is needed. We use a t-test statistic for continuous variables and assuming independence between the groups. A paired t-test may also be used in matched cohort study, and we find similar result when using a paired or unpaired test but only report the unpaired results (104, 132). A chi squared test for independence is used for categorical variables (133).

3.5.2 Method 1: Marginal Effect Estimation with Regression Standardization and Machine Learning

The strategy uses an estimator of marginal effect calculated through regression standardization, an extension of traditional standardization methods (104, 134). This estimator uses the marginal distribution of the baseline covariates and matching variables in the exposed subjects to estimate the familiar average exposure effect on the exposed parameter. This parameter is most commonly referred to as the average treatment effect on the treated (ATT) in the health economics and statistics literature when a treatment is

of interest instead of an exposure (135-137). Inverse probability weighted methods have also been used to estimate marginal parameters, however, these estimators can have poor performance in practice with respect to bias and efficiency, particularly when the probability of exposure is large or small. The standardized estimator is calculated through a process of marginalizing over observed covariate distributions in the exposed subjects after obtaining counterfactual outcomes, given that all possible exposure scenarios are unobserved. This is because the creation of a true counterfactual scenario, which is the goal of causal inference, is never observed with empirical data. The parametric versions of the estimator use regression functions based on an a priori specified parametric model to calculate the expected counterfactual scenarios and obtain a marginal effect (104, 120). The steps for regression standardization are as follows:

1. Estimate the outcome regression using the traditional parametric approach: $E(Y|A,W)$. The expected value of the outcome *Y* given the exposure to an adult NCD death *A*, conditional on all of the covariates of interest, *W*. The vector *W* also contains the matching variables.
2. Use the equation in step 1, to obtain each observation's predicted value under the condition that they were exposed to an adult NCD death (*A = 1)*.
3. Repeat step 2, except this time obtain the predicted values with each observation not being exposed to an adult NCD death (*A = 0*).
4. The predicted values from steps 2 and 3 are then used to calculate the estimator of interest:

$$\hat{\varphi}RR = \frac{\frac{1}{N}\sum_{i=1}^{N}[\hat{E}(Y|A=1,W)]}{\frac{1}{N}\sum_{i=1}^{N}[\hat{E}(Y|A=0,W)]},$$

which here estimates the relative risk parameter of exposure among the exposed.

5. Use bootstrapping to obtain standard errors for the marginal effect of interest obtained from step 4.

One of the limitations of this approach regards fitting the model in step 1. If this model is misspecified, then bias could result in the standardized estimate as well. To explore this further, a machine learning algorithm is used for specifying the regression function and calculating a subsequent standardized estimator. Machine learning is a broad term for flexible computational techniques that use the data to "learn" in order make estimations, generalizations or predictions (138). Machine learning can be used to estimate the conditional expectation given baseline covariates with a more versatile bias-variance trade-off. These methods have been used widely for purposes of prediction and classification; however, more recently, machine learning has been incorporated into effect estimation. When machine learning is integrating into the estimation process for effects, cross-validation must also be implemented to evaluate over-fitting. Cross-validation is the process of dividing a dataset into separate smaller datasets for validation purposes (also referred to as "hold-out samples.") Overfitting is assessed in this fashion by the ability of the algorithm to predict values out of the sample of interest (105, 107, 108, 138).

The machine learning algorithm that is implemented here is a "super-learner", which is an ensembling machine-learning approach (107, 108). Super learning is a framework that allows for the use of multiple machine learning algorithms while producing the best

weighted average of these candidate learners. This is implemented in step 1 of the above 5 step process. The application of the super-learner machine learning algorithm for a matched cohort design is described in full detail in a companion paper to this work (139). The super learner algorithm is implemented in R programming language using the SuperLearner package (140). A collection of 3 algorithms were used in this analysis: logistic regression implemented with the generalized linear models (glm) package, the arithmetic mean where the marginal probability of being poor in each cross-validation fold is assigned to each household and a final package (glmnet) for penalized regression using the least absolute shrinkage and selection operator (LASSO) (141). Super learner performs cross-validation internally, such that the optimal final weighted average of algorithms is built based on algorithm performance in the "hold-out" samples. Bootstrapping is used for obtaining standard errors and confidence intervals.

3.5.3 Method 2: Contingency Tables Analysis

Contingency tables are a traditional method for examining epidemiologic effects. Following recommendations for a matched cohort study with binary treatment and outcome variables, a 2x2 contingency table was used to show the relative risk of being poor two years after death given an NCD mortality shock (132, 142). Stratified contingency tables were used to adjust for variables used in the direct matching as well as other independent variables of interest.

3.5.4 Method 3: Log-Binomial Regression

Multivariate analyses were conducted with a log-binomial regression model. This model, which is mathematically similar to the Poisson regression approach, produces estimates of the relative risk conditional on all independent variables of interest. The model is specified as follows:

$$log\ Y_i(t) = \alpha(t) + \beta_1 NCD_i + \cdots + \beta_k X_i \quad (1)$$

Where Y_i is an indicator of whether household i is poor or not according to one of the three measures for economic status. β_1 is the coefficient on the indicator for whether a household had an NCD adult death in 2010. Taking the exponent β_1 gives the relative risk of being poor for households with an NCD death. β_k is the coefficient on the other independent variables of interest, given by the vector X_i. The model is run separately for each of the three economic outcomes of interest and standard errors are clustered by household. An interaction terms is used in the regression model to assess if the risk of poverty following a health shock is different according to the prime-age status of the individual.

3.6 Results

The results for this matched cohort study are presented with three different methods: a marginal regression standardization estimator, a traditional contingency table approach and multivariate log-binomial regression approach. The regression standardization estimator gives the marginal effect on economic condition following an NCD death

accounting for the distributions of NCD deaths in Matlab as well as the other independent covariates, among those with an NCD death. These are compared to contingency tables and a log-binomial regression. The regression also examines whether the economic impact of having an NCD death is modified when the death is to a prime age member of the household.

3.6.1 Method 1 Results: Regression Standardization for Marginal Effects Results

The results of the regression standardization estimator using parametric regression are shown in **Table 3-3.** The results represent the marginal effects for the risk of being poor in 2012 given an adult NCD death in 2010. Using the asset-based quintile, the relative risk is 1.19 and significant meaning that having a death leads to a 19% greater risk of being poor. For self-rated economic status, the results show that there is a significant relative risk of 1.16, meaning that there is a 16% higher risk of a household perceiving its status as poor in 2012 after the death in 2010. For the variable of land-holding, the risk of being poor is also positive and significant and shows a 14% higher risk of a household being poor given an NCD death (relative risk: 1.14). The results with the super-learner machine learning approach show similar results to the regression standardization approach but overall have slightly smaller relative risks. Interestingly, the relative risk using the asset-based quintile, 1.15, is no longer statistically significant since the confidence interval crosses one (CI: 0.98 to 1.32). The results for self-rated condition (RR = 1.13) and land-holding (RR = 1.11), however do find significantly elevated risks of being poor.

The use of a matched cohort for census data and a relative risk approach for assessing the economic impacts of mortality is novel and these results are not directly comparable to previous research, however, some relative understanding of these results are needed. Using cross-sectional data for Matlab in 1982 and 1996, previous researchers have found that the relative risk of mortality for adults aged 15-59 for a poor versus a non-poor group was around 1.40 (62). The results from this work then show that the relative risk of being poor after an adult NCD health shock is somewhat lower. Another paper in Vietnam assesses the risk of moving into a poor state for those that are non-poor before an injury and find a relative risk of 1.21. They also find that those who are poor and have an injury are less likely, by 4% to move out of poverty. Several studies, however, use a self-reported measure of economic well-being to assess the impact of a health shock. In Tanzania on study found that 20% of households reported having a year of "very bad" living conditions specifically due to the death of a household member (129). Another study in Vietnam found that households with shocks from deaths reported being more likely to have decreased welfare than did households experiencing shocks from droughts. When looking at changes in consumption, several studies have also found declines in consumption following a health shock from mortality. Estimates for the reduction in consumption have been 7-8% (143, 144). Results for the effect of health shocks on poverty incidence have also shown that this could be as large as 2% (143).

3.6.2 Method 2 Results: Contingency Tables

The results for the relative risk of being poor following a death from an NCD are shown with the contingency table calculations in **Table 3-4.** For the pooled group a significant risk of being poor after the death is found using the asset quintile. The relative risk of

1.19 means that there is a 19% higher risk of being poor two years after an adult NCD death compared to a comparison household with no death. Stratifying the study population by the individual characteristics of the deceased, significant increased risks of being poor according to the asset quintile are also seen for deaths to prime age household members and married members. The death of a prime age member leads to nearly two times the risk of being poor, while the death of a married member leads to a 26% higher risk (relative risks: 1.96 and 1.26).

For the outcome of self-rated economic condition in **Table 3-4**, the pooled sample shows a significant increased risk of being poor for those with an NCD death with a relative risk of 1.14. The stratified samples also show that deaths to male members, prime age members, uneducated members, married members and household heads lead to significant increased risks of being poor. The largest increase in risk of death is for a prime age member, where a death results in nearly a 50% increase in the risk of being poor (relative risk: 1.49).

The relative risk of being poor according to landholding is also shown in **Table 3-4.** In the pooled sample, the relative risk of being poor given an NCD death is 1.10 and is significant. In the stratified samples, the death of a male member, old age member, member with primary education, married member or household head show significant increased risks of being poor. The highest relative risk here is seen with the death of a member of the household with primary education, which raises the risk of being poor by 30% (relative risk: 1.30).

3.6.3 Method 3 Results: Log-binomial Regression

Table 3-5 shows the multivariate results from the log-binomial regression. The relative risks are shown, which are the exponentiated coefficients from the regression equation. Results are shown for each economic outcome after controlling for all of the individual and household level independent variable and with an interaction with whether a death was to a prime age member. After adjusting for all independent variables, the relative risks are all significant and consistent with the estimates provided by the regression standardization. The relative risk of being poor after an NCD death with the asset quintile is 1.19, with self-rated economic condition is 1.16 and with landholding is 1.14. Having a prime age death is also shown to significantly increase the risk of being poor when the asset quintile and self-rated condition are the outcomes of interest. For landholding as an economic outcome, an NCD death to a prime age member does not significantly modify the risk of being poor.

3.7 Discussion

The bi-directional nature of the relationship between health and wealth is well-known and many studies have shown that there are important effects in both directions. The emerging burden from NCDs means there may be severe economic impacts for households experiencing NCDs. In this study in Matlab, Bangladesh, a population of households with an adult NCD death and a comparison group with no deaths were identified through surveillance and administered a survey to determine the economic impact. A novel estimator was developed to estimate the marginal risk of being poor in the follow up period for households experiencing an NCD death. The risk of being poor

ranged from 13 to 20% higher for households with NCD deaths. These results were similar when compared to those using traditional analysis methods with contingency tables and conditional regression. For economic outcomes of asset quintile and self-rated economic condition, there is also a higher risk moderated by having an NCD death to a prime age member.

Our findings are provide evidence that health shocks contribute to a condition of poverty. If this is sustained over time, then this may also be a contributor to a medical poverty trap. Previous studies of health shocks in low and middle-income countries have found that economic impacts are not persistent out to 5 years (97). While the follow up period in this study is shorter, it does provide some evidence that there is a medical poverty trap related to the emerging burden of NCDs.

3.7.1 Policy Implications

To date, relatively little has been done in terms of health interventions to address NCDs in rural, low-income areas of Bangladesh. The availability of data from a long-running surveillance program in Matlab, Bangladesh, provides data for further exploration of NCDs and their impact on the rural poor. Previous studies have looked at the socioeconomic inequalities associated with the deaths of adults in Matlab. This has been done for the elderly population (greater than 60 years old) and for the middle aged married couples (ages 45-55) (6, 73). These studies have found that marital status and education are important determinants of mortality, and being single, widowed or of lower education leads to higher mortality. The work here looks at the economic impacts of deaths and whether there are long term effects for households. While increasingNCD

burden in Bangladesh has been emphasized, there has been little attention paid to the negative economic impacts that this may represent for households.

There are several policy instruments that may be warranted. One approach would be to help households smooth the effects of the health shock through better access to financial protection tools and risk-pooled insurance. The further refinement of the micro-lending packages that are available to households in rural Bangladesh. Micro-lending in Bangladesh is ubiquitous and a recent study has established stronger evidence that it can alleviate poverty over the long-term (145). There is also a role for incorporating formal insurance mechanisms although establishing these types of programs for the informal sector and the poor has many challenges (146, 147). Another policy approach would be to address the burden of NCDs directly by providing more health services for NCD prevention and management. The evidence from this study shows that a reduction in premature NCD deaths would have a significant impact on a household's risk of being poor.

3.7.2 Limitations

There are several limitations for this work. First, conducting the work in Matlab may limit the generalizability to other rural, low-income settings. Due to a long running health program that focuses on maternal and child health, Matlab likely has a proportionally higher burden of NCDs than other rural, low-income areas. This would bias the economic impact of NCD mortality upward. On the other hand, if residents of Matlab have healthier behaviors and greater health knowledge because of the long-running surveillance and health programs, the impact of a NCD death on households could be diminished

compared to similar rural areas without intensive health programs and data collection systems.

A second limitation of this work comes from drawing causal inferences for the effect of health on wealth. While we have made attempts to use new modeling approaches that simulate an experimental setting, there may be unobservable factors that cannot be observed and are thus mis-specified in our statistical model. These include factors such as health behaviors, access to services and inter-household preferences that may differ between the two groups in our study population. The interpretation of the results may further be limited because the outcome from this study is not a change in wealth status and thus baseline wealth status is not fully controlled for at baseline. This was done due to limitation in the three economic outcomes that are used; however, further research should advance this topic further by including baseline wealth measures as well.

3.7.3 Future Research

A future direction of this work is to use a double robust estimator that builds on the standardization framework for ensemble learning in targeted maximum likelihood estimation (TMLE). This approach has been shown to out-perform machine learning or standardization alone in other study designs and settings (108).

Beyond the development of better methods, further work should also collect better data on measures of the economic impact from health shocks in low and middle-income countries. While several surveys have used consumption as a measure of economic

welfare, these have not been incorporated into demographic surveillance systems that collect high quality information on the health shock itself (97, 113).

Further research should also specifically examine the intermediate pathways through which the economic impacts from health shocks occur and the coping mechanisms that households use to offset them (114).

3.8 Conclusion

This work is novel because of the use of regression standardization and machine-learning to obtain a marginal effects estimator in a complex study design. The use of this approach in a setting such as Matlab with census level data provides a novel approach for developing new methods to understand the marginal effects of exposures on outcomes of interest. This paper does so by being one of the first to estimate the economic impacts of adult NCD death in a low income country in the absence of consumption and expenditure data.

The long-running health and demographic surveillance system in Matlab is replicated in several other settings worldwide, called the INDEPTH network, and the methods developed in this paper may provide a model for designing studies and estimating effects to answer further research questions in such settings.

This study shows that there is an economic argument to be made for addressing the burden of NCDs in rural, low income settings. Without the introduction of interventions to address the burden from NCDs, households will have higher risks of moving into or staying in poverty because of the expenses and loss of human capital that shocks from

NCDs impose. This may also exacerbate inequality in rural, low income areas, where the effects of a rising NCD burden will more adversely affect the economic condition of worse-off households. Evaluating the economic impacts from NCD deaths provides one tool for breaking the health and poverty link. Future work should also further examine the coping strategies that households use to formally or informally deal with health shocks.

3.9 Tables for Chapter 3

Table 3-1. Comparison and Correlation of Three Economic Outcomes at Follow Up

Economic Outcome - 2012	Description	Percentage Poor (Std. Error)	Correlation - Asset Index	Correlation - Self-rated condition	Correlation - Landholding
1. Asset index	Wealth index based on a list of 26 durable household items and classified into 5 quintiles.	0.22 (0.01) *Threshold: 3rd Quintile*	NA	0.39	0.26
2. Self-rated condition	Perceived ranking of household economic condition by household representative on a scale of 1 = poorest to 5 = richest.	0.42 (0.01) *Threshold: 3rd Ladder Step*	0.39	NA	0.32
3. Landholding	Total amount of land area for homestead and agriculture that a household reports owning.	0.63 (0.01) *Threshold: 50 dm total land*	0.26	0.32	NA

Note: Percentage Poor is for the pooled sample, group with Non-communicable disease (NCD) death and comparison group. Thresholds for being poor include being in the 1st two quintiles for the asset index, being on the first two ladder rungs for self-rated condition and owning less than 50 decimals of land. Correlation for each measure is measured with Spearman's rank coefficient. NA is not applicable because of perfect correlation. The asset index and associated wealth quintile are calculated using polychoric principal component analysis (PPCA) with eigenvalue weights from the Matlab socioeconomic census in 2005. Self-rated condition asks respondents to rank the household's economic condition on a 5 step ladder. Landholding is measured in decimals, which is equivalent to 1/100 of an acre or 40.46 square meters.

Table 3-2. Characteristics of the Study Population Prior to Death for NCD group and Comparison group

Variable	Pooled	NCD death	Comparison	(NCD vs. Comparison)
	Mean (SD)/Proportion	Mean (SD)/Proportion	Mean (SD)/Proportion	(p-value or X^2)
Matching variables (deceased individual and matched comparison)				
Age	67.46 (12.46)	67.71 (12.72)	67.33 (12.33)	0.48
Prime Age (% 15-59)	0.21 (0.01)	0.21 (0.01)	0.21 (0.01)	0.94
Female	0.45 (0.01)	0.45 (0.02)	0.45 (0.01)	NA
Number of villages	145	136	145	NA
Individual characteristics (deceased individual and matched comparison)				
Education				
None	0.61 (0.01)	0.62 (0.02)	0.60 (0.01)	0.20
1-5 years	0.25 (0.01)	0.23 (0.01)	0.26 (0.01)	
6+ years	0.15 (0.01)	0.16 (0.01)	0.14 (0.01)	
Marital Status				
Single/Unmarried	0.02 (0.00)	0.02 (0.00)	0.01 (0.00)	0.11
Married	0.62 (0.01)	0.64 (0.02)	0.61 (0.01)	
Divorced	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)	
Widowed	0.36 (0.01)	0.34 (0.02)	0.38 (0.01)	
Head or Spouse of Head	0.71 (0.01)	0.67 (0.02)	0.73 (0.01)	0.00
Poor	0.43 (0.50)	0.44 (0.50)	0.43 (0.49)	0.43
Household characteristics				
Muslim	0.86 (0.01)	0.85 (0.01)	0.869 (0.01)	0.34
Household Size	6.21 (2.92)	6.18 (2.70)	6.23 (3.02)	0.68
N	2585	856	1729	

Note: NA (not applicable) applies to the test for difference for sex because of exact matching. For villages, the test of differences was not applicable. Student's t-test p-values are calculated for continuous measures of age and household size..X^2 p-values are calculated for categorical and binary variables. All values are estimated in the baseline year prior to death, calendar year 2009. The 856 NCD households represent all of the identified 909 households that had deaths in 2010. This means there was an attrition rate of 6% for the study. Poor is assessed by self-reported economic condition prior to death for NCD households and in 2009 for comparison households (asked retrospectively in the 2012 NCD and Economics survey).

Table 3-3. Regression Standardization Marginal Effect of an Adult Non-communicable Disease Death on Measures of Household Economic Condition using Parametric Regression and Machine Learning

	Relative Risk	Std. Error	Lower	Upper
Parametric Regression Standardization				
Asset quintile	1.19	0.09	1.01	1.37
Self-Rated Condition	1.16	0.05	1.05	1.27
Landholding	1.14	0.03	1.08	1.20
Machine-Learning (Super Learner) Estimation				
Asset quintile	1.15	0.09	0.98	1.32
Self-Rated Condition	1.13	0.05	1.03	1.23
Landholding	1.11	0.03	1.05	1.17

Note: All results are calculated with the relative risk equation: $\hat{\varphi}RR = \frac{\frac{1}{N}\sum_{i=1}^{N}[\hat{E}(Y|A=1,W)]}{\frac{1}{N}\sum_{i=1}^{N}[\hat{E}(Y|A=0,W)]}$*, using parametric regression standardization and machine learning. The machine learning uses an ensembling super-learner algorithm described in the references. The super learner algorithm is implemented in R programming language using the SuperLearner package (140). A collection of 3 algorithms were used in this analysis: logistic regression implemented with the generalized linear models (glm) package, the arithmetic mean where the marginal probability of being poor in each cross-validation fold is assigned to each household and a final package (glmnet) for penalized regression using the least absolute shrinkage and selection operator (LASSO)*

Table 3-4. Relative Risk Estimates for the NCD versus the Comparison group for three economic outcomes

	Asset quintile			Self-rated economic condition			Landholding		
	Relative Risk	Lower	Upper	Relative Risk	Lower	Upper	Relative Risk	Lower	Upper
Full Sample	1.19	1.02	1.39	1.14	1.03	1.26	1.10	1.03	1.17
Sex									
Male	1.22	0.98	1.52	1.18	1.04	1.34	1.18	1.08	1.29
Female	1.16	0.91	1.48	1.09	0.94	1.27	1.01	0.93	1.10
Age									
Prime Age	1.96	1.39	2.76	1.49	1.24	1.79	1.07	0.94	1.22
Old Age	1.04	0.83	1.30	1.05	0.93	1.19	1.11	1.03	1.19
Education									
None	1.13	0.96	1.34	1.16	1.04	1.29	1.04	0.97	1.11
1-5 years	1.28	0.85	1.94	0.99	0.00	INF	1.30	1.12	1.51
6+ years	1.55	0.66	3.64	1.36	0.91	2.03	1.12	0.89	1.40
Marital Status									
Single/Widow/Divorce	1.08	0.81	1.45	1.01	0.71	1.43	1.09	0.99	1.20
Married	1.26	1.03	1.54	1.22	1.08	1.38	1.12	1.03	1.22
Position									
Head/Spouse	1.18	0.97	1.43	1.16	1.03	1.3	1.14	1.06	1.23
Non-Head/Spouse	1.18	0.86	1.63	1.05	0.86	1.28	1.03	0.90	1.18

Note: In the table, "Asset quintile" refers to being in the bottom two quintiles as measured by asset-based principal component analysis. "Self-rated economic condition" refers to being in the poor or very poor group and "Landholding" refers to owning less than 50 decimals of land. A decimal of land refers to 1/100th of an acre or 40.46m^2. "Prime Age" here refers to those deaths to individuals aged 15-59 and "Old Age" refers to deaths to those aged 60 and above.

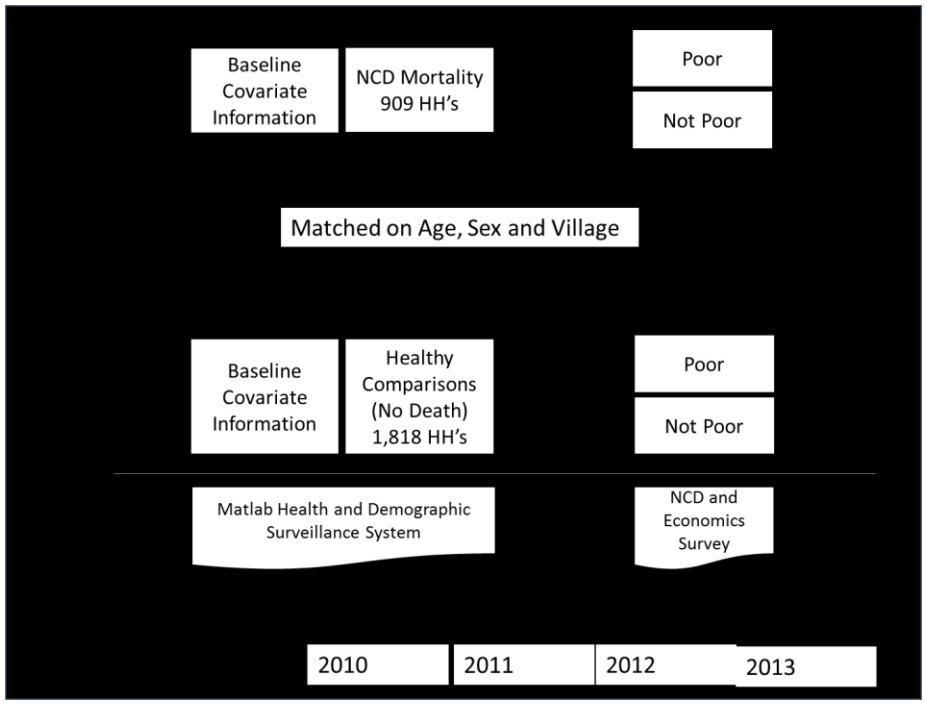
Table 3-5. Log Binomial Regression for the Effect of an Adult Non-communicable Disease Death on Measures of Household Economic Condition

	Asset quintile	Asset quintile - PA Interaction	Self-rated condition	Self rated condition - PA Interaction	Landholding	Landholding - PA Interaction
Intercept	0.85	1.60	1.94*	1.89	1.34	1.55
NCD death	1.19*	1.07	1.16**	1.09	1.14**	1.15**
Prime Age	0.74**	0.74**	0.86*	0.86	0.84**	0.84**
Female	0.99**	0.98***	0.99***	0.99**	0.99***	0.99***
Age	0.55***	0.55***	0.83**	0.83**	0.76***	0.76***
Education						
1-5 years (ref. None)	0.26***	0.27***	0.43***	0.44***	0.65***	0.65***
6+ years (ref. None)	1.69	2.06	1.30	1.34	2.09***	2.14***
Marital Status						
Married (ref. Unmarried)	2.94	3.40	1.23	1.18	1.17	1.23
Divorced (ref. Unmarried)	1.86	2.25	1.41	1.44	2.41***	2.47***
Widowed (ref. Unmarried)	1.01	1.00	0.93	0.93	0.94	0.94
HH head/spouse	0.87	0.87	0.88	0.88	0.78***	0.78***
Muslim	0.92***	0.92***	0.95***	0.95***	0.97***	0.97***
Household size	1.31	1.38	0.80	0.81	0.42	0.42
NCD x Prime Age		1.70***		1.33*		0.94
Log Likelihood	-1216.67	-1212.17	-1863.08	-1861.32	-2203.54	-2203.18
Deviance	1355.33	1346.34	1582.16	1578.63	1255.09	1254.35
Num. obs.	2,491	2,491	2,491	2,491	2,490	2,490

*Note: Significance: ***p<0.01, **p<0.05, *p<0.1. PA stands for prime-age, which is ages 15-59. All standard errors are clustered at the household level.*

3.10 Figures for Chapter 3

Figure 3-1. Diagram of Study Design

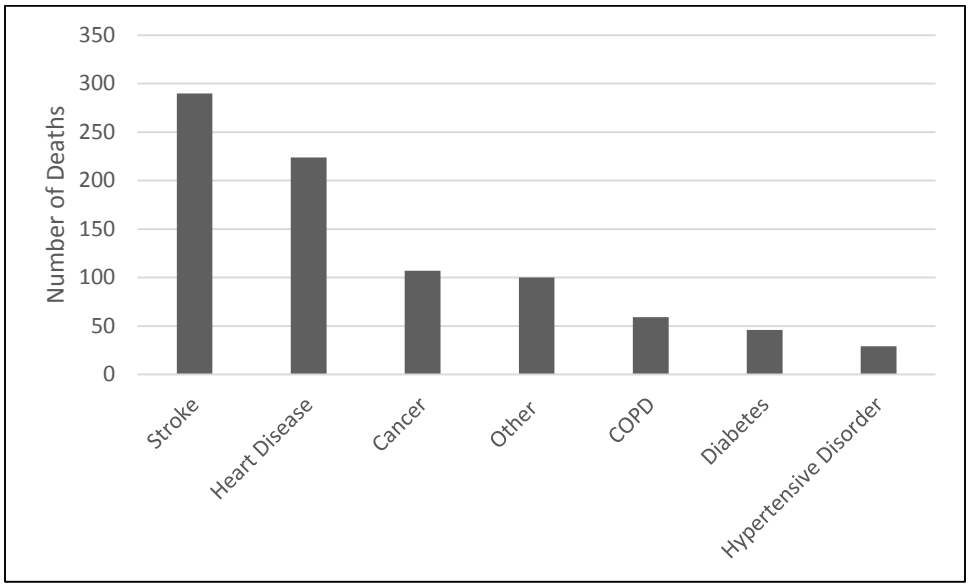


Note: NCD stands for non-communicable disease. The 909 households with an NCD death were identified from the demographic surveillance system run by the non-profit icddr,b. Causes of death were assigned by verbal autopsy to international classification of disease version 10 (ICD-10) code, which was used to identify all NCD deaths. Being poor or not was measured by three outcomes, asset index, self-rated economic condition or total landholding.

Figure 3-2. Pros and Cons of Different Measures of Economic Condition

Measure of Economic Outcome	Pros and Cons
1. Asset index with PCA	**Pros:** Standard for measuring wealth in the absence of consumption and price data. **Cons:** May no correlate well with consumption. May not accurately reflect the prices of assets.
2. Self-rated condition	**Pros:** Captures broader components of economic well-being and effects not related to asset ownership. **Cons:** Non-poor households may underreport economic condition. Household respondents may not be able to compare to the entire area.
3. Landholding	**Pros:** Proven as a good measure of economic status in rural Bangladesh. **Cons:** May be less important as economies shift away from agriculture. Threshold for poor status may be arbitrary.

Figure 3-3. Causes of Adult NCD Death in Matlab in 2010



Note: Causes of death identified by ICD-10 code based on underlying cause of death as recorded by verbal autopsy. The total number of deaths are 909. NCD stands for non-communicable disease. Other represents other non-communicable diseases. Deaths from Injury are excluded.

Chapter 4. Evaluating Household Coping Strategies after an Adult Non-Communicable Disease Death in Rural Bangladesh

4.1 Abstract

With the emerging burden of non-communicable diseases (NCD) in low-income countries, understanding how the illness or death of an adult household member affects the economic condition of a household is important for mitigating health-related poverty. After an adverse health event, households adopt coping strategies to offset the effects of the economic consequences such as high medical expenditures or lost human capital. The adverse event, or health "shock" may impose a large economic impact on households and coping strategies represent intermediate pathways through which these effects occur. This research looks at how households cope after an adult NCD death in the rural, low income area of Matlab, Bangladesh. Household and individual-level characteristics are explored as determinants using certain coping strategies, which fall into the categories of financial, demographic and behavioral coping. Adult NCD deaths in the year 2010 were identified through the Matlab surveillance system and surviving household members were interviewed in 2012 to identify which coping strategies were used. A multivariate logistic regression is used to examine the determinants of coping within the group of households with deaths and in relation to a comparison group of households with no deaths in 2010. An econometric difference-in-difference (DiD) approach is used to examine the level of human capital replacement with objective measures of household composition. The most common coping strategy among households after the death was the reduction expenditure on basic items such as food and utilities. Having a prime age death led to an increase in

the most number of coping strategies, four out of ten. Being poor prior to the death appeared lead to restricted options for financial coping as these household were less likely to use such strategies. The DiD results show that overall, households with adult NCD have modest levels of replacement of human capital. More replacement is seen for prime age deaths in terms of recruiting adult women into the household, which may be due to a higher likelihood of males re-marrying females that are of reproductive age. The results from this work may be used to inform further poverty-reduction and NCD health programming in this rural area of Bangladesh and may inform the creation of policies in other rural, low-income settings as well.

4.2 Introduction

The emerging burden of non-communicable disease (NCD) in rural, low income settings may have significant adverse impact on the livelihoods of populations living in these settings. An adult death in a household from an NCD may be considered a health "shock" that poses costs and has consequences for the economic well-being of the household. There may be high levels of health expenditure surrounding the death and the death itself could pose a loss to household human capital, especially if it's to a prime, working age member. Households, however, can offset the cost of the health shocks by engaging in coping activities. These may include adjusting household finances, changing the composition of the household to shift human capital or engaging in other behaviors, which impact household economic condition.

In rural Bangladesh, there has been a rise in proportion of the mortality burden from NCDs in adults (5). In Matlab, a rural sub-district in Bangladesh where intensive

maternal and child health services have been conducted for decades, there has been an exceptional rise in the burden of adult and NCD mortality. Research using data from Matlab has shown that there is a socioeconomic gradient in NCD outcomes and risk factors where the worse off are more likely to have elevated risk factor levels and worse mortality (18). Understandings of the socioeconomic gradient, however, provide only a partial picture of the relationship between health and wealth. Adverse health events pose costs to households and may cause either short or long-term impacts to overall household wealth. In Matlab, this has been documented in terms of the economic impacts from maternal health complications, but it has not been as well studied for adult outcomes from NCDs (100).

The impacts of NCD-related health shocks for households may also been seen by the coping strategies, which households use to adjust for the effects of illness or death (148-150). One coping strategy that may be harmful is a reduction in basic household consumption. This may have severe effects for the development of children in the household and for the health of adults as well. Additionally, the adoption of high interest loans that cannot be paid off easily may damage a household's financial prospects. Other potentially harmful coping strategies include: spending down savings or selling assets, experiencing a decrease in social safety net transfers or having a member sacrifice education to take up a job or work in the household. All of these coping strategies reduce the resources of households, which may make them more vulnerable to future shocks. Households in rural Bangladesh have been seen to use many types of coping strategies following a health shock (151). Rural Bangladesh also provides an understanding of

coping in terms of micro-lending because of the ubiquity of microfinance institutions (MFI) in the country (121, 145).

The impact from harmful coping strategies may also be related to characteristics of the household before the shock occurs. For instance poor households may be more likely to use harmful coping strategies because safer ways of adjusting to the cost of the shock are not available. Additionally, the characteristics of the deceased may determine which coping strategies are used as a prime age (working age, 15 to 59 years old) death or death to a higher ranking member of the household could mean a larger economic consequence for the household. In the patriarchal societal structure in Matlab, where most of the primary income earners are males, a death to a male versus a female member would lead to a stronger coping response in terms of recruiting another prime age male into the household, which has been seen in studies in Tanzania (99). Alternately, this effect could be reversed in a setting such as Matlab where reproductive age females are recruited into the household by males, but female widows are not able to re-marry another male. Deaths also impose a change in the household composition which may require coping strategies to change household size further or change the household labor structure (112). In response to a health shock from a death, households may either recruit new members into the household or send members away. Additionally, the duration of morbidity prior to the death may be an indicator for the severity of the health shock and for whether households spent much time in a prolonged, depressed state prior to the death.

The objective of this research is to understand how households cope *ex post* after an adult NCD death in rural Bangladesh. Special attention is paid to coping strategies that may be

harmful for households in terms of long-term poverty impacts. Individual and household level determinants of using coping strategies are also examined both within a group of NCD deaths and in relation to a comparison group of households with no deaths.

4.3 Literature Review for Understanding the Health and Wealth Link in Terms of Coping Strategies

The way in which households handle economic impacts from NCDs is of interest as NCDs become more prevalent. In several low and middle-income country examples, studies have looked at household coping strategies in response to health shocks both before *(ex ante)* and after *(ex post)* the shock occurs (152-154) (118). Coping mechanisms that households engage in following a health shock may have important implications for understanding poverty as well. Coping itself may impose a direct or indirect cost on households that extends beyond the cost of the illness itself (43). The adverse effects of coping may pose a significant cost to households in the long term and cause the household to become more vulnerable to future shocks and impoverishment (155-157). Coping, however, is not inherently bad for households will occur to some degree after any shock to a household.

Coping in rural Bangladesh has been looked at previously and idiosyncratic shocks from health events are found to be quite important (158). When households are faced with a health shock, there are several financial responses that are available to them. These include strategies such as reducing expenditure on basic items. This has been looked at in terms of expenditures on food for the household (100). While reduced expenditures may

be for either a short period of time after the shock, it could also have longer term impacts on the well-being of children.

Another important coping strategy for households is to borrow money from MFI's. The ubiquity of MFI lenders means there is a high rate of borrowing for such a rural, low income area (121, 158). There has been mixed evidence about the effectiveness of microfinance for mitigation economic risk and raising households out of poverty, but a recent review found that over the long-term it appears to be helpful (146, 159). In rural areas of South Asia, though, there is still a high level of reliance on informal borrowing sources such as friends, relatives and moneylenders (160). Borrowing from both formal and informal sources has been seen to be detrimental to households when loans are given at high interest rates (98).

In addition to borrowing, households may also cope by selling asset or spending savings (98). This may also lead to higher vulnerability since households are less able to adjust for future shocks. In rural areas, some studies have shown that selling productive assets such as livestock is a common form of coping (99). Coping in this manner indicates that there is a lack of formal safety net options available.

A household death means a loss of human capital for the household. The death may result in lost income through the reduction in labor supply (158). A decrease in human capital is most detrimental for households with prime age deaths. Several studies have attempted to look at whether or not households are able to replace human capital after a death through recruitment of new prime age members into the household. One study in Tanzania found that household do not replace adult human capital very well. In comparison with a control

group, they found that the loss of a prime age adult led to only 20% of households replacing the lost human capital (99).

Beyond household finances and labor supply, there are many other strategies that households may use to cope with shocks. Two of these that are of interest in rural areas are the effects on marriage and education. Having a household member marry early may be another way to adjust the human capital in the household. Marriage of a daughter early would then mean one less person in the household and linkages to another social network where resources can be shared; however, early marriage's harmful effects in terms of reduced education and labor force participation for the female have been well-documented (161). In terms of education, households with deaths to prime age members may be more likely to have a school-aged child leave education early and begin working (100). Given the strong positive relationship that is seen between education and later life health and economic condition. This reduced level of education will have resonating effects for the rest of the child's life.

Understanding coping strategies in terms of the initial resources available to households is also important. Access to coping strategies is likely not just an issue of household preference, but is more likely to be based on access based on a household's status or wealth (162). Previous work looking at household coping from mortality shocks have found that resource-rich households have more access to resources and social capital and can thus rely more on private transfers. The resource-poor, having less social capital, networks of wealthy donors and trust for repayment rely more on credit (163). In terms of

human capital replacement, households that were poor before a prime age death have been shown to replace human capital at lower rates (99).

4.4 Data

4.4.1 Identifying How Households Cope

The data for this study comes from the routine surveillance system from Matlab, Bangladesh administered through the International Center for Diarrhoeal Disease Research in Bangladesh (icddr,b). This is an ongoing surveillance system that has been administered for several decades in this rural region. In addition to the routine surveillance data, information is used from a survey designed to assess the economic impacts from an adult NCD death. A version of this survey is found in the **Appendix 7.1.** The survey includes modules for demographic information of the household and the household head, information about the NCD death and deceased individual and a module to assess the coping strategies that a household reports using after a death. This survey was administered in 2012 for the group of households experiencing an adult NCD death in 2010 in Matlab. A similar survey for a comparison group of households with no death in 2010 matched on the age, sex and village of the deceased individual was also collected. Information on the household in the years prior to the death were obtained from the routine Matlab surveillance data. Baseline demographic and socioeconomic information was for the year 2009, the year prior to the identified NCD deaths.

Ten different coping strategies, considered to have important economic consequences for households are included in addition to household composition broken down four different

ways. The ten strategies are classified into three coping categories: financial coping, demographic coping and behavioral coping. The ten strategies that are used in this study have been looked at in previous literature on coping analysis (158, 160, 163). These then strategies are given in A-C below and the household composition variables are given in D. All coping outcomes are described in further detail in the following sub-sections:

A. Financial Coping
    1. Decline in expenditure on basic items.
    2. Taking out a high interest institutional loan.
    3. Taking out a high interest independent loan.
    4. Selling household assets.
    5. Spending household savings.
    6. Having decreased transfers from social safety net programs.

B. Demographic Coping
    7. Having someone move out of the household.
    8. Having someone move in to the household.

C. Behavioral Coping
    9. Having someone in the household marry early.
    10. Having someone in the household leave education.

D. Household Composition
    - Household size
    - Total Males
    - Total Females
    - Total Children

4.4.2 Dependent Measures of Household Coping

The dependent variables of interest were the ten coping strategies that houses reported using after an adult NCD death in 2010. These were coded as either a one or zero depending on whether a household reported using the strategy or not.

4.4.2.1 Financial Coping

The decline in basic expenditure was defined as a reduction in spending on items such as food and utilities in the one to two year period since the death. A further question asked about whether households experienced a decline in expenditure on discretionary items, but these results are not shown here. One limitation of this question is that the time when the decline in expenditure on basic items occurred is not known. Households may have experienced the decline immediately after the death or have an extended decline in expenditure that lasted up to the time of the interview in 2012.

Detailed information was collected concerning any loans the households took out after the death. Two types of loans were specified, institutional loans received from banks or nonprofit organizations and independent loans taken from friends, neighbors, relatives or moneylenders. For each household, information on up to two loans from each source were collected. Loan information included the interest rate, length of the loan and the collateral. For this study, only the information on the first loan in each category of institutional or independent sources was used since there were very few households reporting a second loan. High interest loans are also distinguished by whether the interest rate was higher than the standard commercial loan interest rate of 13% (145).

Further coping strategies in the financial category included selling assets, spending savings and having a decrease in the amount of transfers received form social safety net programs. These variables all represent a decrease in the stock of financial resources or income streams that are available to households.

4.4.2.2 Demographic Coping

The two strategies for demographic coping included having a member move out of the household or having a member move in to the household. These were asked independently, thus a household was able to report having used both strategies. For the comparison group, it was asked whether a member had to move out or move in at any time since 2009. One limitation from this question is that information about the person that moved into or out of the household was not asked.

4.4.2.3 Behavioral Coping

Behavioral coping included two strategies of whether a household had someone marrying early because of the NCD death or whether someone had to leave education to work or attend to the household because of the NCD death. For the comparison group, this was asked in terms of the entire reference period since 2009. These strategies also did not collect further information about the characteristics of the person who either married early or left education.

4.4.2.4 Household Composition

The analysis of coping in terms of household composition used the household roster in the baseline year 2009, one year before the death, and two years after the death, at the

time the survey was collected in 2012. Dependent variables for this analysis included the total adult members aged 15 and above and the total number of children, under age 15. Total adults were looked at in aggregate and by sex and prime age status.

4.4.3 Independent Measures

Explanatory characteristics at the household level and for the deceased individual were also examined to see how they were associated with individual coping strategies. At the household level, baseline characteristics of the household size in terms of total members and the age, sex and years of completed education of the head of the household were included. A baseline indication of being poor or not, whether a household was in the lower 40% of a self-rated 5 step ladder of economic condition distribution, or the lowest 2 steps, was also controlled for.

Explanatory variables for the deceased individual are used to give an indication of the severity of the health shock and include the age, sex and position in the household. Age here was a binary variable according to whether the individual who died was prime age or not. Household position was also coded as binary, according to whether the individual was the head of the household.

The time of severe illness of the deceased individual prior to their death was also used to explore how a household coped after differing periods of severe morbidity that may put the household in a depressed state prior to the death or lead a household to anticipate a health shock from an NCD death, also called *ex ante* coping. To measure this, a disease timeline was developed. Households were asked to identify the time of death of the

individual and to work backwards to develop the times of severe illness, non-severe illness and disease onset. The time of severe illness was defined as: not being able to work, go to school, or perform daily activities without assistance. Households indicated the dates for each of these times and the measure was reported in years. For regression, analysis a dummy variable was used for whether an NCD death was above or below the median period of severe morbidity which was 120 days.

4.5 Analytical Framework

The percentage of households using each coping strategy is reported as well as the percentage of households reporting using at least one strategy from one of the three categories. Additionally, the extent to which households use multiple strategies or multiple coping categories is also evaluated.

4.5.1 Multivariate Logistic Regression Analysis

In multivariate analysis, a logistic regression model was specified for each coping strategy, *Y*, to examine which characteristics are associated with each coping strategy. The regression model was run for just the population of households with an NCD death to evaluate the determinants of coping conditional on having a death in the household. This model was specified as follows:

$$logit(Y) = \beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n \quad (1)$$

In equation 1, the left-hand side of the equation, *logit(Y),* is the log odds that each coping strategy was adopted and β_0 is the intercept term. The vector *X* represents *n* number of

independent variables at the individual and household level. These include the individual characteristics of the NCD death itself as well as a list of exogenous household controls. The vector of coefficients, β_{1-n}, represent the change in the explanatory variable of interest that relates to a unit change in the log odds of *Y*. All standard errors for equation 1 are clustered at the village level.

The likelihood of increased coping levels that are a result of the NCD health shock itself is also of interest and may provide more understanding of the wealth impacts that result from NCD health shocks. For this reason, the logistic regression model was also run with a comparison group of households with no deaths. This model was specified according to the following equation:

$$logit(Y) = \beta_0 + \delta NCD + \beta_1 X_1 + \cdots + \beta_n X_n \quad (2)$$

Equation 2 similarly looks at *Y* as a dependent variable for household coping strategies and the vector of *X's* for individual and household level controls. The standard errors for equation 2 are also clustered at the village level. This equation now incorporates a dummy variable for whether a household experienced an NCD death or not, *NCD*. The coefficient δ represents the log odds that a household used a particular coping strategy after an NCD death in comparison to the counterfactual comparison group.

To understand how the odds of using a coping strategy may differ by the characteristics of the death itself or whether the household was poor prior to the death, a series of five equations that are extensions of equation 2, run with the entire sample of NCD death and comparison households were implemented:

$$logit(Y) = \beta_0 + \delta^{PA} NCD^{PA} + \delta^{Non-PA} NCD^{Non-PA} + \beta_{1-n} X_{1-n} \quad (3)$$

$$logit(Y) = \beta_0 + \delta^{Head} NCD^{Head} + \delta^{Non-Head} NCD^{Non-Head} + \beta_{1-n} X_{1-n} \quad (4)$$

$$logit(Y) = \beta_0 + \delta^{Fem} NCD^{Fem} + \delta^{Male} NCD^{Male} + \beta_{1-n} X_{1-n} \quad (5)$$

$$logit(Y) = \beta_0 + \delta^{Long} NCD^{Long} + \delta^{Short} NCD^{Short} + \beta_{1-n} X_{1-n} \quad (6)$$

$$logit(Y) = \beta_0 + \delta NCD + \beta_1 POOR + \gamma NCDxPOOR + \beta_{2-n} X_{2-n} \quad (7)$$

Equations 3 through 7 show the variable for an NCD death with superscripts that represent dummy variables for whether the death was to a prime age (PA/Non-PA) person, a head of household (Head/Non-Head), the sex of the deceased (Fem/Male) or whether the death had a prior long period of severe morbidity (Long/Short). Equation 7 keeps the same dummy variable for any NCD death as equation 2 but also includes a dummy variable for whether a household was poor (*POOR*), which is interacted with the variable for NCD death. All five of the equations include a vector of *X's* for exogenous controls and cluster the standard errors according to village.

4.5.2 Difference-in-Difference Analysis

To evaluate changes to household composition, an econometric difference-in-difference (DiD) analysis with direct matching of the households with an adult NCD death to a comparison group of households that had no deaths in 2010 is used. This approach assesses the difference in the change to the number of adults and children present in the household relative to this difference in the comparison group. The direct matching

ensures that potential confounders of household status are balanced at baseline and the DiD approach accounts for time-variant and time-invariant unobservable factors of the households by taking into account differences in the outcome variable both within and between each group (99).

The DiD approach compares the mean difference between the NCD death and comparison groups. Initially, the difference in the outcomes of household composition for each group between the baseline year and two years post death is estimated (first difference). These differences are then compared to each other (second difference) with the following equation:

$$E(\delta) = E(\Delta Y_{NCD}) - E(\Delta Y_{Comp}) \quad (8)$$

In equation 8, the term $E(\Delta Y)$ is the change in the expected value of the composition variable for each of the NCD and comparison groups. The $E(\delta)$ term denotes the DiD estimate of the change in the expected value of the composition variable of interest.
To assess the significance of the DiD estimate in equation 8, an ordinary least squares (OLS) regression model is specified:

$$Y_t = \beta_0 + \beta_1 NCD + \beta_2 Time + \beta_3 NCD * TIME + \varepsilon_t \quad (9)$$

In equation 9, Y_t is the composition variable of interest at time *t.* β_0 is the intercept, $\beta_1$and β_2 are the main effects of the change in composition explained by a dummy variable representing whether a household had an NCD death (*NCD)* and the time period (*TIME)*. The coefficient for the interaction between having an NCD death and time, β_3, represents

the equivalent of the DiD estimate provided in equation 8, which now includes a standard deviation, clustered at the village level, for assessing significance.

To further assess the DiD estimates, equation 9 is also run with a vector of assumed exogenous household controls. This is given in equation 10 below:

$$Y_t = \beta_0 + \beta_1 NCD + \beta_2 Time + \beta_3 NCD * TIME + \beta_{4-n} X_{4-n} + \varepsilon_t \quad (10)$$

The vector of *X's* in equation 10 represents these controls. Characteristics of the death are assessed with dummy variable in two separate equations.

$$Y_t = \beta_0 + \delta_1 NCD^{PA} + \delta_2 NCD^{Non-PA} + \beta_1 TIME + \delta_3 NCD^{PA} * TIME + \delta_4 NCD^{Non-PA} * TIME + \beta_{2-n} X_{2-n} + \varepsilon_t \quad (11)$$

$$Y_t = \beta_0 + \delta_1 NCD^{Fem} + \delta_2 NCD^{Male} + \beta_1 TIME + \delta_3 NCD^{Fem} * TIME + \delta_4 NCD^{Male} * TIME + \beta_{2-n} X_{2-n} + \varepsilon_t \quad (12)$$

Equations 11 and 12 show the DiD regression equation with dummy variables for whether a death is to a prime age (PA/Non-PA) individual or to a male or female (Fem/Male). The coefficients for the dummy death variables interacted with time $\delta_3$and $\delta_4$represent the DiD estimates of interest.

4.6 Results

Descriptive information for the study population is provided **Table 4-1.** The top half of the table lists the household-level variables that are considered controls for the analysis.

The households in each of the groups appear balanced in all of the characteristics. The variable for being poor in this section is a binary indicator of whether a household responded to the 2012 survey saying that the household was in the first two self-rated quintiles either before the death for the NCD group or in 2009 for the comparison group. 44% of the NCD households and 43% of the comparison households rated themselves as poor, giving us confidence in the matching process. This is higher than the rural poverty rate provided by the World Bank in 2010 which was 35.16% (164).

The second half of the table includes information at the individual level. The information for age and sex was used in the original direct matching for the selection of the study population. The population appears to be evenly balanced except for the condition of whether the individual was the head or spouse of the head of the household. For this variable, the comparison group has a 7% more household heads and spouses. The length of severe illness leading up to an NCD death is only applicable for the NCD group and was found to be around a third of a year (SD 1.2 years).

4.6.1 Results for How Households Cope

Table 4-2 lists the percentage of households that reported using each coping strategy and each coping strategy category for each of the groups. For the individual coping strategies, there are some stark differences. In the category of financial coping strategies, the households experiencing adult NCD deaths are much more likely to report having a reduction in expenditure on basic household items. This is the most prevalent form of coping reported by the NCD group, with 43% of households saying they reduced basic expenditure. The NCD households are also less likely to have a high interest institutional

loan or high interest loan from an independent source. A lower percentage of NCD households report spending savings or selling assets, but a higher percentage report having a decline in social safety net transfers. For the financial coping category overall, a similar percentage of each group, about half, report using at least one version of financial coping during the time period.

For the two strategies classified as demographic coping, the NCD households were much less likely to report having someone move out than the comparison households. Alternately, the NCD households were more likely to report having someone move in than the comparison households though moving out was more common for both. Overall for the category, the comparison households had twice as much demographic coping than the NCD households which was mainly driven by high levels of moving out in the comparison group. The least differences between groups were seen in the behavioral coping strategy. For both having someone in the household marry early and for having someone in the household leave education, about 1.5% of the households reported using the former strategy and about 5% reported using the latter strategy. Overall, 5.6% and 5.7% of the NCD and comparison households reported using a behavioral coping strategy.

Table 4-3 lists the results for how many coping strategies and coping categories each household used among those that we observed. These were relatively stable for both groups. The NCD death households were more likely to use zero or one strategy, and the comparison households were more likely to use 2 or more. A similar pattern was seen for the categories, where comparison households were more likely to use more coping

categories although the differences appear minimal. **Table 4-3** also shows that households are most likely to use zero or one coping strategy or coping strategy category with a rapid decrease in the percentage of households using more than one strategy.

The differences in the coping strategy use show that there may be limitations to the data in terms of how the information for the coping strategies was collected. In the survey instrument, the NCD households were asked about coping strategies "as a result of the NCD death", while the comparison group was asked about whether the coping strategy was used at any point during the time period. This may be one reason why there are several coping strategies that are much more common for the comparison group. Using administrative data would be one way to test for this bias in the results. An attempt to do this with information for household composition is done with the DiD analysis subsequently in this paper.

4.6.2 Results for Multivariate Determinants of Coping

Multivariate results for the nine coping strategies are provided in **Tables 4-4 and 4-5**. **Table 4-4** shows the results of the logistic regression results for just the population of households with an adult NCD death. The regression models included all of the household and individual level variables and standard errors clustered at the village level, although only the household-level variable for being poor is shown in **Table 4-4.** For the category of financial coping, it is seen that a male death or a death with a long period of severe morbidity leads to a significantly higher likelihood of a household reducing expenditure on basic items. In terms of taking out high interest loans. Being poor leads to

a significantly higher likelihood of taking out institutional loans and a long period of severe morbidity lead to a significantly higher odds of an independent loan. A household being poor was significant and inversely associated with spending savings or selling assets. A household with a prime age death was more likely to sell assets. A decrease in social safety net transfers, which are provided through national-level government programs, was significantly positively associated with a death to a female.

There were not many variables significantly associated with reporting demographic coping. Having a prime age death was positively associated with having a household member move out of the household and no variables were significant for having someone move in. The two strategies for behavioral coping showed more significant associations. Households with prime age deaths were significantly more likely to both have someone marry early and to have someone leave education. In addition, female deaths were strongly associated with having a household member marry early and having a death preceded by a long period of severe morbidity was positively associated with having someone leave education.

Overall, **Table 4-4** shows that having a prime age death is positively associated with the most number of coping strategies, four, and with coping strategies in each of the three categories. Having a long period of severe morbidity was also significantly positively associated with three coping strategies in two out of the three categories. Being poor prior to the death was positively associated with taking out a high interest institutional loan but negatively associated with reporting spending savings or selling assets. Interestingly, the position of the deceased person in the household did not show any significance.

Table 4-5 shows the results for the likelihood of reporting coping for the households with a death in relation to the comparison group of households with no deaths. The rows each represent separate regressions with all household controls included and standard errors clustered at the village level. For the category of financial coping, an NCD death is more likely to lead to decline in basic expenditures compared to a comparison group, which is consistent regardless of the characteristics of the death or the economic condition of the household prior to death. This is seen with the large positive and significant coefficients in the first column and the non-significant coefficient on the interaction term with being poor. The only other financial strategy with large positive association with NCD death is reporting a decline in social safety net transfers. This strategy also shows differences by death characteristics where households with deaths to older individual and females more likely to report a decline. The other four coping strategies in the financial category, having a high interest institutional or independent loan; spending savings or selling assets, show many significant inverse associations with having an adult NCD death. The interaction term for being poor prior to death is only significant for the strategy of spending savings where poor households with NCD deaths are less likely to use this strategy.

The two demographic coping strategies in **Table 4-5** show opposite relationships to having an NCD death. Reporting someone moving out of the household is negatively associated with an NCD death for many of the models and does not appear to differ much by the characteristics of the deceased. Reporting having someone move into the household is positively associated with an NCD death for many of the models and

appears especially strong for having a prime age death. Neither of the demographic coping strategies are associated with the initial economic status of the household.

For the behavioral coping category, having a prime age NCD death is positively associated with reporting having a member marry early. None of the other characteristics of the deaths are significant for this strategy, including having a female death, which was a strong predictor when looking only at the NCD group. Having any adult NCD death was not associated with reporting having someone leave education, but in several situations, such as having a female death or death to an older member, households were less significantly less likely to report having someone leave education.

Overall, when compared to a groups of households with no NCD death, the coping strategies of reducing basic expenditure and having reduced transfers from social safety net programs appear to be the most likely coping strategies that a household with an NCD death uses. By characteristics of the deceased, some important differences are seen when the death is to a prime age individual, which leads to a higher likelihood of having someone move into the household or marry early. The initial economic condition of the household does not play as important of a role for reporting using strategies, but there is some indication that poor households have less options available to them.

4.6.3 Difference-in-Difference Results

The results for the DiD analysis are provided in the four tables, **Tables 4-6 to 4-9.** Each of the tables shows the ordinary least squares regression model results for changes to the four outcomes of household composition. The models only report the DiD estimate on the

NCD death variable of interest and standard errors clustered at the level of the village. In each of the four tables, model 1 shows the results for the unadjusted regression with any NCD death and model 2 shows the results for the model with any NCD death including all of the household controls. Models 3 and 4 also include the exogenous household level controls and include dummy variables for the prime age status of the deceased and for the sex of the deceased. The prime age status is included because it has been seen to have important impacts on household economic condition and likelihood of using coping strategies. The sex of the deceased is included to explore the impact on the household composition variable, which also include a breakdown by sex.

Table 4-6 shows the DiD results for change in total household size. In both the unadjusted model 1 and model 2, which adjusts for household controls, the total change in the household size is -0.7 and significant. This means that on average, households are able to attract new members. A DiD estimate of -1 would mean perfect non-replacement and a DiD estimate of zero would mean perfect replacement. The estimate of -0.7 means that for every 100 households with deaths, 30 of them are able to attract new members. By prime age status and sex of the deceased, it's also seen that households are more likely to attract members with a prime age death and with a female death. The prime age death shows a positive DiD estimate of -0.45 meaning that for every prime age death, over half of them are able to attract new members. This is in contrast to a non-prime age death where the DiD estimate of -0.77 means that less than half, or 23 out of 100 households with these deaths attract new members.

In **Table 4-7,** the results are shown for the change in total adult males. The DiD estimate is lower here, about -0.49 for the unadjusted and adjusted estimates in models 1 and 2. This is consistent with the results in **Table 4-8** showing that the DiD estimate for change in total females is -0.31 in the unadjusted and adjusted model. The larger loss in males is likely because of the higher number of male deaths in the sample. An interesting difference between the replacement of male and female adults is seen by comparing the DiD differences for prime age and non-prime age deaths for the two outcomes in **Tables 4-7** and **4-8.** While the prime age status of the deceased has no bearing on the change in total males, households with prime age deaths are more likely to replace total adult females. This is seen by the DiD estimate closer to zero for prime age deaths in **Table 4-8.** Model 4 for the changes in numbers of males and females according to the sex of the deceased is consistent with each model, showing significant declines in males and females matching the sex of the deceased.

Table 4-9 shows the change in total children in the household given an adult death. The unadjusted and adjusted models both show marginally significant increases in total children after a death to the household. The positive DiD estimate means that for every 100 households, 10 of them will add one child after a death. This result also changes depending on whether the age or sex of the deceased member. Households with a death to a non-prime age member see a significant increase in the number of children with a positive DiD estimate of 0.13 and households with deaths to females see a positive significant DiD estimate of 0.23. This means that for 100 households with an old age death or a 100 households with a female death, approximately 13 and 23 of them will add one child after the death.

In sum, the DiD analysis shows that households moderately replace human capital after an NCD death and consistent with the multivariate regression results, a prime age death is more likely to lead to human capital replacement. This is mainly driven by the replacement of adult females after a prime age death. There is some evidence that households balance dependency ratios by replacing children after an old age death. A considerable increase in the number of children after a female death is an interesting result that should be explored further.

4.7 Discussion

The findings show that after an adult NCD death, households cope through the reduction in expenditure on basic items such as food and utilities. This is seen for the models using just the NCD death sample and for the whole population, including a counterfactual comparison group. Reporting a reduction in expenditure drives the results that most households cope with only one of the ten strategies in this analysis and usually through financial means. A reduction in basic household expenditure is important and it should be studied further to see if there are any long-term effects for the household, even if the short-term reduction in expenditure is able to be managed. This has especially been proposed when reductions in basic expenditure affect the diet of children (100). There is also worry that reductions to household expenditure may disproportionately affect the lower status members of the household. Because Matlab is a patriarchal society, this means that the females may be affected more. A reduction in basic expenditure is also positively associated with longer periods of severe illness and with deaths to male members. Both of these characteristics could be considered indicators of the severity of the shock. For the former, a death to a male member means more repercussions for the

household while a longer period of severe morbidity means a higher cost as a result of medical expenditures and reduced human capital.

In addition to the sex and period of severe illness deaths to prime age household members also indicate that the impacts of the shock will be more severe. This is consistent with the literature looking at health shocks from all forms (e.g. self-reported illness episodes) but also health shocks from death where a prime age death represents a permanent loss of human capital (99, 129). Prime age deaths are positively associated with four out of the ten coping strategies representing all three coping categories: financial, demographic and behavioral. The positive relationship of a prime age death with coping due to selling assets is troublesome if those assets represent productive items that households use for income generation. Prime age deaths have been shown to lead to the selling of such items as livestock in previous research (97). One limitation of this research is that the type of assets that were sold is not ascertained. The coping due to selling of assets means that formal financial coping mechanisms, such as insurance and safety net programs are not adequate to completely offset the costs of the shock when there is a prime age death.

Another finding of interest is the changes in how households cope after an NCD death depending on *a priori* economic condition. Being in the bottom 40% of a self-rated economic condition led to a positive relationship with taking out a high interest institutional loan. While not completely explanatory, this finding may be consistent with previous work showing that the poor are less likely to have informal networks such as friends or family from which they can smooth the effects of a health shock (165). The ubiquity of microfinance institutions in rural Bangladesh make this a troublesome

finding. Poor households incurring high interest loans are may be caught in a poverty trap that worsens their economic situation. There are also indications that households that are poor have a much more limited set of other financial coping options available. This is seen with inverse relationships with spending savings and selling assets. This intuitively makes sense and has been seen in other studies in low income countries (158, 166). The limited palette of option for the poor, though, further emphasizes the need for affordable coping options for these households.

The results from the DiD analysis that looks at objective measures of household composition finds that there is moderate replacement of household members after an adult death. The finding that only 30% of households replace human capital is consistent with the range of 20% provided by a study looking at death shocks in Tanzania (99). Households tended to be more likely to replace female human capital after a prime age death than they were male human capital. This is inconsistent with theories of higher values of male human capital in the area and should be explored further. This The DiD results are also consistent with the multivariate regression using a comparison group. These results found that households with any NCD death were more likely to report having someone move into the household than the healthy group. Further, likelihood of reporting having someone move in increased for prime age deaths and deaths with longer periods of severe morbidity. This may indicate that households with prime age deaths and with deaths that can be anticipated gives households a higher likelihood of anticipating the effects of health shocks and taking measures to offset the effects (99).

4.7.1 Policy Implications

The understanding of the coping strategies that households use after a health shock may provide several insights for policy. Importantly, the large percentage of households reporting reductions in expenditure on basic items means that households are not insured against the effects of health shocks from adult NCD deaths. This has been found to also be the case in an important work in Indonesia that also finds households lack the ability to smooth consumption and that more severe effects from chronic illness (20). The finding from this work means that there will need to be new creative ways of providing risk protection to households experiencing health shocks so that they do not need reduce basic expenditure. The rural areas of Bangladesh have a prevalence of micro-lenders and these have been shown to effective mechanisms for reducing the impact of health shocks (121). Further incorporations of community based health insurance or building micro-insurance packages into the current micro-lending options could be directions for developing these mechanisms. There have been some recent attempts to do this, however, the results show that the demand for micro-insurance is not strong and that the informal economy has a large role to play (147).

A further direction for policy is through implementing health services in the region that are geared towards NCD prevention and management. The result that a prime age death leads to higher levels of potentially harmful coping strategies was found in these results and is consistent with previous work for health shocks in other settings. Prime age deaths should be equated to premature deaths, which are a concern for global efforts to scale up the attention to NCDs. Matlab has a history of being at the forefront of implementing

large-scale health programs in a rural, low income setting. Providing services and programs to address the emerging burden of NCDs should be adopted as a priority goal.

4.7.2 Limitations

A limitation of this work is that the setting in Matlab is not necessarily generalizable to other rural, low income settings in other countries, or even in Bangladesh (78). This study was possible because of the availability of data on NCD prevalence, mortality and associated economic impacts. Matlab has reliable surveillance data for a rural, low income setting and the deaths from NCDs can be individually identified and linked to household information and socioeconomic status characteristics. The pros and cons of using information from Matlab for broader generalizations have been previously noted.

A further major limitation of the analysis of coping mechanisms may be that our survey itself induced bias for household reporting of coping strategies that signal hardship for the household. This may be further exacerbated by the fact that the survey was done two years after the death and thus recall of the death and post-death experience could be reported as more severe than it actually was. The potential for biased reporting of the impacts of a health shock from adult NCD death would mean that these conclusions overestimate the broad economic costs of NCD deaths. In the DiD analysis that uses household composition and comparison group, much of this bias is removed by using an objective outcome, so it is encouraging that there is consistency with the subjective reporting.

4.7.3 Future Research

This work motivates future research to better understand the coping mechanisms that households use in terms of the actual monetary benefit that they provide. This could include a research protocol to understand better the patterns of health utilization and out of pocket health expenditures resulting from a health shock and how coping mechanisms offset the costs of the shock in the short and long term. Understanding social mobility in terms of changes in socioeconomic status and which coping strategies are more likely to be associated with improving economic conditions over time would also be important. Lastly, more implementation research about the use of formal and informal borrowing mechanisms, specifically focusing on the behaviors of the poor will be important for understanding coping and poverty traps in a rural, low income setting such as Matlab.

4.8 Conclusion

This study examines how households cope in terms of financial, demographic and behavioral strategies after an adult NCD death in rural Bangladesh. The adult NCD mortality burden is rising in this area, and studies have proposed that there is a potential for large economic consequences for households. The results from this work show that households with adult deaths engage in coping strategies that may have harmful impacts. Households are most likely to use financial strategies such as reducing basic expenditure, but they also deplete financial stocks and take on high interest loans. Policies that develop formal financial protection tools for rural households need to be further developed to prevent deleterious coping activity. Adult NCD deaths to prime age household members are also shown to cause significant economic consequences to

households. The importance of prime-age deaths has been found previously in the literature, but to our knowledge has not been explored with NCDs in low income settings. This provides further justification for scaling up health policies that address the emerging burden of NCDs in rural Bangladesh since premature deaths represent tragic and costly losses for households.

4.9 Tables for Chapter 4

Table 4-1. Descriptive Information for Study Population at Baseline

Variable	NCD death Mean (SD)/Proportion	Comparison Mean (SD)/Proportion
1. Household-level Control Variables		
Household size	6.18 (2.70)	6.23 (3.02)
Head Age	61.76 (13.92)	62.62 (13.72)
Head Female	0.23	0.23
Head Education	2.84 (3.69)	2.87 (3.59)
Muslim	0.85	0.87
Poor	0.44	0.43
2. Individual-level Variables (Deceased Individual and Matched Individual)		
Age	67.71 (12.72)	67.33 (12.33)
Prime Age (%15-59)	0.21	0.21
Female	0.45	0.45
Head/Spouse of Head	0.66	0.73
Length Severe Illness (year)	0.36 (1.18)	NA
N	856	1695

Note: Poverty is defined as being in wealth quintiles 1 or 2, based on PCA of assets in 2005. MFI membership (microfinance institution) is defined as being a member in 2005. Length of severe illness is defined as the period when the deceased individual was no longer being able to work, go to school or perform daily activities without assistance.

Table 4-2. Prevalence of Coping Strategy Usage for Study Population

		NCD death (N=856)		Comparison (N=1695)	
Category	**Coping Strategy**	**% Using Strategy**	**% Using Category**	**% Using Strategy**	**% Using Category**
Financial	1. Decline in basic expenditure	43.1%	53.4%	7.9%	51.2%
	2. High interest institutional loan	6.8%		10.3%	
	3. High interest independent loan	1.1%		2.5%	
	4. Spend Savings	8.1%		33.0%	
	5. Sell Assets	4.2%		11.6%	
	6. Social Safety Net decrease	1.8%		0.2%	
Demographic	7. Move out	3.2%	5.6%	11.2%	11.9%
	8. Move in	2.8%		1.9%	
Behavioral	9. Marry early	1.6%	5.6%	1.4%	6.8%
	10. Leave education	4.6%		5.7%	

Note: Decline in basic expenditure refers to a reduction in spending on food and utilities. A high interest loan refers to one with an interest rate above 13%. An institutional loan is a loan from a bank or a non-profit organization. An independent loan is a loan from friends, neighbors, relatives or moneylenders. Spending savings or selling assets is whether the household had to do so after the death. A decline in social safety net transfers is whether there is any decline in transfers. Moving in or moving out is reporting having a person move in or out of the household after the death. Marry early is having someone marry early after the death and leave education having someone leave current education to enter the workforce or attend to the household after death.

Table 4-3. Percentage of households reporting multiple coping activities

	NCD death (N=856)	Comparison (N=1695)
Number of Strategies	**% Using**	**% Using**
0	42.3%	41.6%
1	42.0%	38.0%
2	12.4%	14.9%
3	2.9%	4.7%
≥4	0.3%	0.8%
Number of Categories		
0	42.3%	41.6%
1	51.5%	48.7%
2	5.4%	8.0%
3	0.8%	1.8%

Note: The number of strategies is the total number out of a maximum possible of ten strategies. There are three categories of coping, which include Financial, Demographic and Behavioral coping strategies. Financial coping includes: reducing basic expenditure, taking out a high interest loan from a formal or informal source, selling assets, spending savings or having a decline in social safety net transfers. Demographic coping includes: having someone move out or movie in to the household. Behavioral coping includes: having someone marry early and having someone leave education early.

Table 4-4. Logistic Regression on Coping Strategy Use for Households with NCD Deaths

	Financial						Demographic		Behavior	
	Basic Expenditure	Institutional Loan	Independent Loan	Spend Savings	Sell Assets	Decrease Soc. Safety Transfers	Move Out	Move In	Marry Early	Leave Education
(Intercept)	-0.307 (0.501)	-2.479 (0.892)***	-2.558 (2.650)	-2.302 (0.850)***	-3.022 (1.113)***	-3.749 (2.170)*	-4.774 (1.527)***	-3.911 (1.300)***	-5.126 (1.255)***	-1.948 (0.958)**
Prime Age	0.119 (0.196)	-0.542 (0.463)	0.527 (0.910)	-0.047 (0.373)	1.004 (0.417)**	-1.332 (1.239)	0.886 (0.521)*	0.420 (0.521)	1.243 (0.540)**	0.830 (0.417)**
Head	-0.190 (0.212)	-0.105 (0.489)	0.805 (1.045)	0.124 (0.392)	-0.621 (0.451)	-0.310 (1.120)	0.343 (0.625)	0.394 (0.432)	-0.151 (0.651)	0.213 (0.523)
Female	-0.272 (0.161)*	0.272 (0.309)	-0.558 (0.680)	-0.068 (0.300)	0.029 (0.382)	1.537 (0.900)*	-0.436 (0.492)	-0.789 (0.494)	1.387 (0.633)**	-0.315 (0.396)
Long Severe	0.359 (0.143)**	0.320 (0.285)	1.635 (0.845)*	0.183 (0.251)	0.533 (0.352)	-0.314 (0.544)	0.272 (0.402)	0.633 (0.438)	-0.082 (0.574)	0.591 (0.348)*
Poor	0.201 (0.151)	0.808 (0.321)**	0.568 (0.676)	-0.467 (0.267)*	-0.678 (0.409)*	0.638 (0.568)	0.497 (0.440)	-0.680 (0.515)	-0.208 (0.644)	0.298 (0.379)
Log Likelihood	-570.786	-195.794	-44.176	-236.353	-143.543	-60.462	-114.578	-104.178	-62.478	-147.667
Deviance	1141.571	391.588	88.351	472.706	287.086	120.923	229.156	208.356	124.956	295.333
Num. obs.	845	845	845	845	845	845	845	845	845	845

Note: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. *Poor is defined as being in quintiles 1 or 2 of self-rated economic condition in 2009. All models here include controls for household-level information. Prime age refers to being in the age group 15-59 in 2010. Long Severe refers to the natural log of the length of severe illness. Standard errors are clustered at the village level.*

Table 4-5. Logistic Regression Models on Coping Strategy Use for Study Population

Model	Financial						Demographic		Behavior	
	Basic Expenditure	Institutional Loan	Independent Loan	Spend Savings	Sell Assets	Decrease Soc. Safety Transfers	Move Out	Move In	Marry Early	Leave Education
Death + Controls	2.195 (0.115)***	-0.556 (0.164)***	-0.944 (0.369)**	-1.701 (0.136)***	-1.080 (0.187)***	2.162 (0.639)***	-1.335 (0.212)***	0.557 (0.281)**	0.161 (0.339)	-0.269 (0.196)
PA Death + Controls	2.345 (0.179)***	-1.123 (0.363)***	-0.212 (0.479)	-1.716 (0.286)***	-0.428 (0.307)	0.523 (1.286)	-0.735 (0.330)**	1.034 (0.440)**	0.827 (0.489)*	0.315 (0.283)
Non-PA Death + Controls	2.155 (0.122)***	-0.407 (0.174)**	-1.435 (0.527)***	-1.697 (0.151)***	-1.319 (0.227)***	2.520 (0.633)***	-1.601 (0.266)***	0.415 (0.312)	-0.145 (0.415)	-0.555 (0.242)**
Head Death + Controls	2.136 (0.129)***	-0.552 (0.198)***	-0.754 (0.449)*	-1.713 (0.164)***	-1.324 (0.245)***	1.740 (0.730)**	-1.067 (0.240)***	0.585 (0.330)*	0.185 (0.400)	-0.052 (0.232)
Non-Head Death + Controls	2.321 (0.162)***	-0.562 (0.243)**	-1.246 (0.601)**	-1.675 (0.227)***	-0.654 (0.280)**	2.524 (0.743)***	-1.947 (0.433)***	0.503 (0.405)	0.118 (0.564)	-0.648 (0.331)*
Female Death + Controls	2.103 (0.140)***	-0.443 (0.216)**	-1.334 (0.603)**	-1.721 (0.199)***	-0.971 (0.262)***	2.704 (0.650)***	-1.840 (0.371)***	0.187 (0.396)	0.589 (0.431)	-0.579 (0.294)**
Male Death + Controls	2.267 (0.133)***	-0.663 (0.216)***	-0.674 (0.440)	-1.685 (0.176)***	-1.168 (0.251)***	0.907 (0.915)	-1.016 (0.248)***	0.805 (0.330)**	-0.318 (0.493)	-0.047 (0.232)
Long Morbidity Death + Controls	2.373 (0.135)***	-0.384 (0.207)*	-0.435 (0.412)	-1.614 (0.183)***	-0.827 (0.233)***	2.033 (0.701)***	-1.265 (0.286)***	0.820 (0.325)**	0.208 (0.440)	-0.044 (0.241)
Short Morbidity Death + Controls	2.027 (0.134)***	-0.737 (0.225)***	-1.821 (0.727)**	-1.788 (0.189)***	-1.381 (0.283)***	2.272 (0.688)***	-1.404 (0.293)***	0.233 (0.388)	0.116 (0.430)	-0.525 (0.277)*
Poor x Death + Controls	0.380 (0.233)	0.251 (0.334)	0.252 (0.786)	-0.576 (0.286)**	-0.510 (0.395)	-0.255 (1.356)	0.172 (0.426)	0.153 (0.639)	0.369 (0.713)	0.032 (0.395)

*Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All models (each row) includes controls for all household and individual level variables. Standard errors are clustered at the village level. Poor is defined as being in quintiles 1 or 2 of self-rated economic condition in 2009. Full Tables for these models available in Appendix D.*

Table 4-6. Difference in Difference Estimates for Total Household Size

	Total Household Size			
	Model 1	**Model 2**	**Model 3**	**Model 4**
(Intercept)	6.227 (0.074)***	6.664 (0.207)***	6.736 (0.208)***	6.610 (0.208)***
Death	-0.702 (0.157)***	-0.702 (0.152)***		
PA Death			-0.449 (0.253)*	
Non-PA Death			-0.770 (0.166)***	
Female Death				-0.615 (0.193)***
Male Death				-0.773 (0.190)***
R^2	0.048	0.1	0.101	0.101
Adjusted R^2	0.047	0.098	0.099	0.1
Num. obs.	5020	5020	5020	5020

*Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Model 1 is the unadjusted model with only an indicator of an NCD death included. Model 2-4 include all household level controls and indicators for all deaths, prime age (or not) deaths and male or female deaths. All std. errors are clustered at the village level.*

Table 4-7. Difference in Difference Estimates for Total Adult Males

	Total Adult Males			
	Model 1	**Model 2**	**Model 3**	**Model 4**
(Intercept)	1.954 (0.030)***	2.292 (0.100)***	2.291 (0.100)***	2.263 (0.100)***
Death	-0.492 (0.071)***	-0.492 (0.068)***		
PA Death			-0.491 (0.114)***	
Non-PA Death			-0.492 (0.074)***	
Female Death				-0.042 (0.085)
Male Death				-0.858 (0.083)***
R^2	0.031	0.128	0.128	0.139
Adjusted R^2	0.031	0.126	0.126	0.137
Num. obs.	5020	5020	5020	5020

*Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Model 1 is the unadjusted model with only an indicator of an NCD death included. Model 2-4 include all household level controls and indicators for all deaths, prime age (or not) deaths and male or female deaths. All std. errors are clustered at the village level.*

Table 4-8. Difference in Difference Estimates for Total Adult Females

	Total Adult Females			
	Model 1	**Model 2**	**Model 3**	**Model 4**
(Intercept)	2.627 (0.031)***	2.568 (0.089)***	2.597 (0.090)***	2.564 (0.089)***
Death	-0.312 (0.066)***	-0.312 (0.064)***		
PA Death			-0.116 (0.119)	
Non-PA Death			-0.364 (0.069)***	
Female Death				-0.735 (0.083)***
Male Death				0.033 (0.079)
R^2	0.083	0.113	0.115	0.122
Adjusted R^2	0.083	0.112	0.113	0.12
Num. obs.	5020	5020	5020	5020

*Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Model 1 is the unadjusted model with only an indicator of an NCD death included. Model 2-4 include all household level controls and indicators for all deaths, prime age (or not) deaths and male or female deaths. All std. errors are clustered at the village level.*

Table 4-9. Difference in Difference Estimates for Total Children

	Total Children			
	Model 1	**Model 2**	**Model 3**	**Model 4**
(Intercept)	0.693 (0.021)***	0.739 (0.088)***	0.762 (0.089)***	0.726 (0.088)***
Death	0.110 (0.065)*	0.110 (0.065)*		
PA Death			0.028 (0.113)	
Non-PA Death			0.132 (0.071)*	
Female Death				0.234 (0.086)***
Male Death				0.009 (0.080)
R^2	0.116	0.12	0.121	0.122
Adjusted R^2	0.115	0.119	0.119	0.12
Num. obs.	5020	5020	5020	5020

*Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Model 1 is the unadjusted model with only an indicator of an NCD death included. Model 2-4 include all household level controls and indicators for all deaths, prime age (or not) deaths and male or female deaths. All std. errors are clustered at the village level.*

4.10 Figures for Chapter 4

Figure 4-1. Study Design for Assessing Prevalence and Determinants of Coping Strategies

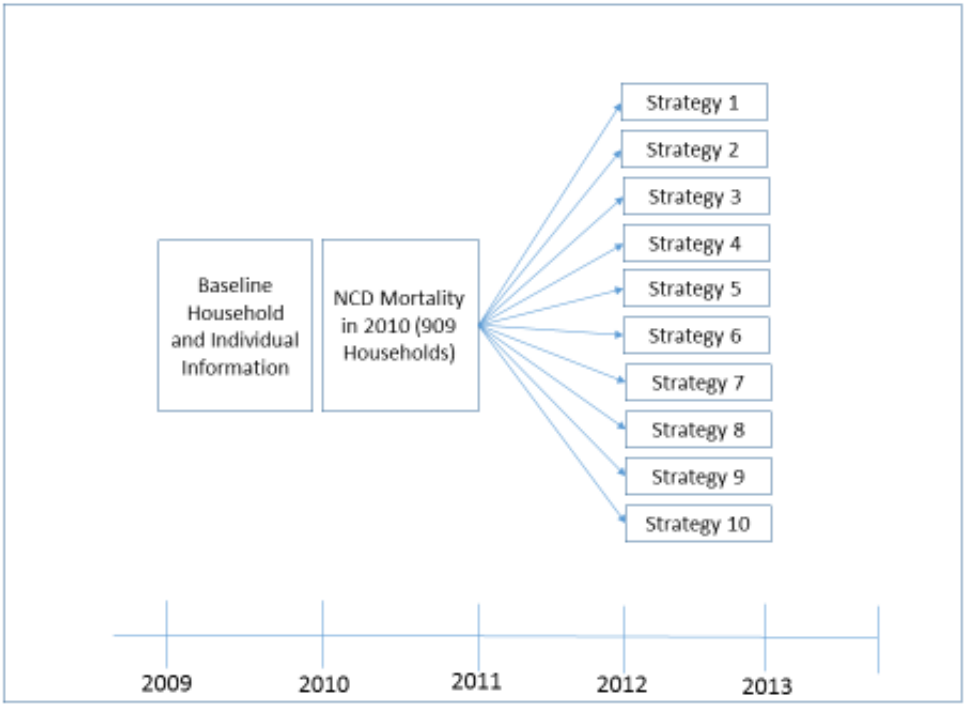
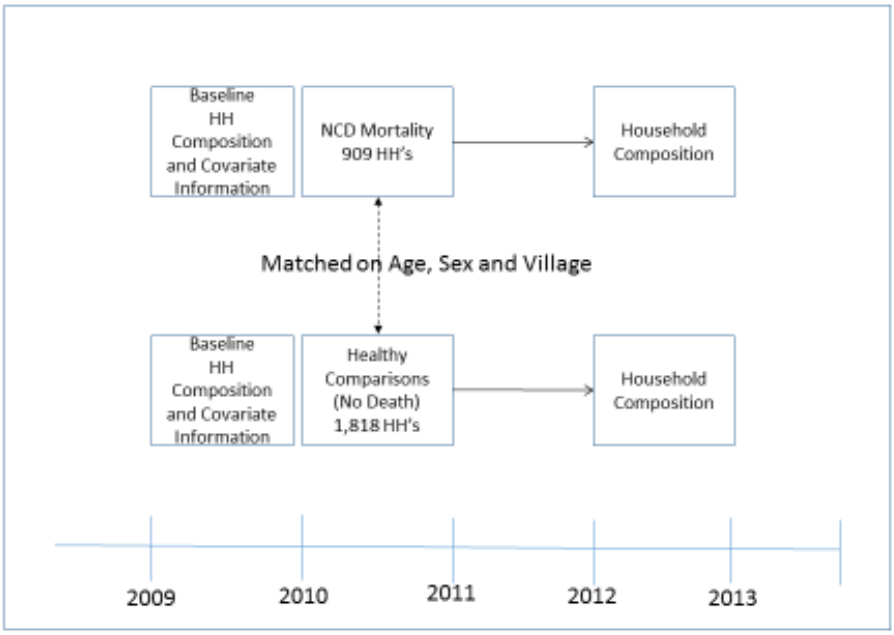


Figure 4-2. Study Design for Assess Changes in Household Composition



Chapter 5. Conclusions

5.1 Summary of results

The main objective of this dissertation was to gain further understanding of the relationship between economics and non-communicable diseases (NCD) in rural Bangladesh. The study takes place in the rural sub-district of Matlab where long-term surveillance permits the examination of the education gradient in mortality over a long period of time (Paper #1). The surveillance also permits the identification of households with adult NCD deaths in a given year and a matched healthy comparison group with no deaths for understanding the economic impact in terms of the risk of being poor two years after the death and the use of coping strategies (Paper #2 and #3).

In paper #1, the education gradient in mortality is examined for NCD and infectious diseases separately for males and female. An extra year of education is found to provide up to a 7% reduction in NCD mortality. Using simulation, it is also found that if everyone had achieved a primary level of education, there would be over 800 NCD deaths averted in the period of interest for the study. Overall, there are steeper gradients for females and for infectious diseases meaning that an extra year of education provides more benefit in terms of reduce mortality for these groups. Looking at education levels over time finds that female education has improved over the time period of the study, from 1982 to 2005, and converged to the same levels of males — a mean of 3 years of formal schooling completed. This increase in education is associated with health gains for females even though overall the average level of education for males and females remains well below that of a primary education.

Paper #1 also explores the components of the education gradient, evaluating how much economic resources (measured through wealth and occupation) and social-psychological resources (measured through marital status) explain the observed education gradient in mortality. Overall, the three component measures explain more of the education gradient in males than they do for females meaning that unmeasured components of the gradient are playing a larger role for females. These could include cognitive abilities, health behaviors or aspects of economic and social-psychological resources not captured in the data. Among the three components, marital status is found to be the most explanatory for each sex. This is in contrast to the research in high income countries finding that wealth or income explain the largest portion of the gradient. This finding could be due to the extent of the informal economy that exists for most of Bangladesh.

Paper #2 develops a new method to estimate the marginal risk of a household being poor after an "exposure" to an adult NCD death. This research develops a regression standardization marginal estimator method that uses a parametric model and an ensembling machine learning algorithm to develop an efficient marginal effect given the observed covariates. There is a significant 14-19% increased risk of being poor for households that had an NCD death when using three different measures of economic outcomes: an asset-based wealth index, self-rated economic condition and total landholding. The results are compared to traditional matched cohort methods using contingency tables and multivariate regression and found to be similar.

In unadjusted analyses, paper #2 finds that there is a consistently higher risk of being poor post-death for the outcome of asset-based index followed by self-rated economic

condition and then total landholding. There are also differential effects depending on individual-level (deceased) characteristics prior to the death. Deaths to male members, prime age members, married members and heads of household are found to lead to higher risks of being poor, though to varying degrees depending on the economic outcome that is used. Multivariate adjustment finds that prime age deaths lead to significantly higher risks of being poor when using asset-based index and self-rated economic condition, but not total landholding.

Paper #3 supports the results found in paper #2 and finds that a prime age death leads to a household reporting the highest number of coping strategies, four out of a total of ten that were identified. For all of the deaths, households were most likely to report using financial coping strategies, and of those, primarily reducing expenditure on basic household items such as food and utilities. Among those households with NCD deaths, there were also important effects based on the reported length of severe morbidity and the poor status of the household prior to death. The length of severe morbidity was positively associated with taking out a high interest independent loan (friends, family or moneylenders) and being poor was positively associated with taking out a high interest institutional loan (formal micro-lender).

Paper #3 also reports the results of a difference in difference (DiD) analysis for those households with an NCD death compared to a health group of households with no deaths in terms of household composition. The results show that there is moderate replacement of human capital with 3 out of 10 households recruiting new members to the household in the two period prior to death. There is slightly more replacement to the total number of

adult females than the adult males when there is an NCD death to a member of the same sex. Stratifying by whether deaths are to prime age members or not finds that prime age deaths lead to more replacement in terms of adult females than for adult males. There are also more children added to the household when there is a death to an older member or to a female.

Overall all three of the papers provide an understanding of the relationship between NCD health and economics at the microeconomic level. The level of education of an individual is associated with lower NCD mortality, and given the rising burden from NCDs, shows that health benefits from investments in education will only increase. NCD mortality may also lead to a higher risk of impoverishment for households. This may be in relation to the direct costs of the morality in terms of increased medical expenditures and lost human capital, but it may also be due to the adoption harmful coping strategies that lead to indirect costs with risks for long term impoverishment.

5.2 Policy Implications

Bangladesh has made great strides towards reducing mortality from maternal causes and towards reducing mortality from childhood illnesses, which are primarily from infectious diseases. Previous research has shown that these reductions will yield economic benefits for the country (100, 101). With an increasing importance of adult NCDs illnesses to the overall burden in the country, greater economic development through improved education will yield health benefits. The results in this dissertation motivate that in a rural population with low levels of education, there is a significant protective effect of

education and scaling up services for NCD prevention and treatment will yield benefits in terms of decreasing household vulnerability to impoverishment. The implications of these findings are that there is a case for public policy interventions because of equity concerns – those that are less educated are impacted more severely by NCDs, and through efficiency gains, which are here seen as costs imposed through impoverishment facing households with adult deaths.

There are three key policy messages related to this work. The first is that increases in levels of education will continue to provide health benefits. This is seen for both NCDs and infectious diseases in Paper #1. This is likely seen through the effect of increasing primary education in the population and further non-linear effects of the education and health relationship in these types of settings may be informative future research. It should also be noted that the observed education gradient in mortality is steeper for infectious diseases, this is a relative effect, and in absolute terms, when any education gradient exists, the level of mortality will also play a role in the total health benefits associated with higher education. Given the trends of rising NCD burden that is seen in Matlab, this means that investments to increase education will mean better overall health. Bangladesh has already engaged in efforts to increase levels of education for females in rural areas and realized the benefits of these efforts. The results from this work promote the continuation of these efforts and the creation of further policy initiatives to increase education levels further.

The second policy message is to scale up efforts to address the NCD burden directly through interventions for prevention and management. In the past several years there

have been efforts by the country to begin to develop surveillance networks, research collaborations and pilot studies to address the emerging NCD burden (167). These efforts should be continued and the results from papers #2 and #3 provide motivation for further benefits from reduction in the NCD burden. These results also show that there are significant economic impacts for households experiencing prime age deaths and deaths preceded by longer periods of severe morbidity. Premature onset of NCDs can be reduced through improved measures for prevention and screening and severe morbidity can be mitigated through adequate treatment.

The final policy message is the further development of improved access to affordable borrowing mechanisms and formal risk-pooling. Bangladesh has had many years of experience with micro-lending and new evidence is beginning to emerge showing that these efforts have had impacts for reducing poverty (121, 145). Policies for micro-lending may contribute to a toolkit for addressing chronic diseases that can be developed for rural, poor settings. Such toolkits have been developed before in support of HIV/AIDS as a poverty reduction strategy (168). There have also been critiques of these efforts and well-known shortcomings, even when the average effects are beneficial (159). Our results in Paper #3 suggest that the poor are more likely to adopt high interest loans from micro-lenders as a response to an NCD death and thus further refinement of these programs to provide affordable loan packages to the poor may be needed. In terms of risk-pooling, several calls have been made recently to provide formal insurance services for households to be able to insure the cost of adverse health events (146). In settings in Bangladesh, this may be done through combination of micro-insurance programs with micro-lending, although these programs have been shown to have important problems as

well (147) . Overall a range of services that include access to both formal and informal borrowing and the development of future formal insurance options will provide more options for households in Bangladesh for mitigating economic consequences from poor health.

Several recent attempts have been made to document the current level of effort to address the NCD burden and found that while improvements have been made, more efforts are needed (5, 19). Additionally, all of the efforts listed take a clinical perspective. Our results will help contribute to a society-wide perspective of this issue, for example leading to financial and education sector interventions to reduce the impact of chronic diseases for households. Most importantly, the results will show that by focusing efforts on the chronic disease burden, a broader economic goal of reducing poverty may be addressed.

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Appendix A – Data Collection Instrument

Bangladesh Non-communicable Conditions and Poverty Survey

ICDDR,B and Johns Hopkins School of Public Health

Developed by: Antonio Trujillo, Andrew Mirelman, David Peters, Jahangir Khan

VERSION 1 (TOTAL QUESTIONS: 96)

CASES SURVEY (NON-COMMUNICABLE DISEASE)

Filter: Households with one non-communicable disease death in the year 2010 and no deaths from any other causes in 2010.

Village Name: _____
Bari Name: _____

Name of Household Head : _____ D.O.B: |___|___|___|___|___|___|___|___| (dd/mm/yyyy)

RID of Household Head: |___|___|___|___|___|___|___|___|___|___|

CID of Household Head: |___|___|___|___|___|___|___|___|___|

Is Respondent Household Head (circle): YES (if yes, skip the shaded box)
NO

Name of the Respondent: _____ D.O.B |___|___|___|___|___|___|___|___| (dd/mm/yyyy)

RID of Respondent: |___|___|___|___|___|___|___|___|___|___|

Relation of Respondent to Household Head: _____ |___| Code
(1) Head (2) Spouse (3) Sibling (4) Child (5) Parent (6) Grandparent (7) Other (specify:_____)

Name of Interviewer: _____ Interviewer Code: |___|

Date of Interview |___|___|___|___|___|___|___|___| (dd/mm/yyyy):

Time Started---------- |___|___| : |___|___| am/pm

Time Finished:---------- |___|___| : |___|___| am/pm

Part1: Head of the Household Basic Information:

The respondent should have been present in the household when the death from the non-communicable condition occurred in 2010 and able to speak competently about the economic situation for the entire household before and after the non-communicable disease death. A household is one or a group of persons occupying a part or an entire building and usually live together eating from same kitchen, this means that the arrangement to fulfil daily necessities is jointly managed. Information here refers to the **HEAD of the household**. The head of the household is someone among the group living in the household who is responsible for satisfying daily necessities of the household or someone who is regarded as the head of the household. For questions that ask for 'household' information, all members living in the house should be referenced.

1.1	Sex	(1) Male (2) Female
1.2	Marital status	(1)Single (2) Married (3)Divorced (4)Widowed
1.3	Number of total family members in your household	Total ----------|___|____| Female ----------|___|____| Children (<15y/o)----------|___|____|
1.4	Household type	1 = Unit family 2 = Joined family
1.5	Religion	1=Islam 2= Hindu 3= Christian 4= Buddhist 5= Others, specify.....
1.6	Highest level of education attained by the head of the household	00=None 01-09=Exact year (specify:_____) 10=S.S.C 12=H.S.C 14=B.A, B.Sc, B.Com 16=M.A, M.Sc, M.Com.
1.7	Occupation of the head of the household	00/Blank= None (No Occupation). 01=Farmer / Agriculturist (Owner worker) 02=Farm owned (Not cultivator). 03=No land owned (Rent cultivator). 04=Fisherman (Catch Fish) 05=Sells fish 06=Rent fishing equipment 07=Agriculture labor/Daily labor 08=Domestic labor 09=Mill / Factory worker (Large)

<table>
<tr><td></td><td></td><td>10=Unskilled labor
11=Skilled labor
12=Boatman
13=Cottage industry
14=Unskilled service employee
15=Skilled Service employee
16=Jute Business
17=Business (Mobile)
18=Business (Established)
19=Beggar
20=Student
21=Disabled
22=Unemployed
23=Other (specify:_____)
24=Unknown
25=House wife</td></tr>
<tr><td>1.8</td><td>What is your current working status</td><td>(1) Employed for wages / salary
(2) Self-employed
(3) Out of work and looking for work
(4) Out of work and not currently looking for work
(5) Homemaker
(6) Student
(7) Retired
(8) Unable to work</td></tr>
<tr><td>1.9</td><td>Weekly average total current household income</td><td>Working:---------- |___|___|___|___|___|___|Tk/week
Non-Working:---------- |___|___|___|___|___|___|Tk/week
Cash Transfers: ----------|___|___|___|___|___|___|Tk/week
Government Assistance:___ |___|___|___|___|___|___|Tk/week
Other (specify_____):_|___|___|___|___|___|___|Tk/week.</td></tr>
<tr><td>1.10</td><td>Monthly average total current household income</td><td>Working:---------- |___|___|___|___|___|___|Tk/month
Non-Working:---------- |___|___|___|___|___|___|Tk/ month
Cash Transfers: ----------|___|___|___|___|___|___|Tk/ month
Government Assistance:___ |___|___|___|___|___|___|Tk/ month
Other (specify_____):_|___|___|___|___|___|___|Tk/ month</td></tr>
<tr><td>1.11</td><td>How much land do you own?</td><td>Homestead (including ponds and ditch):

Kani:_____ gonda:_____kors:_____ = |____|____|____|____| DM

Agricultural:

Kani:_____gonda:_____kors:_____=|____|____|____|____|DM</td></tr>
<tr><td>1.12</td><td>During the last 12 months what was the sources of income of your household?</td><td colspan="3"><table>
<tr><th>No.</th><th>Source of Income</th><th>Y</th><th>N</th></tr>
<tr><td>1</td><td>Agriculture (own land)</td><td>1</td><td>2</td></tr>
<tr><td>2</td><td>Agriculture (share crops)</td><td>1</td><td>2</td></tr>
<tr><td>3</td><td>Mortgage/Kot/Poshani (In/Out)</td><td>1</td><td>2</td></tr>
<tr><td>4</td><td>Day Laborer</td><td>1</td><td>2</td></tr>
</table></td></tr>
</table>

		5	Catching fish and selling fish	1	2
		6	Cattle/Chicken/Duck farm	1	2
		7	Handicraft	1	2
		8	Tailoring works	1	2
		9	Business	1	2
		10	Service	1	2
		11	Pension	1	2
		12	Remittance (within country)	1	2
		13	Remittance (other country)	1	2
		14	Food for work	1	2
		15	VGD old age/destitute allowance	1	2
		16	Renting house/shop	1	2
		17	Other:_____	1	2

1.13	From question 1.13 above, what was the main source of income?	No:----------|___|____| (list number only)
1.14	How many dwellings does the household have?	No.:----------|___|

1.15 Materials used for the main dwelling (check before writing)

1. Pacca/Sami Pacca
2. Tin
3. Tin and Bamboo
4. Tin and others
5. Bamboo and others
6. Kachha (mud)
7. Wood
8. Other

(use code in the box)

Roof	Wall	Floor

1.16 Are you or any of your household members the member of an NGO or samity? (If yes, please list for how many years and months they have been a member.)

(1) yes

	Year		Month	
(a) BRAC				
(b) Grameen Bank				
(c) ASA				
(d) Others 1(mention)_____				
(e) Others 2(mention)_____				
(f) Others 3 (mention) _____				

(2) NO

Part2: Household Asset Information:

Information here refers to the **entire household.**

2.1		No.	Commodity	Yes	No

	Do you have the following commodities in your household?	1	Cow or goat	1	2
		2	Fishing net	1	2
		3	Chicken/Duck	1	2
		4	Grocery shop	1	2
		5	Rickshaw/van	1	2
		6	Modern agricultural equipment	1	2
		7	Engine boat for carrying goods and passengers	1	2
		8	Fishing boat	1	2
		9	Boat	1	2
		10	Khat/chowki	1	2
		11	Quilt/blanket	1	2
		12	Mattress	1	2
		13	Hurricane	1	2
		14	Chair/table	1	2
		15	Dining table	1	2
		16	Almerah/showcase	1	2
		17	Sofa set	1	2
		18	Television	1	2
		19	Radio/tape recorder	1	2
		20	Watch/wall clock	1	2
		21	Telephone/Mobile	1	2
		22	Bicycle	1	2
		23	Motorcycle	1	2
		24	Refrigerator	1	2
		25	Fan	1	2
		26	Sewing machine	1	2

2.2	What type of latrines are you using?	**No.**	**Type**	**Male**	**Female**
		1	Septic tank/modern toilet	1	2
		2	Water sealed (closed tank)	1	2
		3	Water sealed (not closed tank)	1	2
		4	Pacca latrine (open tank)	1	2
		5	Kacha latrine (open tank)	1	2
		6	Other (specify:_____)	1	2

2.3	What is the main source of drinking water in dry and rainy seasons?	**No.**	**Type**	**Dry**	**Rainy**
		1	Tubewell (green)	1	2
		2	Tubewell (red)	1	2
		3	Tubewell (not yet checked)	1	2
		4	Pond	1	2
		5	River	1	2
		6	Ditch/canal	1	2
		7	PSF/RSF	1	2
		8	Three pitchers	1	2

		9	Rain water	1	2
		10	Other filter water	1	2
		11	Pipe/Tap/Supply Water	1	2
		12	Others (specify:_____)	1	2
		13	Unknown	1	2

Part 3: Non-communicable Disease Event Information. This section deals with information related to the death from the non-communicable condition that the household experienced in the year 2010. If there were more than one of these deaths, please refer to the one from the highest ranking household member. The ranking of household members should start with the head of the household as the highest ranking. Subsequent rankings should be by age of the person who died.

3.1	Sex of the deceased	(1)Male (2)Female
3.2	Education of the deceased	00=None 01-09=Exact year (specify:_____) 10=S.S.C 12=H.S.C 14=B.A, B.Sc, B.Com 16=M.A, M.Sc, M.Com.
3.3	Position of the deceased in the household in relation to the head of the household	(1) Head (2) Spouse (3) Sibling (4) Child (5) Parent (6) Grandparent (7) Other(specify:_____)
3.4	Date of birth of the deceased	|___|___|___|___|___|___|___|___| (dd/mm/yyyy
3.5	Date of death	|___|___|___|___|___|___|___|___| (dd/mm/yyyy
3.6	Main cause of death (Verify the medical records/ death certificate if any) (only one answer)	(1)Cancer (2)Diabetes (3)COPD (4)Stroke (5)Heart Disease (6)Other Non-communicable condition (specify:_____) (7)Non Communicable condition (specify:_____)
3.7	Other non-communicable conditions that the deceased suffered from in addition to the one they died from (list all) (can be multiple answer)	(1)Cancer (2)Diabetes (3)COPD (4)Stroke (5)Heart Disease (6)Other Non-communicable condition (specify:_____) (7)The deceased did not suffer from in addition NCDs

3.8	Other communicable conditions that the deceased suffered from in addition to the one they died from (list all) (can be multiple answer	((1) Diarrhea (2) Tuberculosis (3) EPI related (4) Septicaemia (5) Respiratory Infection (6)Other communicable condition (specify:_____) (7) No communicable disease
3.9	When did the deceased person become sick with the non-communicable condition?	|___|___|___|___|___|___|___|___| (dd/mm/yyyy
3.10	When did the deceased person become severely ill and not able to function? ('Not able to function' refers to not being able to work, go to school, or perform daily activities without assistance)	|___|___|___|___|___|___|___|___| (dd/mm/yyyy
3.11	Who was the main provider of medical care outside of the household when the person had the condition? only one answer)	1= Medical doctor 2 = Nurse 3 = Village doctor 4 = Homeopath doctor 5= Kabiraj (ayurveda) 6 = Care not sought 7 = Others, specify ……
3.12	In what type of facility was outside care received while the person had the condition? only one answer)	1 = Public Hospital 2 = Private Hospital 3 = NGO Hospital 4 = At home 5 = Care not sought 6 = Others, specify……
3.13	Was care received inside the household during the illness?	(1)Yes (specify who from) (a) Spouse (b) Child (c) Parent (d)Other (specify:_____) (2) No

Part 4: Assessment of change in socioeconomic status.
All Questions here use the date of death referenced in **question #3.5** above, when the person with the non-communicable condition passed away. Please assess changes in the periods: before the person was sick and not able to function, after the person became sick and not able to function and before death (mostly in the year before death from the non-communicable condition), and in the current period (at least one year since the death).

4.1	How do you think your socioeconomic condition changed mainly as a result of having a non-communicable disease death in your household (please make a general	(1) Was good and remained good (2) Was bad and remained bad (3) Improved

	statement regarding the change over the time before the death from the non-communicable condition to the time afterwards)?	(4) Got worse
Questions 4.2 – 4.4 Have a 5 step ladder for assessment of economic condition. The steps on the ladder represent the following: 1) Very Poor, 2) Moderately Poor, 3) Neither Poor nor Rich, 4) Moderately Rich, 5) Very Rich		
4.2	On a ladder of five steps, where very poor is on the first step and very rich is on the fifth step, where would you place your household economic condition in the period **BEFORE** the person became sick and unable to function (before the date in question 3.10 above).	1 2 3 4 5 Don't Know
4.3	On a ladder of five steps, where very poor is on the first step and very rich is on the fifth step, mainly as a result from the non-communicable condition, where would you place your household economic condition in the period **AFTER** the person was sick and not able to function	1 2 3 4 5 Don't Know
4.4	On a ladder of five steps, where very poor is on the first step and very rich is on the fifth step, mainly as a result from the non-communicable condition, where would you place your household economic condition in the period **IN THE CURRENT PERIOD** (at least one year since the death).	1 2 3 4 5 Don't Know

Part 5: Economic Impact DURING Time with Non-communicable Condition
All Questions here refer to the period referenced in **question #3.10** above, when the person with the non-communicable condition could not function, ('Not able to function' refers to not being able to work, go to school, or perform daily activities without assistance) prior to death. All monetary figures should be in Taka.

Expenditures & Food Security		
5.1	Approximately how much was spent for care DURING the time with the non-communicable condition, including cost of transport, hospitalization, medicine and diagnostic tests?	(1)Food:----------|___|___|___|___|___|Tk./week (2) Utilities:----------|___|___|___|___|___| Tk./week (3) Rent:----------|___|___|___|___|___| Tk./week (4) Tobacco:---------- |___|___|___|___|___| Tk./week (5) Cell phone:----------|___|___|___|___|___| Tk./week (6) Transportation:----------|___|___|___|___|___| Tk./week (7) Hospitalization /Outpatient/ Diagnostic Test -|___|___|___|___|___| Tk./week (8)Medication:----------|___|___|___|___|___| Tk./week (9) Others (specify):----------|___|___|___|___|___| Tk./week (10) Don`t Know
5.2	Was any source external to the household used to pay for care (Hospitalization/Outpatient/Diagnostic test and Medication from 5.1)?	(1)Yes (a)Contribution from family (b)Contribution from friends (c)Others, specify:_____ (2)No (3)Don't Know
5.3	Did total household expenditures per week on basic items (food, utilities, etc.) change during the time that the person had the condition?	(1)Yes (a) Increased (by how much:--------|___|___|___|___| Tk/week.) (b) Decreased (by how much :----- |___|___|___|___| Tk/week.) (2)No, Stayed the same (3)Don't Know
5.4	Did total household expenditures on discretionary items (non-essential foods, cell phone, etc.) per week change during the time that the person had the condition?	(1)Yes (a) Increased (by how much: :---------|___|___|___|___| Tk/week.) (b) Decreased (by how much: :--------|___|___|___|___| Tk/week.) (2)No, Stayed the same (3)Don't Know
5.5	If tobacco was consumed in the household, did household expenditure on tobacco products change while the person had the non-communicable condition?	(1)Yes (a) Increased (by how much: :---------|___|___|___|___| Tk/week.) (b) Decreased (by how much: :--------|___|___|___|___| Tk/week.) (2)No, Stayed the same (3) Not Applicable (Did not consume any tobacco) (4) Don't Know
Assets, Savings, Loans		
5.6	Were household savings used to provide care for the person with the non-communicable condition?	(1)Yes (how much was used:---------- |___|___|___|___|___|___|Tk.) (2)No (3)Don't Know (4) Not Applicable (no savings)
5.7	Were household assets sold to pay for care for the non-communicable condition?	(1)Yes (amount received from the sale:- |___|___|___|___|___|___|Tk.). (2) No (3)Don't Know
5.8	Were any institutional loans taken out with banks, NGOs, or	(1)Yes (2)No(If no skip to q # 5.11)

	other organizations during the time of the illness?	(3)Don't Know
5.9	If yes to question 5.9 above, please provide the institutional loan details for (up to) the two largest loan in question 5.10a-b	
5.9a	Institutional loan 1	(1) Amount borrowed:-------- |___|___|___|___|___|___|Tk.. (2) Length:---------- |___|___|___| Month (3)Interest rate:----------|___|___| (4)Collateral (guarantee): _____
5.9b	Institutional loan 2	(1)Amount borrowed:------ |___|___|___|___|___|___|Tk.. (2)Length:---------- |___|___|___| Month (3)Interest rate:----------|___|___| (4) Collateral (guarantee): _____
5.10	Were the institutional debts able to be paid off?	(1) Yes (2) No
5.11	Were any independent loans (from friends, neighbors, relatives, moneylenders etc.) taken out to pay for care from the non-communicable condition?	(1)Yes (2)No(If no skip to q # 5.14) (3)Don't Know
5.12	If yes to question 5.12 above, please provide the independent loan details in 5.13a-b below.	
5.12a	Independent loan 1	(1)Amount borrowed:------ |___|___|___|___|___|___|Tk.. (2)Length:---------- |___|___|___| Month (3)Interest rate:----------|___|___| (4) Collateral (guarantee): _____
5.12b	Independent loan 2	(1)Amount borrowed:------ |___|___|___|___|___|___|Tk.. (2)Length:---------- |___|___|___| Month (3)Interest rate:----------|___|___| (4) Collateral (guarantee): _____
5.13	Were the independent debts able to be paid off?	(1)Yes (2) No
5.14	If no to question 5.11 or 5.14 above, and loans were not able to be paid off, were any assets lost as a consequence?	(1)Yes (2)No (3) N/A
Earnings – questions in this section refer to the period when the person became sick (question 3.9)		
Person with the Non-communicable Condition		
5.15	Did the working status of the person with the non-communicable condition change because they had the non-communicable condition?	(1)Yes (a) Worked More (by how much:------ |___|___| hour/week [1] (b) Worked Less (by how much: :------ |___|___| hour/week [2] (c) Have to stop working [3] (2)No, Stayed the same [4] (3)Not applicable, they were not working [5] (4)Don't Know [6]

5.16	Was work absenteeism an issue for the person with the non-communicable condition person because they had the condition?	(1)Yes (2) No (3)Don't Know (4) Not applicable (not in working)
5.17	Did the earnings of the person with the non-communicable condition change while they were still working, because they had the condition?	(1)Yes (a) Increased (by how much:---------- |___|___|___|___|Tk./week (b) Decreased (by how much: ---------|___|___|___|___|Tk./week (2)No, Stayed the Same ~~(3)Not applicable, they were not working~~ (3)Don't Know
Household Members		
5.18	Did the working status of the household members already in the labor force change because the person had the non-communicable condition?	(1)Yes (a) Worked More (by how much :------ |___|___| Hour/week (b) Worked Less (by how much:------- |___|___| Hour/week (2)No, Stayed the same (3)Not applicable, they were not working (4)Don't Know
5.19	Was work absenteeism an issue for the household members because the deceased person had the condition?	(1)Yes (2) No (3)Not applicable,(they were not working) (4)Don't Know
5.20	Did household members not previously in the labor force have to enter the labor force because the person had the condition?	(1)Yes (2) No (3)Don't Know
5.21	If Yes to question 5.21 above, did the person have to leave school to enter the work force?	(1)Yes If yes specify the level) 00=None 01-09=Exact year (specify:_____) 10=S.S.C 12=H.S.C 14=B.A, B.Sc, B.Com 16=M.A, M.Sc, M.Com. (2) No (3) Not applicable(No school going member in HH) (4)Don't Know
5.22	Did the earnings of the household members already in the labor force change because the person had the condition?	(1)Yes (a) Increased (by how much:---------- |___|___|___|___|Tk./week (b) Decreased (by how much:--------- |___|___|___|___|Tk./week (2)No, Stayed the Same ~~(3)Not applicable, they were not working~~ (3)Don't Know
5.23	If a person had to stop working while the person was sick with the condition, were they able to re-enter the workforce at a later point?	(1)Yes (2) No (3) Don't Know (4) Not applicable (Nobody stop working)

Total Household		
5.24	Did total household earnings (person with non-communicable condition and other household members) change because the person had the condition?	(1)Yes (a) Increased (by how much:---------- |___|___|___|___|Tk./week (b) Decreased (by how much:---------- |___|___|___|___|Tk./week (2)No, Stayed the Same (3)Not applicable, they were not working (4)Don't Know
Remittances Received		
5.25	Did the amount of remittances received change during the time when the person had the illness mainly due to the illness?	(1)Yes (a) Increased (by how much:---------- |___|___|___|___|Tk./Month (b) Decreased (by how much:---------- |___|___|___|___|Tk./Month (2)No, Stayed the Same (3)Not applicable, none received (4)Don't Know
Government Transfers		
5.26	Did income received from any public or government transfers (i.e. the social safety net programs, SSNP) change during the time of the illness, mainly due to the illness?	(1)Yes (a) Increased (by how much:---------- |___|___|___|___|Tk./Month (b) Decreased (by how much: ----------|___|___|___|___|Tk./Month (2)No, Stayed the Same (3)Not applicable, none received (4)Don't Know
Family Arrangements & Education		
5.27	Did family members have to move out of the house, during the time of the illness of the person who died, mainly due to the illness?	(1)Yes (2)No (3)Don't Know
5.28	Did family members have to move into the house, during the time of the illness of the person who died, mainly due to the illness?	(1)Yes (2)No (3)Don't Know
5.29	Did any members of the household marry early or marry underage (ages 0-18) or delay marriage, during the time of the illness, mainly as a result of the economic impact due to the illness of the person who died?	(1)Yes (check all that apply) marry early-- 1 delay marriage -- 2 (2)No (3)Don't Know
5.30	Did any household members have to stop attending school to provide care for the person with the condition during the time of the illness of the person who died?	(1)Yes (If yes specify the level) 01-09=Exact year (specify:_____) 10=S.S.C 12=H.S.C 14=B.A, B.Sc, B.Com 16=M.A, M.Sc, M.Com. (2) No (3) Don't Know

		(4) Not applicable(No school going member in HH)
5.31	If a person had to stop education during the time of the illness of the person who died, were they able to start again at a later point?	(1)Yes (2)No (3)Don't Know (4) N/A
5.32	Did any household members attending school have worse school performance during the time of the illness due to the illness of the person who died?	(1)Yes (2)No (3) Don't Know (4) Not applicable(No school going member in HH)

Part 6: Economic Impact AFTER Time with Non-communicable Disease
All Questions refer to the current period in the household after the family member died (reference **date in question 3.5**) of a non-communicable disease (minimum one year). All monetary figures should be in Taka.

Expenditures & Food Security		
6.1	Did total household expenditures per week on basic items (food, utilities, etc.) change after the person passed away?	(1)Food:----------|___|___|___|___|___|Tk./week (2) Utilities:----------|___|___|___|___|___| Tk./week (3) Rent:----------|___|___|___|___|___| Tk./week (4) Tobacco:---------- |___|___|___|___|___| Tk./week (5) Cell phone:----------|___|___|___|___|___| Tk./week (6) Transportation:----------|___|___|___|___|___| Tk./week (7) Hospitalization /Outpatient/ Diagnostic Test -|___|___|___|___|___| Tk./week (8)Medication:----------|___|___|___|___|___| Tk./week (9) Others (specify):----------|___|___|___|___|___| Tk./week (10) Don`t Know
6.2	Did total household expenditures per week on basic items (food, utilities, etc.) change after the person passed away?	(1)Yes (a) Increased (by how much:--------|___|___|___|___| Tk/week.) (b) Decreased (by how much :----- |___|___|___|___| Tk/week.) (2)No, Stayed the same (3)Don't Know
6.3	Did total household expenditures on discretionary items (non-essential foods, cell phone, etc.) per week change after the person passed away?	(1)Yes (a) Increased (by how much: ----------|___|___|___|___|Tk./week (b) Decreased (by how much: ---------|___|___|___|___|Tk./week (2)No, Stayed the same (3)Don't Know
6.4	If tobacco was consumed in the household, did household expenditure on tobacco products change after the person passed away?	(1)Yes (a) Increased (by how much: ----------|___|___|___|___|Tk./week (b) Decreased (by how much: ----------|___|___|___|___|Tk./week (2)No, Stayed the same (3) Not applicable(tobacco was not consumed) (4)Don't Know
Assets Savings and Loans		

6.5	Were household savings used to provide for the household after the person passed away?	(1)Yes (how much was used: ----------|___|___|___|___|___|___|Tk. (2)No (3)Don't Know (4) Not applicable(No savings)
6.6	Were household assets sold to provide for the household after the person passed away?	(1)Yes (amount received from the sale: --|___|___|___|___|___|___|Tk.) (2) No
6.7	Were any institutional loans taken out with banks, NGOs, or other organizations after the person passed away?	(1)Yes (2)No(If no skip to q # 6.10) (3)Don't Know
6.8	If yes to question 6.7 above, please provide the institutional loan details in questions 6.8a-b	
6.8a	Institutional loan 1	(1)Amount borrowed:------ |___|___|___|___|___|___|Tk.. (2)Length:---------- |___|___|___| Month (3)Interest rate:----------|___|___| (4) Collateral (guarantee): _____
6.8b	Institutional loan 2	(1)Amount borrowed:------ |___|___|___|___|___|___|Tk.. (2)Length:---------- |___|___|___| Month (3)Interest rate:----------|___|___| (4) Collateral (guarantee): _____
6.9	Were the institutional debts able to be paid off?	(1) Yes (2) No (3) Partially
6.10	Were any independent loans (from friends, neighbors, relatives, moneylenders, etc.) taken out after the person passed away?	(1)Yes (2)No(If no skip to q # 6.13) (3)Don't Know
6.11	If yes to question 6.10 above, please provide the independent loan details in 6.11a-b below.	
6.11a	Independent loan 1	(1)Amount borrowed:------ |___|___|___|___|___|___|Tk.. (2)Length:---------- |___|___|___| Month (3)Interest rate:----------|___|___| (4) Collateral (guarantee): _____
6.11b	Independent loan 2	(1)Amount borrowed:------ |___|___|___|___|___|___|Tk.. (2)Length:---------- |___|___|___| Month (3)Interest rate:----------|___|___| (4) Collateral (guarantee): _____
6.12	Were the independent debts able to be paid off?	(1)Yes (2) No
6.13	If no to question 6.7or 6.10 above, and loans were not able to be paid off, were any assets lost as a consequence?	(1)Yes (2)No (3) Not applicable
Earnings		
Household Members		

6.14	Did the working status of the household members already in the labor force change mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (a) Worked More (by how much :------- |___|___| Hour/week [1] (b) Worked Less (by how much :------- |___|___| Hour/week [2] (c) Have to stop working [3] (2)No, Stayed the same [4] (3)Not applicable, they were not working [5] (4)Don't Know [6]
6.15	Was work absenteeism an issue for the household members mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (2) No (3) Not applicable, no member was working (4)Don't Know
6.16	Did household members not previously in the labor force have to enter the labor force mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (2) No --→ Go to 6.18 (3)Don't Know
6.17	If Yes to question 6.16 above, did the person have to leave school to enter the work force?	(1)Yes If yes specify the level) 01-09=Exact year (specify:_____) 10=S.S.C 12=H.S.C 14=B.A, B.Sc, B.Com 16=M.A, M.Sc, M.Com. (2) No (3)Don't Know
6.18	Did the earnings of the household members in the labor force change mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (a) Increased (by how much: ---------|___|___|___|___|Tk./week (b) Decreased (by how much: ---------|___|___|___|___|Tk./week (2)No, Stayed the Same (3)Don't Know
Total Household		
6.19	Did total household earnings (all surviving household members) change mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (a) Increased (by how much: ---------|___|___|___|___|Tk./week (b) Decreased (by how much: ---------|___|___|___|___|Tk./week (2)No, Stayed the Same (3)Don't Know
Remittances Received		
6.20	Did the amount of remittances received change mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (a) Increased (by how much: ---------|___|___|___|___|Tk./Month (b) Decreased (by how much: ---------|___|___|___|___|Tk./Month (2)No, Stayed the Same (3)Not applicable, none received (4)Don't Know
Government Transfers		

6.21	Did income received from any public or government transfers (i.e. the social safety net programs, SSNP) change mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (a) Increased (by how much: ---------|___|___|___|___|Tk./Month (b) Decreased (by how much: ---------|___|___|___|___|Tk./Month (2)No, Stayed the Same (3)Not applicable, none received (4)Don't Know
Family Arrangements & Education		
6.22	Did family members have to move out of the house, mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (2)No (3)Don't Know
6.23	Did family members have to move into the house, mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (2)No (3)Don't Know
6.24	Did any members of the household marry early or marry underage (ages 0-18) or delay marriage, mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (check all that apply) marry early --1 delay marriage--2 (2)No (3)Don't Know
6.25	Did any household members have to stop attending school mainly due to the death from the non-communicable condition after the person passed away?	(1) YES (If yes specify the level) 01-09=Exact year (specify:_____) 10=S.S.C 12=H.S.C 14=B.A, B.Sc, B.Com 16=M.A, M.Sc, M.Com. (2) No (3) Not applicable (no school going member) (4) Don't Know
6.26	Did any household members attending school have worse school performance mainly due to the death from the non-communicable condition after the person passed away?	(1)Yes (2)No (3) Not applicable (no school going member) (4) Don't Know

Appendix B - Extra Tables for Chapter 2

Table B-1. (Corresponds to Table 2-2). OLS Regressions on the components of Wealth, Marital Status and Occupation

	Marital Status – Male	Marital Status – Female	Occupation – Male	Occupation – Female	Wealth – Male	Wealth - Female
Constant	-0.171***	0.447***	0.932***	0.097***	1.694***	1.341***
	(0.006)	(0.006)	(0.005)	(0.003)	(0.016)	(0.015)
Edu Year	0.007***	0.008***	0.010***	0.016***	0.110***	0.154***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
Age	0.023***	0.004***	-0.006***	-0.001***	-0.006***	0.007***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Muslim	-0.005*	0.001	-0.100***	0.003*	0.361***	0.319***
	(0.003)	(0.003)	(0.003)	(0.002)	(0.008)	(0.008)
Household size	-0.005***	0.005***	0.006***	-0.002***	0.143***	0.147***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
Cohort ages 40-59	-0.243***	-0.249***	0.044***	0.018***	0.075***	0.300***
	(0.004)	(0.004)	(0.004)	(0.002)	(0.012)	(0.011)
Cohort ages 60 and above	-1.012***	-0.721***	0.106***	0.033***	0.590***	0.315***
	(0.007)	(0.007)	(0.007)	(0.004)	(0.021)	(0.019)
Census 1996	0.089***	0.126***	0.069***	-0.029***	0.087***	-0.085***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.007)	(0.007)
Census 2005	0.135***	0.175***	0.109***	-0.039***	0.104***	-0.190***
	(0.003)	(0.003)	(0.002)	(0.002)	(0.007)	(0.007)
R^2	0.184	0.175	0.051	0.044	0.204	0.223
Num. obs.	186264	203266	170652	203266	186264	203266

***p < 0.01, **p < 0.05, *p < 0.1

Table B-2 (Corresponds to Table 2-3 and 2-5) Cox Proportional Hazards Model on Male NCD Mortality.

	Unadjusted	Adjusted	Adjusted + Marital	Adjusted + Occ	Adjusted + Wealth	Adjusted + Marital + Occ + Wealth
Edu Year	-0.019***	-0.021***	0.003	-0.017***	-0.011**	0.004
	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)

Age	0.084***	0.068***	0.018***	0.067***	0.068***	0.018***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Muslim (ref. Hindu)	-0.210***	-0.218***	-0.159***	-0.234***	-0.188***	-0.154***
	(0.043)	(0.043)	(0.044)	(0.044)	(0.043)	(0.045)
Household size	-0.021***	-0.016***	-0.001	-0.014**	-0.005	0.004
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Cohort ages 40-59 (ref 15-39)		0.679***	0.923***	0.776***	0.671***	0.937***
		(0.082)	(0.103)	(0.087)	(0.081)	(0.103)
Cohort ages 60 and above (ref 15-39)		1.052***	1.109***	1.153***	1.056***	1.121***
		(0.109)	(0.128)	(0.114)	(0.109)	(0.129)
Census 1996 (ref. 1982)		0.117***	0.828***	0.158***	0.120***	0.842***
		(0.045)	(0.046)	(0.045)	(0.045)	(0.046)
Census 2005 (ref. 1982)		0.441***	2.465***	0.476***	0.440***	2.472***
		(0.042)	(0.047)	(0.043)	(0.042)	(0.047)
Married (ref. Single/Never Married)			-5.115***			-5.087***
			(0.464)			(0.472)
Widow/Divorced (ref. Single/Never Married)			3.378***			3.401***
			(0.126)			(0.153)
student (ref. No Occupation)				-0.690**		-0.748**
				(0.302)		(0.322)
housework (ref. No Occupation)				0.389		1.277
				(0.740)		(0.905)
skilled agri (ref. No Occupation)				-0.611***		-0.559***
				(0.069)		(0.073)
elementary labor (ref. No Occupation)				-0.448***		-0.476***
				(0.076)		(0.079)
manufacture/skilled work/service (ref. No Occupation)				-0.608***		-0.484***
				(0.078)		(0.079)
business (ref. No Occupation)				-0.576***		-0.474***
				(0.083)		(0.085)
others (ref. No Occupation)				-0.441**		-0.386**
				(0.180)		(0.181)
Quintile 2 (ref. Quintile 1)					-0.155***	-0.067
					(0.054)	(0.054)

Quintile 3 (ref. Quintile 1)					-0.242***	-0.112**
					(0.053)	(0.053)
Quintile 4 (ref. Quintile 1)					-0.310***	-0.116**
					(0.053)	(0.053)
Quintile 5 (ref. Quintile 1)					-0.317***	-0.101*
					(0.055)	(0.056)
AIC	93457.023	93212.628	82336.758	93126.969	93177.684	82279.876
R^2	0.052	0.053	0.107	0.053	0.053	0.107
Max. R^2	0.426	0.426	0.426	0.426	0.426	0.426
Num. events	4317	4317	4317	4317	4317	4317
Num. obs.	186264	186264	186264	186264	186264	186264
PH test	0.512	0.000	0.000	0.000	0.000	0.000

*** p < 0.01, ** p < 0.05, * p < 0.1

Table B-3 (Corresponds to Table 2-3 and 2-5) Cox Proportional Hazards Model on Male Infectious Mortality.

	Unadjusted	Adjusted	Adjusted + Marital	Adjusted + Occ	Adjusted + Wealth	Adjusted + Marital + Occ + Wealth
Edu Year	-0.096***	-0.080***	-0.063***	-0.066***	-0.064***	-0.041***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Age	0.076***	0.072***	0.049***	0.068***	0.074***	0.047***
	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Muslim (ref. Hindu)	-0.179***	-0.093*	-0.111**	-0.137**	-0.043	-0.103*
	(0.057)	(0.056)	(0.056)	(0.058)	(0.056)	(0.057)
Household size	0.012*	-0.013*	-0.010	-0.012*	0.009	0.009
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)
Cohort ages 40-59 (ref 15-39)		0.118	-0.295***	0.270***	0.087	-0.238**
		(0.092)	(0.112)	(0.098)	(0.092)	(0.113)
Cohort ages 60 and above (ref 15-39)		0.333**	-0.300**	0.508***	0.315**	-0.218
		(0.131)	(0.145)	(0.137)	(0.131)	(0.146)
Census 1996 (ref. 1982)		-1.248***	-0.685***	-1.193***	-1.250***	-0.637***
		(0.048)	(0.050)	(0.048)	(0.048)	(0.051)
Census 2005 (ref. 1982)		-1.996***	-0.369***	-1.945***	-2.001***	-0.321***
		(0.060)	(0.070)	(0.061)	(0.060)	(0.070)
Married (ref. Single/Never Married)			-4.096***			-3.978***
			(0.333)			(0.347)

Widow/Divorced (ref. Single/Never Married)			1.878***			2.001***
			(0.140)			(0.163)
student (ref. No Occupation)				0.036		-0.224
				(0.248)		(0.260)
housework (ref. No Occupation)				-11.418***		-11.027***
				(0.178)		(0.355)
skilled agri (ref. No Occupation)				-0.788***		-0.815***
				(0.076)		(0.073)
elementary labor (ref. No Occupation)				-0.452***		-0.582***
				(0.083)		(0.081)
manufacture/skilled work/service (ref. No Occupation)				-0.888***		-0.822***
				(0.099)		(0.095)
business (ref. No Occupation)				-0.854***		-0.836***
				(0.110)		(0.106)
others (ref. No Occupation)				-0.623***		-0.671***
				(0.222)		(0.233)
Quintile 2 (ref. Quintile 1)					-0.040	0.010
					(0.066)	(0.066)
Quintile 3 (ref. Quintile 1)					-0.357***	-0.279***
					(0.069)	(0.069)
Quintile 4 (ref. Quintile 1)					-0.383***	-0.275***
					(0.068)	(0.068)
Quintile 5 (ref. Quintile 1)					-0.526***	-0.392***
					(0.072)	(0.072)
AIC	53229.125	51675.298	48874.156	51527.793	51602.348	48702.968
R^2	0.026	0.035	0.049	0.035	0.035	0.050
Max. R^2	0.268	0.268	0.268	0.268	0.268	0.268
Num. events	2433	2433	2433	2433	2433	2433
Num. obs.	186264	186264	186264	186264	186264	186264
PH test	0.025	0.091	0.000	0.002	0.065	0.000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table B-4 (Corresponds to Table 2-3 and 2-4) Cox Proportional Hazards Model on Female NCD Mortality.

	Unadjusted	Adjusted	Adjusted + Marital	Adjusted + Occ	Adjusted + Wealth	Adjusted + Marital + Occ + Wealth
Edu Year	-0.058***	-0.069***	-0.033***	-0.068***	-0.059***	-0.028**
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)
Age	0.092***	0.080***	0.064***	0.079***	0.081***	0.063***
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Muslim	-0.253***	-0.253***	-0.218***	-0.252***	-0.236***	-0.209***
	(0.050)	(0.050)	(0.049)	(0.050)	(0.050)	(0.050)
Household size	0.005	0.012*	0.032***	0.011*	0.019***	0.036***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)
Cohort ages 40-59		0.107	-0.531***	0.178*	0.122	-0.508***
		(0.090)	(0.106)	(0.092)	(0.091)	(0.106)
Cohort ages 60 and above		0.518***	-0.465***	0.595***	0.529***	-0.437***
		(0.116)	(0.129)	(0.120)	(0.116)	(0.130)
Census 1996		-0.114**	0.155***	-0.087	-0.115**	0.180***
		(0.054)	(0.056)	(0.054)	(0.054)	(0.056)
Census 2005		0.340***	0.897***	0.366***	0.338***	0.931***
		(0.050)	(0.055)	(0.051)	(0.050)	(0.055)
Married			-5.153***			-5.099***
			(0.460)			(0.465)
Widow/Divorced			0.971***			1.042***
			(0.143)			(0.159)
Student				-0.029		-0.117
				(0.295)		(0.295)
Housework				-0.331***		-0.432***
				(0.097)		(0.093)
Skilled agriculture				-0.238		-0.467
				(0.326)		(0.324)
Elementary Labor				-0.317*		-0.649***
				(0.170)		(0.167)
Manufacture/skilled work/service				-0.227		-0.463*
				(0.260)		(0.259)
Business				-0.106		-0.223
				(0.422)		(0.419)
Others				-0.569*		-0.380
				(0.330)		(0.273)
Quintile 2					0.007	0.053
					(0.060)	(0.060)

Quintile 3					-0.013	0.060
					(0.060)	(0.060)
Quintile 4					-0.104*	-0.019
					(0.060)	(0.061)
Quintile 5					-0.163**	-0.066
					(0.064)	(0.064)
AIC	67998.153	67833.796	65660.844	67821.011	67829.616	65653.375
R^2	0.040	0.041	0.051	0.041	0.041	0.051
Max. R^2	0.313	0.313	0.313	0.313	0.313	0.313
Num. events	3163	3163	3163	3163	3163	3163
Num. obs.	203266	203266	203266	203266	203266	203266
PH test	0.843	0.017	0.003	0.001	0.005	0.000

*** p < 0.01, ** p < 0.05, * p < 0.1

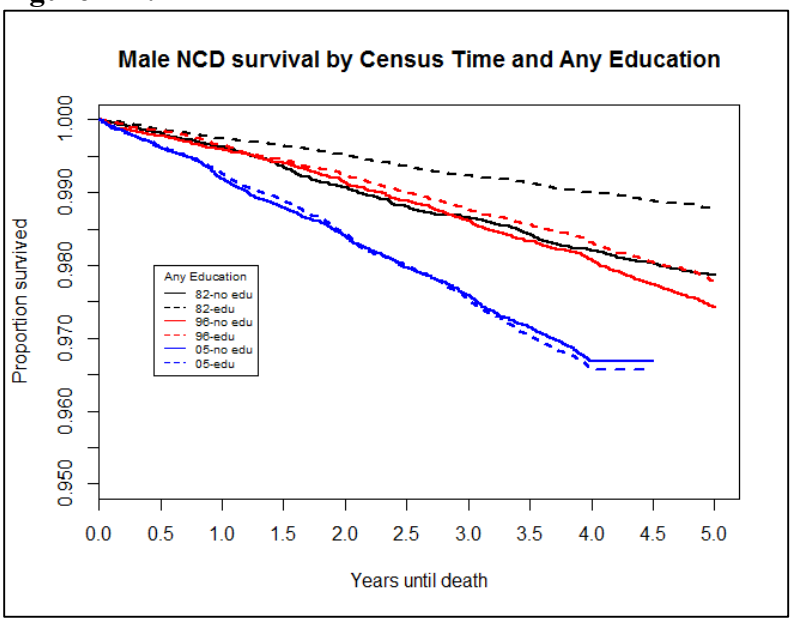
Table B-5 (Corresponds to Table 2-3 and 2-4) Cox Proportional Hazards Model on Female Infectious Mortality.

	Unadjusted	Adjusted	Adjusted + Marital	Adjusted + Occ	Adjusted + Wealth	Adjusted + Marital + Occ + Wealth
Edu Year	-0.212***	-0.128***	-0.108***	-0.129***	-0.114***	-0.094***
	(0.018)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Age	0.076***	0.080***	0.073***	0.076***	0.081***	0.069***
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Muslim	-0.128**	-0.059	-0.054	-0.055	-0.026	-0.024
	(0.062)	(0.062)	(0.062)	(0.063)	(0.062)	(0.063)
Household size	0.039***	0.007	0.015**	0.007	0.022***	0.028***
	(0.008)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)
Cohort ages 40-59		-0.507***	-1.147***	-0.404***	-0.495***	-1.079***
		(0.087)	(0.090)	(0.090)	(0.087)	(0.091)
Cohort ages 60 and above		-0.116	-0.895***	0.019	-0.110	-0.812***
		(0.128)	(0.125)	(0.133)	(0.128)	(0.127)
Census 1996	-1.162***	-0.951***	-1.110***	-1.162***	-0.897***	
	(0.049)	(0.050)	(0.050)	(0.049)	(0.051)	
Census 2005	-2.287***	-1.910***	-2.232***	-2.291***	-1.844***	
	(0.069)	(0.073)	(0.069)	(0.069)	(0.073)	
Married		-5.179***			-5.050***	
		(0.427)			(0.430)	
Widow/Divorced		-0.171			-0.015	
		(0.152)			(0.163)	
Student			0.063		-0.112	

				(0.286)		(0.270)
Housework				-0.618***		-0.623***
				(0.083)		(0.080)
Skilled agriculture				-1.328**		-1.396**
				(0.604)		(0.597)
Elementary Labor				-0.450***		-0.683***
				(0.173)		(0.171)
Manufacture/skilled work/service				-1.018**		-1.185***
				(0.461)		(0.458)
Business				-0.451		-0.512
				(0.527)		(0.528)
Others				0.029		0.028
				(0.300)		(0.281)
Quintile 2					-0.137*	-0.095
					(0.071)	(0.071)
Quintile 3					-0.226***	-0.163**
					(0.071)	(0.071)
Quintile 4					-0.223***	-0.168**
					(0.070)	(0.070)
Quintile 5					-0.364***	-0.306***
					(0.075)	(0.075)
AIC	46774.889	45184.614	44167.070	45125.240	45169.862	44107.065
R^2	0.023	0.030	0.035	0.031	0.030	0.036
Max. R^2	0.224	0.224	0.224	0.224	0.224	0.224
Num. events	2131	2131	2131	2131	2131	2131
Num. obs.	203266	203266	203266	203266	203266	203266
PH test	0.046	0.112	0.174	0.164	0.049	0.137

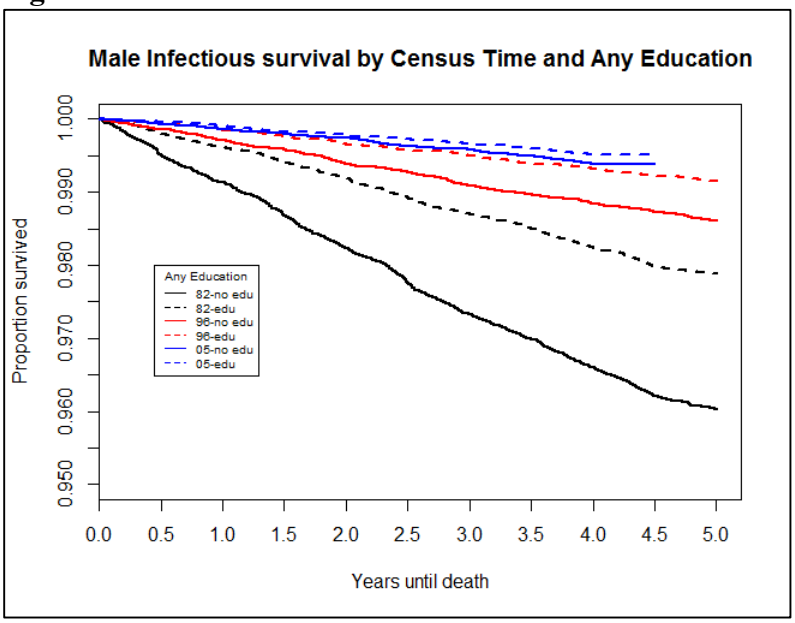
***p < 0.01, **p < 0.05, *p < 0.1

Figure B-1.



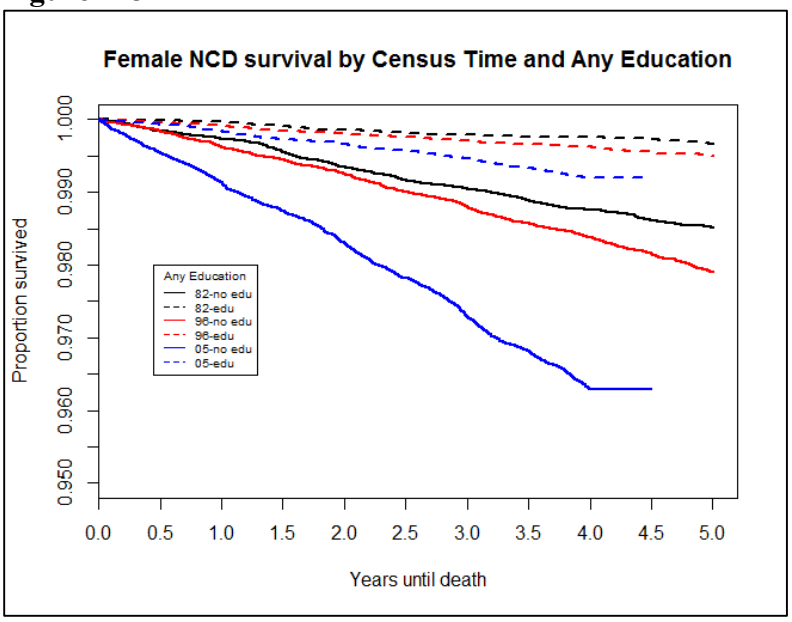
Note: All models use Cox Proportional Hazard regression with censoring from death or outmigration for the Matlab population in 1982, 1996 and 2005 (82-XX, 96-XX, 05-XX). The dependent variable, death, is coded as binary. The independent variable for education is coded as having "no edu" and "edu" by whether an individual had any years of formal education completed. 5 year follow up was used for years 1982 and 1996 and 4.5 years of follow up was used for 2005 due to data limitations.

Figure B-2



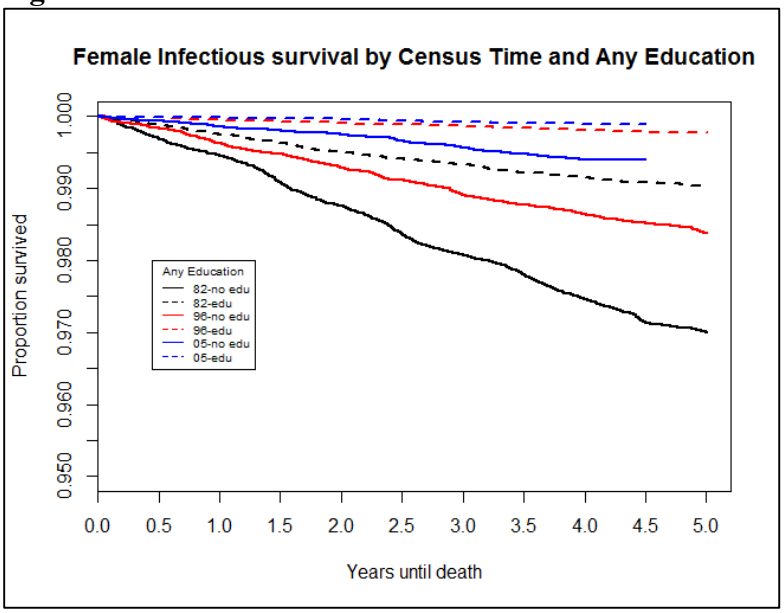
Note: All models use Cox Proportional Hazard regression with censoring from death or outmigration for the Matlab population in 1982, 1996 and 2005 (82-XX, 96-XX, 05-XX). The dependent variable, death, is coded as binary. The independent variable for education is coded as having "no edu" and "edu" by whether an individual had any years of formal education completed. 5 year follow up was used for years 1982 and 1996 and 4.5 years of follow up was used for 2005 due to data limitations.

Figure B-3



Note: All models use Cox Proportional Hazard regression with censoring from death or outmigration for the Matlab population in 1982, 1996 and 2005 (82-XX, 96-XX, 05-XX). The dependent variable, death, is coded as binary. The independent variable for education is coded as having "no edu" and "edu" by whether an individual had any years of formal education completed. 5 year follow up was used for years 1982 and 1996 and 4.5 years of follow up was used for 2005 due to data limitations.

Figure B-4



Note: All models use Cox Proportional Hazard regression with censoring from death or outmigration for the Matlab population in 1982, 1996 and 2005 (82-XX, 96-XX, 05-XX). The dependent variable, death, is coded as binary. The independent variable for education is coded as having "no edu" and "edu" by whether an individual had any years of formal education completed. 5 year follow up was used for years 1982 and 1996 and 4.5 years of follow up was used for 2005 due to data limitations.

Appendix C – Extra Tables for Chapter 4

Table C-1. (Corresponding to Table 4-5) Logistic Regression Model for Coping Strategy for NCD death and Comparison Group

	Basic Exp	Instit. Loan	Ind. Loan	Spend Savings	Sell Assets	Decrease SSN Transfer	Move Out	Move In	Marry Early	Leave Education
(Intercept)	-2.493 (0.357)***	-0.704 (0.422)*	-1.626 (0.776)**	-1.213 (0.307)***	-2.544 (0.439)***	-4.396 (2.086)**	-2.170 (0.454)***	-4.745 (1.003)***	-4.300 (0.915)***	-1.459 (0.503)***
ncd	2.195 (0.115)***	-0.556 (0.164)***	-0.944 (0.369)**	-1.701 (0.136)***	-1.080 (0.187)***	2.162 (0.639)***	-1.335 (0.212)***	0.557 (0.281)**	0.161 (0.339)	-0.269 (0.196)
h_age_09	0.001 (0.004)	-0.027 (0.005)***	-0.032 (0.010)***	0.003 (0.004)	0.006 (0.005)	-0.045 (0.021)**	-0.009 (0.005)*	0.005 (0.010)	-0.015 (0.013)	-0.026 (0.006)***
h_sex_09	-0.015 (0.136)	-0.467 (0.193)**	-0.324 (0.380)	-0.006 (0.123)	-0.216 (0.188)	0.544 (0.520)	0.312 (0.170)*	0.496 (0.327)	-0.900 (0.546)*	-0.340 (0.233)
h_edu_any_09ind	-0.036 (0.118)	-0.511 (0.149)***	-0.550 (0.281)**	0.077 (0.101)	0.064 (0.148)	-1.082 (0.532)**	0.160 (0.154)	0.321 (0.307)	0.434 (0.340)	-0.075 (0.185)
relig	0.141 (0.170)	-0.146 (0.195)	-0.363 (0.367)	0.102 (0.144)	-0.066 (0.199)	0.956 (1.055)	0.279 (0.234)	0.317 (0.477)	0.712 (0.607)	-0.128 (0.244)
hh_size_09	-0.029 (0.021)	0.063 (0.022)***	0.038 (0.062)	0.025 (0.017)	0.032 (0.022)	-0.036 (0.086)	0.012 (0.027)	-0.001 (0.049)	0.050 (0.049)	0.039 (0.029)
pov_sr	0.083 (0.117)	0.527 (0.150)***	0.491 (0.295)*	0.029 (0.100)	-0.008 (0.148)	0.520 (0.527)	0.344 (0.152)**	-0.679 (0.329)**	-0.153 (0.329)	0.414 (0.188)**
AIC	2085.743	1476.795	489.313	2597.793	1505.259	186.964	1394.172	508.592	399.722	1040.886
BIC	2132.367	1523.419	535.937	2644.417	1551.883	233.588	1440.796	555.216	446.346	1087.510
Log Likelihood	-1034.871	-730.397	-236.656	-1290.896	-744.629	-85.482	-689.086	-246.296	-191.861	-512.443
Deviance	2069.743	1460.795	473.313	2581.793	1489.259	170.964	1378.172	492.592	383.722	1024.886
Num. obs.	2510	2510	2510	2510	2510	2510	2510	2510	2510	2510

***p < 0.01, **p < 0.05, *p < 0.1

Table C-2. (Corresponding to Table 4-5) Logistic Regression Model for Coping Strategy for Prime Age NCD death and Comparison Group

	Basic Exp	Instit. Loan	Ind. Loan	Spend Savings	Sell Assets	Decrease SSN Transfer	Move Out	Move In	Marry Early	Leave Education
(Intercept)	-2.568 (0.364)***	-0.614 (0.419)	-1.763 (0.776)**	-1.212 (0.307)***	-2.658 (0.450)***	-3.777 (2.123)*	-2.254 (0.455)***	-4.927 (1.023)***	-4.525 (0.905)***	-1.612 (0.505)***
Prime Age	2.345 (0.179)***	-1.123 (0.363)***	-0.212 (0.479)	-1.716 (0.286)***	-0.428 (0.307)	0.523 (1.286)	-0.735 (0.330)**	1.034 (0.440)**	0.827 (0.489)*	0.315 (0.283)
Not Prime Age	2.155 (0.122)***	-0.407 (0.174)**	-1.435 (0.527)***	-1.697 (0.151)***	-1.319 (0.227)***	2.520 (0.633)***	-1.601 (0.266)***	0.415 (0.312)	-0.145 (0.415)	-0.555 (0.242)**
h_age_09	0.002 (0.004)	-0.029 (0.005)***	-0.030 (0.010)***	0.003 (0.004)	0.008 (0.006)	-0.055 (0.022)**	-0.008 (0.005)	0.008 (0.011)	-0.012 (0.013)	-0.024 (0.006)***
h_sex_09	-0.004 (0.137)	-0.484 (0.193)**	-0.296 (0.378)	-0.006 (0.123)	-0.202 (0.188)	0.421 (0.529)	0.326 (0.170)*	0.525 (0.329)	-0.853 (0.545)	-0.310 (0.234)
h_edu_any_09ind	-0.031 (0.118)	-0.523 (0.149)***	-0.530 (0.279)*	0.077 (0.101)	0.071 (0.147)	-1.196 (0.564)**	0.168 (0.154)	0.331 (0.307)	0.456 (0.341)	-0.056 (0.184)
relig	0.134 (0.170)	-0.135 (0.195)	-0.382 (0.365)	0.102 (0.145)	-0.079 (0.200)	1.070 (1.059)	0.272 (0.234)	0.293 (0.479)	0.671 (0.616)	-0.150 (0.244)
hh_size_09	-0.028 (0.021)	0.061 (0.022)***	0.042 (0.061)	0.025 (0.017)	0.033 (0.022)	-0.068 (0.094)	0.014 (0.027)	0.001 (0.049)	0.054 (0.048)	0.044 (0.029)
pov_sr	0.076 (0.117)	0.538 (0.151)***	0.473 (0.296)	0.029 (0.100)	-0.019 (0.149)	0.619 (0.540)	0.335 (0.153)**	-0.701 (0.332)**	-0.173 (0.334)	0.396 (0.190)**
AIC	2086.572	1474.803	488.175	2599.789	1501.764	183.277	1391.913	509.011	398.931	1036.740
BIC	2139.024	1527.255	540.627	2652.241	1554.216	235.729	1444.365	561.464	451.383	1089.192
Log Likelihood	-1034.286	-728.401	-235.087	-1290.895	-741.882	-82.638	-686.956	-245.506	-190.465	-509.370
Deviance	2068.572	1456.803	470.175	2581.789	1483.764	165.277	1373.913	491.011	380.931	1018.740
Num. obs.	2510	2510	2510	2510	2510	2510	2510	2510	2510	2510

*** p < 0.01, ** p < 0.05, * p < 0.1

Table C-3. (Corresponding to Table 4-5) Logistic Regression Model for Coping Strategy for Head of Household NCD death and Comparison Group

	Basic Exp	Instit. Loan	Ind. Loan	Spend Savings	Sell Assets	Decrease SSN Transfer	Move Out	Move In	Marry Early	Leave Education
(Intercept)	-2.619 (0.378)***	-0.702 (0.424)*	-1.548 (0.771)**	-1.219 (0.310)***	-2.681 (0.457)***	-4.914 (2.111)**	-2.061 (0.459)***	-4.706 (1.045)***	-4.273 (1.026)***	-1.297 (0.522)**
Head	2.136 (0.129)***	-0.552 (0.198)***	-0.754 (0.449)*	-1.713 (0.164)***	-1.324 (0.245)***	1.740 (0.730)**	-1.067 (0.240)***	0.585 (0.330)*	0.185 (0.400)	-0.052 (0.232)
Not Head	2.321 (0.162)***	-0.562 (0.243)**	-1.246 (0.601)**	-1.675 (0.227)***	-0.654 (0.280)**	2.524 (0.743)***	-1.947 (0.433)***	0.503 (0.405)	0.118 (0.564)	-0.648 (0.331)*
h_age_09	0.004 (0.005)	-0.027 (0.005)***	-0.033 (0.010)***	0.003 (0.004)	0.009 (0.006)	-0.033 (0.023)	-0.011 (0.005)**	0.004 (0.011)	-0.016 (0.014)	-0.029 (0.007)***
h_sex_09	-0.039 (0.139)	-0.466 (0.194)**	-0.307 (0.380)	-0.007 (0.123)	-0.241 (0.189)	0.395 (0.591)	0.336 (0.171)**	0.504 (0.321)	-0.895 (0.550)	-0.306 (0.233)
h_edu_any_09ind	-0.041 (0.119)	-0.511 (0.148)***	-0.546 (0.279)*	0.077 (0.101)	0.060 (0.148)	-1.104 (0.535)**	0.166 (0.154)	0.322 (0.307)	0.435 (0.341)	-0.067 (0.185)
relig	0.140 (0.170)	-0.146 (0.195)	-0.363 (0.367)	0.102 (0.144)	-0.070 (0.200)	0.961 (1.051)	0.282 (0.234)	0.318 (0.476)	0.712 (0.608)	-0.128 (0.243)
hh_size_09	-0.032 (0.021)	0.063 (0.022)***	0.040 (0.062)	0.025 (0.017)	0.030 (0.022)	-0.057 (0.097)	0.015 (0.027)	0.000 (0.050)	0.051 (0.048)	0.044 (0.029)
pov_sr	0.084 (0.117)	0.527 (0.150)***	0.491 (0.295)*	0.029 (0.100)	-0.007 (0.148)	0.536 (0.528)	0.343 (0.152)**	-0.679 (0.330)**	-0.153 (0.329)	0.413 (0.188)**
AIC	2086.566	1478.794	490.846	2599.774	1503.858	187.563	1392.374	510.564	401.710	1040.253
BIC	2139.018	1531.246	543.298	2652.226	1556.310	240.016	1444.826	563.017	454.162	1092.705
Log Likelihood	-1034.283	-730.397	-236.423	-1290.887	-742.929	-84.782	-687.187	-246.282	-191.855	-511.126
Deviance	2068.566	1460.794	472.846	2581.774	1485.858	169.563	1374.374	492.564	383.710	1022.253
Num. obs.	2510	2510	2510	2510	2510	2510	2510	2510	2510	2510

*** p < 0.01, ** p < 0.05, * p < 0.1

Table C-4. (Corresponding to Table 4-5) Logistic Regression Model for Coping Strategy for Male or Female Household NCD death and Comparison Group

	Basic Exp	Instit. Loan	Ind. Loan	Spend Savings	Sell Assets	Decrease SSN Transfer	Move Out	Move In	Marry Early	Leave Education
(Intercept)	-2.460 (0.358)***	-0.727 (0.420)*	-1.581 (0.780)**	-1.212 (0.307)***	-2.556 (0.441)***	-4.620 (2.053)**	-2.144 (0.454)***	-4.679 (1.011)***	-4.500 (0.925)***	-1.394 (0.501)***
fem_death	2.103 (0.140)***	-0.443 (0.216)**	-1.334 (0.603)**	-1.721 (0.199)***	-0.971 (0.262)***	2.704 (0.650)***	-1.840 (0.371)***	0.187 (0.396)	0.589 (0.431)	-0.579 (0.294)**
male_death	2.267 (0.133)***	-0.663 (0.216)***	-0.674 (0.440)	-1.685 (0.176)***	-1.168 (0.251)***	0.907 (0.915)	-1.016 (0.248)***	0.805 (0.330)**	-0.318 (0.493)	-0.047 (0.232)
h_age_09	0.000 (0.004)	-0.027 (0.005)***	-0.033 (0.010)***	0.003 (0.004)	0.006 (0.005)	-0.040 (0.020)**	-0.010 (0.005)*	0.004 (0.010)	-0.011 (0.013)	-0.027 (0.006)***
h_sex_09	0.021 (0.139)	-0.482 (0.192)**	-0.296 (0.382)	-0.004 (0.124)	-0.228 (0.190)	0.250 (0.547)	0.347 (0.173)**	0.591 (0.334)*	-0.987 (0.557)*	-0.302 (0.238)
h_edu_any_09ind	-0.037 (0.118)	-0.513 (0.149)***	-0.546 (0.279)*	0.077 (0.101)	0.064 (0.148)	-1.085 (0.538)**	0.160 (0.154)	0.310 (0.307)	0.430 (0.340)	-0.071 (0.185)
relig	0.135 (0.170)	-0.143 (0.194)	-0.370 (0.367)	0.102 (0.144)	-0.066 (0.200)	1.086 (1.062)	0.275 (0.234)	0.303 (0.479)	0.733 (0.608)	-0.137 (0.244)
hh_size_09	-0.028 (0.021)	0.062 (0.022)***	0.039 (0.062)	0.025 (0.017)	0.031 (0.022)	-0.055 (0.088)	0.014 (0.027)	0.002 (0.049)	0.043 (0.050)	0.042 (0.029)
pov_sr	0.083 (0.117)	0.528 (0.150)***	0.490 (0.295)*	0.029 (0.100)	-0.008 (0.148)	0.577 (0.524)	0.345 (0.152)**	-0.678 (0.330)**	-0.151 (0.329)	0.413 (0.189)**
AIC	2086.487	1478.199	490.421	2599.774	1506.933	181.666	1392.208	508.647	399.138	1040.474
BIC	2138.939	1530.651	542.874	2652.226	1559.386	234.118	1444.660	561.099	451.591	1092.926
Log Likelihood	-1034.243	-730.099	-236.211	-1290.887	-744.467	-81.833	-687.104	-245.324	-190.569	-511.237
Deviance	2068.487	1460.199	472.421	2581.774	1488.933	163.666	1374.208	490.647	381.138	1022.474
Num. obs.	2510	2510	2510	2510	2510	2510	2510	2510	2510	2510

*** p < 0.01, ** p < 0.05, * p < 0.1

Table C-5. (Corresponding to Table 4-5) Logistic Regression Model for Coping Strategy for Long or Short Severe Morbidity NCD death and Comparison Group

	Basic Exp	Instit. Loan	Ind. Loan	Spend Savings	Sell Assets	Decrease SSN Transfer	Move Out	Move In	Marry Early	Leave Education
(Intercept)	-2.485 (0.357)***	-0.697 (0.422)*	-1.598 (0.783)**	-1.212 (0.307)***	-2.540 (0.439)***	-4.416 (2.074)**	-2.169 (0.455)***	-4.751 (0.999)***	-4.301 (0.916)***	-1.451 (0.504)***
severe.long	2.373 (0.135)***	-0.384 (0.207)*	-0.435 (0.412)	-1.614 (0.183)***	-0.827 (0.233)***	2.033 (0.701)***	-1.265 (0.286)***	0.820 (0.325)**	0.208 (0.440)	-0.044 (0.241)
severe.short	2.027 (0.134)***	-0.737 (0.225)***	-1.821 (0.727)**	-1.788 (0.189)***	-1.381 (0.283)***	2.272 (0.688)***	-1.404 (0.293)***	0.233 (0.388)	0.116 (0.430)	-0.525 (0.277)*
h_age_09	0.001 (0.004)	-0.027 (0.005)***	-0.032 (0.010)***	0.003 (0.004)	0.006 (0.005)	-0.045 (0.021)**	-0.009 (0.005)*	0.005 (0.010)	-0.015 (0.013)	-0.026 (0.006)***
h_sex_09	-0.028 (0.137)	-0.475 (0.193)**	-0.347 (0.380)	-0.007 (0.123)	-0.221 (0.189)	0.566 (0.510)	0.310 (0.170)*	0.487 (0.328)	-0.902 (0.546)*	-0.352 (0.235)
h_edu_any_09ind	-0.038 (0.119)	-0.514 (0.149)***	-0.561 (0.282)**	0.077 (0.101)	0.063 (0.148)	-1.077 (0.535)**	0.160 (0.154)	0.320 (0.308)	0.433 (0.341)	-0.080 (0.186)
relig	0.142 (0.171)	-0.145 (0.195)	-0.363 (0.367)	0.102 (0.144)	-0.066 (0.200)	0.956 (1.055)	0.279 (0.234)	0.318 (0.476)	0.713 (0.607)	-0.127 (0.245)
hh_size_09	-0.030 (0.021)	0.063 (0.022)***	0.037 (0.063)	0.025 (0.017)	0.032 (0.022)	-0.035 (0.085)	0.012 (0.027)	-0.001 (0.050)	0.050 (0.049)	0.039 (0.029)
pov_sr	0.084 (0.117)	0.529 (0.150)***	0.496 (0.292)*	0.029 (0.100)	-0.008 (0.148)	0.518 (0.530)	0.345 (0.152)**	-0.680 (0.329)**	-0.152 (0.330)	0.417 (0.188)**
AIC	2081.579	1477.206	487.723	2599.312	1504.672	188.775	1396.045	508.652	401.693	1040.785
BIC	2134.032	1529.658	540.176	2651.765	1557.124	241.227	1448.497	561.105	454.145	1093.237
Log Likelihood	-1031.790	-729.603	-234.862	-1290.656	-743.336	-85.388	-689.023	-245.326	-191.846	-511.392
Deviance	2063.579	1459.206	469.723	2581.312	1486.672	170.775	1378.045	490.652	383.693	1022.785
Num. obs.	2510	2510	2510	2510	2510	2510	2510	2510	2510	2510

*** p < 0.01, ** p < 0.05, * p < 0.1

Table C-6. (Corresponding to Table 4-5) Logistic Regression Model for Coping Strategy with Poor Interaction with NCD death and Comparison Group

	Basic Exp	Instit. Loan	Ind. Loan	Spend Savings	Sell Assets	Decrease SSN Transfer	Move Out	Move In	Marry Early	Leave Education
(Intercept)	-2.406 (0.359)***	-0.680 (0.422)	-1.611 (0.762)**	-1.240 (0.309)***	-2.572 (0.440)***	-4.521 (2.059)**	-2.161 (0.453)***	-4.730 (1.010)***	-4.261 (0.898)***	-1.456 (0.501)***
ncd	2.030 (0.151)***	-0.704 (0.260)***	-1.102 (0.625)*	-1.472 (0.170)***	-0.881 (0.234)***	2.326 (1.107)**	-1.425 (0.313)***	0.515 (0.332)	0.020 (0.439)	-0.287 (0.291)
pov_sr	-0.157 (0.190)	0.467 (0.169)***	0.449 (0.318)	0.110 (0.109)	0.074 (0.159)	0.728 (1.262)	0.321 (0.162)**	-0.751 (0.443)*	-0.291 (0.407)	0.405 (0.218)*
h_age_09	0.001 (0.004)	-0.027 (0.005)***	-0.032 (0.010)***	0.003 (0.004)	0.006 (0.005)	-0.045 (0.021)**	-0.009 (0.005)*	0.005 (0.010)	-0.015 (0.013)	-0.026 (0.006)***
h_sex_09	-0.014 (0.137)	-0.466 (0.193)**	-0.323 (0.380)	-0.007 (0.123)	-0.218 (0.188)	0.545 (0.520)	0.312 (0.170)*	0.497 (0.327)	-0.898 (0.546)	-0.340 (0.233)
h_edu_any_09ind	-0.029 (0.118)	-0.507 (0.149)***	-0.547 (0.281)*	0.072 (0.101)	0.059 (0.148)	-1.085 (0.524)**	0.162 (0.154)	0.323 (0.310)	0.441 (0.348)	-0.074 (0.186)
relig	0.142 (0.171)	-0.145 (0.194)	-0.362 (0.367)	0.103 (0.145)	-0.065 (0.200)	0.951 (1.061)	0.279 (0.234)	0.317 (0.477)	0.714 (0.607)	-0.128 (0.244)
hh_size_09	-0.029 (0.021)	0.063 (0.022)***	0.038 (0.062)	0.025 (0.017)	0.032 (0.022)	-0.036 (0.086)	0.012 (0.027)	-0.001 (0.049)	0.050 (0.048)	0.039 (0.029)
ncd:pov_sr	0.380 (0.233)	0.251 (0.334)	0.252 (0.786)	-0.576 (0.286)**	-0.510 (0.395)	-0.255 (1.356)	0.172 (0.426)	0.153 (0.639)	0.369 (0.713)	0.032 (0.395)
AIC	2085.055	1478.222	491.206	2595.588	1505.516	188.928	1396.007	510.533	401.445	1042.879
BIC	2137.507	1530.675	543.658	2648.041	1557.968	241.380	1448.459	562.986	453.897	1095.331
Log Likelihood	-1033.527	-730.111	-236.603	-1288.794	-743.758	-85.464	-689.003	-246.267	-191.722	-512.439
Deviance	2067.055	1460.222	473.206	2577.588	1487.516	170.928	1378.007	492.533	383.445	1024.879
Num. obs.	2510	2510	2510	2510	2510	2510	2510	2510	2510	2510

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Appendix D - Curriculum Vitae

EDUCATION AND TRAINING

1. UNIVERSITY OF VIRGINIA
   Degree: Bachelor of Science in Biomedical Engineering, Minor in Spanish Literature
   Year: 2006
2. JOHNS HOPKINS BLOOMBERG SCHOOL OF PUBLIC HEALTH
   Degree: Master of Public Health, Concentration in Comparative Health Systems, Certificate in Health Economics
   Year: 2009
   Capstone title: Evaluation of the decision-making process for vaccine introduction in Peru
3. JOHNS HOPKINS BLOOMBERG SCHOOL OF PUBLIC HEALTH
   Department: International Health, Health Systems Program
   Degree: PhD, Certificate in Demographic Methods
   Year: 2014 (expected summer graduation)
   Dissertation title: The economic impacts of adult non-communicable disease mortality for households in rural Bangladesh
   Advisor: Antonio J. Trujillo

PROFESSIONAL EXPERIENCE

2014 – Present Harvard Medical School, Cambridge, MA
- Collaborate with a professor of Biostatistics in the Health Care Policy Department to develop analytical methods for matched cohort studies.

2009 – 2010 Research Associate, University of East Anglia, Norwich, UK
- Developed probabilistic life table model to estimate chronic disease and risk factor burden and prevention cost-effectiveness in China
- Major contributions to the analysis and writing of the final report: "Toward a Healthy and Harmonious Life in China: Stemming the Rising Tide of Non-Communicable Diseases." World Bank Press, July 2011.

Summer 2009 Intern, The Stimson Center, Washington, DC
- Work on *Global Trends 2030* report commissioned by the NSA.
- Conducted expert interviews and contributed to chapters on the topics of biotechnology and climate change.

2006 – 2008 Project Manager, Washington Occupational Health Associates, Washington, DC
- Management of cancer screening program large US chemical company.
- Review of client policy for pandemic flu preparedness.

PROFESSIONAL ACTIVITIES

Society Membership
- International Health Economics Association (iHEA)

Consultations
- The World Bank

- Providing regression modeling support in STATA.
- Westat/National Heart Lung Blood Institute (NHLBI)
  - Developed online training module for NHLBI fellows titled: "Introduction to Health Economics for Health Researchers."
- Save the Children USA (SC USA)
  - Developed a manual, "Introduction to Cost-Effective Analysis" for SC USA employees and worked updated cost estimates used for SC USA advocacy.
- Center for Public Program Evaluation
  - Qualitative logic model evaluation of project for USA national public health organization.

EDITORIAL ACTIVITIES

Peer Review Activities

- Health Policy
- PloS Medicine
- PloS ONE
- Journal of Health Population and Nutrition
- Health Policy and Planning

PUBLICATIONS

Journal Articles – Published peer reviewed

1. Ozawa, Sachiko; **Mirelman, Andrew**; Stack, Meghan L; Walker, Damian G; Levine, Orin S. Cost-effectiveness and Economic Benefits of Vaccines in Low- and Middle- Income Countries: A Systematic Review. *Vaccine* Dec 2012; 31(1): 96-108.
2. **Mirelman, Andrew**; Mentzakis, Emmanouil; Kinter, Elizabeth; Paolucci, Francesco; Fordham, Richard; Ozawa, Sachiko; Ferraz, Marcos; Baltussen, Rob; Niessen, Louis W. Decision Making Criteria among National Policymakers in Five Countries: A Discrete Choice Experiment Eliciting Relative Preferences for Equity and Efficiency. *Value in Health* May 2012; 15(3): 534-539.
3. Defechereux, Thierry; Paolucci, Francesco; **Mirelman, Andrew**; Youngkong, Sitaporn; Botten, Grete; Hagen, Terje P; Niessen, Louis W. Health care priority setting in Norway a multicriteria decision analysis. *BMC Health Services Research* 2012. 12(39).
4. Curran, Kelly; Njeuhmeli, Emmanuel; **Mirelman, Andrew**; Dickson, Kim; Adamu, Tigistu; Cherutich, Peter; Mahler, Hally; Fimbo, Bennett; Mavuso, Thembisile Khumalo; Albertini, Jennifer. Voluntary Medical Male Circumcision: Strategies for Meeting the Human Resources Needs of Scale-Up in Southern and Eastern Africa. *PLoS Medicine* Nov 2011; 8(11): e1001129.
5. Stack, Meghan L; Ozawa, Sachiko; Bishai, David M; **Mirelman, Andrew**; Tam, Yvonne; Niessen, Louis; Walker, Damian G; Levine, Orin S. Estimated Economic Benefits During The 'Decade Of Vaccines' Include Treatment Savings, Gains In Labor Productivity. *Health Affairs* 2011; 30(6): 1021-1028.
6. Ozawa, Sachiko; Stack, Meghan L; Bishai, David M; **Mirelman, Andrew**; Friberg, Ingrid K; Niessen, Louis; Walker, Damian G; Levine, Orin S. During The 'Decade Of Vaccines', The Lives Of 6.4 Million Children Valued At $231 Billion Could Be Saved. *Health Affairs* 2011; 30(6): 1010-1020.
7. Boyette, Lisa B; Reardon, Michael A; **Mirelman, Andrew J**; Kirkley, Terry D; Lysiak, Jeffrey J; Tuttle, Jeremy B; Steers, William D. Fiber Optic Imaging of Cavernous Nerve In Vitro. *The Journal of Urology* 2007; 178(6): 2694-2700.

Journal Articles – In Press, Accepted for publication, Submitted for publication

1. **Mirelman, Andrew**; Grewal, Simrun; Ozawa Sachiko. The benefits and challenges for new childhood vaccines in BRICS countries. Accepted for publication. Bulletin WHO.
2. Liang, Lilin; **Mirelman, Andrew;** The Impacts of Government Size, Indebtedness and Polity on Government Health Expenditure: A Cross-Country Analyses over 1995-2010. Accepted for publication. Social Science and Medicine.
3. Khan, Jahangir AM; Trujillo, Antonio J; Ahmed, Sayem; Siddiquee, Ali T; Alam, N; **Mirelman, Andrew;** Koehlmoos, Tracey P; Niessen, Louis W; Peters, David H. Distribution of Non-Communicable Disease Mortality and Deterioration in Socioeconomic Status in Rural Bangladesh. Working Paper.
4. Cárdenas, María K; Galvin, Cooper; **Mirelman, Andrew**; Lazo, María; Pinto, Miguel; Miranda, J. Jaime; Gilman, Robert H. The cost of illness attributable to diabetic foot and cost-effectiveness of secondary prevention in Peru. Working Paper.

Journal Articles and Editorials – Not peer reviewed

1. Hospedales, James; Malekzadeh, Reza; Godoy, Daniela; **Mirelman, Andrew**; Boffetta, Paolo. Improving National and Subnational Surveillance Data: The Models of Bangladesh, Iran and Chile, and the Role of PAHO. In Press. Scientific American.
2. **Mirelman, Andrew**; Koehlmoos, Tracey P; Niessen, Louis W. Risk-Attributable Burden of Chronic Diseases and Cost of Prevention in Bangladesh. *Global Heart* March 2012; 7(1): 61-66.

Reports, Manuals and Technical Guidelines

1. Institute of Medicine. Country-Level Decision Making for Control of Chronic Diseases: Workshop Summary. 2012. Washington, DC; The National Academies Press.
2. Constenla, Dagna; **Mirelman, Andrew**; Alvaro, Arielle; Chen, A; Socal, M. The Economic Value of Vaccines and Immunization Programs in Low- and Middle-Income Countries: An Annotated Bibliography. International Vaccine Access Center (IVAC), August 2012.

TEACHING

Classroom Instruction

2013 – 2014: Johns Hopkins School of Public Health

1. Applications in Managing Health Organizations in Low and Middle Income Countries. Lecture – *Developing a Health System Budget.* Faculty: David Peters
2. Pharmaceutical Management in Low and Middle Income Countries. Lecture – *The Cost-Effectiveness of Multi-dose combination therapy.* Faculty: Maria Eng, Alan Lyles, David Peters.

2012 – 2013: Johns Hopkins School of Public Health

1. Summary Measures in Population Health. Lecture – *Disease Modeling for National Burden of Disease Estimates.* Faculty: Adnan Hyder, Richard Morrow
2. Economic Evaluation II. Lecture – *Incorporating Equity into Cost-Effectiveness Analysis.* Faculty: Dagna Constenla
3. Comparative Evaluation of Public Health Policies. Lecture – *Equity and Efficiency tradeoffs when measuring preferences for health policy.* Faculty: Louis Niessen.

Teaching Assistantships

2013-2014: Johns Hopkins School of Public Health

1. Applications in Managing Health Organizations in Low and Middle Income Countries. Faculty: David Peters.

2012-2013: Johns Hopkins School of Public Health

1. Applications in Managing Health Organizations in Low and Middle Income Countries. Faculty: David Peters.
2. Economic Evaluation III. Faculty: Louis Niessen, John Bridges.
3. Pharmaceutical Management in Low and Middle Income Countries. Faculty: Maria Eng, Alan Lyles, David Peters

2011-2012: Johns Hopkins School of Public Health

1. Applications in Managing Health Organizations in Low and Middle Income Countries. Faculty: David Peters.
2. Economic Evaluation III. Faculty: Louis Niessen, John Bridges.
3. Comparative Evaluation of Public Health Interventions in Low and Middle Income Countries. Faculty: Louis Niessen.
4. Health Economics I. Faculty: Kevin Frick.

2010-2011: Johns Hopkins School of Public Health

1. Applications in Managing Health Organizations in Low and Middle Income Countries. Faculty: David Peters.
2. Understanding Cost-Effectiveness Analysis (online). Faculty: Kevin Frick.
3. Economic Evaluation II. Faculty: Amnesty LeFevre, Krishna Rao.

2009-2010: Johns Hopkins School of Public Health

1. Concepts and Application in Economic Evaluation I and II. Faculty: Damian Walker
2. Introduction to Health Systems in Low and Middle Income Countries. Faculty: Hafizur Rahman.
3. Understanding Cost-Effectiveness Analysis (online). Faculty: Kevin Frick.
4. Statistical Reasoning in Public Health. Faculty: John McGready.

Other Significant Teaching

1. March 2011: Instructor, International Center for Diarrhoeal Disease Research (icddr,b), Introduction to Modeling Concepts for Cost-Effectiveness Analysis

RESEARCH GRANT PARTICIPATION

Title: Collaborating Centers of Excellence for Chronic Disease
PI: David Peters. **Year:** 2011-2014
Source: United Health and the National Heart Lung Blood Institute
Role: Research Assistant

Title: Decade of Vaccines Economics Research
PI: Sachiko Ozawa. **Year:** 2010-2014
Source: The Bill and Melinda Gates Foundation
Role: Research Assistant

PRESENTATIONS

Scientific Meetings

- A cost-effectiveness analysis of human and pig vaccination strategies to reduce the burden of Japanese encephalitis in Bangladesh. American Society of Tropical Medicine and Hygiene (ASTMH). Poster Presentation. Washington DC. Nov. 13-17, 2013.
- The impacts of non-communicable disease deaths on household wealth in rural Bangladesh. International Health Economics Association (iHEA). Biennial Conference. Sydney Conference Center; Sydney, Australia. June 20, 2013.
- Developing a Price Tag for NCD Prevention: Example Country Case Studies from NHLBI Centers of Excellence. Workshop on Country-Level Decision Making for Control of Chronic Diseases. IOM House of Sweden; Washington, DC. July 19-21, 2011.

Invited Seminars

- "The impacts of non-communicable disease deaths on household wealth in rural Bangladesh." University of Washington Department of Global Health, June 20, 2013.
- "A cost-effectiveness analysis of vaccination strategies to reduce the burden of Japanese encephalitis in Bangladesh". JHSPH Health Economics Seminar, April 2013.