The poverty-vulnerability-resilience nexus: Evidence from Bangladesh

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Highlights:

- We present the first empirical study that tests the nexus among poverty, vulnerability and resilience.
- Our results suggest that high vulnerability does not necessarily imply low resilience.
- We also develop a state-and-transition model for assessing socio-economic resilience to natural disasters.
- The model provides the opportunity to incorporate a broad spectrum of resilience dynamics.

Abstract

Vulnerability and resilience lie at the core of the new paradigm governing natural disaster risk management frameworks. However, empirical understandings of socio-economic resilience and its links with poverty and vulnerability are limited. This paper presents an empirical investigation of socio-economic resilience to natural disasters in a tropical cyclone-prone coastal community in Bangladesh. The results indicate that the cyclone in question had negative impacts on the community, particularly in terms of income, employment and access to clean water and sanitation. Consistent with the findings of the social vulnerability literature, our results also suggest that the poor were more vulnerable and suffered significantly higher economic, physical and structural damage. However, this high vulnerability did not necessarily lead to low resilience, as these individuals exhibited a greater ability to withstand the shock compared to their non-poor neighbors. This refutes the flip-side hypothesis of the link between vulnerability and resilience (i.e. vulnerability is the flip side of resilience). The findings imply that the increased risk of tropical cyclones is likely to reduce incomes and standards of living among the tropical coastal communities. However, the burden of these adverse impacts is unlikely to be disproportionally borne by the poorer segment of the society.

Key words

State-and-transition model, poverty, socio-economic vulnerability, socio-economic resilience, natural disasters, tropical cyclone, Bangladesh

1. Introduction

Natural disaster risk management frameworks have witnessed a paradigm shift in recent years, evolving from a process of providing a one-off emergency response towards a proactive and holistic disaster risk management system (UN/ISDR, 2005). One of the defining characteristics of this new paradigm is its emphasis on building climate-resilient societies by enhancing the capacity of vulnerable people to cope with environmental hazards.

Definitions of vulnerability and resilience vary within and across research traditions (Gallopi´n, 2006). The disaster risk literature defines vulnerability in terms of susceptibility to harm (IPCC, 2012). More specifically, vulnerability is the propensity of exposed elements to suffer adverse effects when impacted by a hazard (Cannon, 1994, 2006; Janssen et al., 2006; IPCC, 2012). The development research community uses a broader definition of vulnerability, referring to it as a combination of sensitivity, exposure and response capacity (Adger, 2006; Gallopi´n, 2006). The concept of sensitivity corresponds closely to the susceptibility-centered definition of vulnerability common in the disaster risk literature. Sensitivity is an internal (inherent) property of the system and refers to the degree to which a system is likely to be affected by an internal or external disturbance (Gallopi´n, 2006). Exposure refers to the degree, duration and/or extent to which the system is in contact with or subject to a disturbance (Gallopi´n, 2006). Capacity of response is the system's ability to respond to or cope with the disturbance.

The term 'resilience' originated in the discipline of ecology and refers to an ecosystem's ability to absorb and recover from the occurrence of a hazardous event. There are two approaches that are commonly applied to explain disaster resilience in human communities: (1) outcome and (2) process. The outcome-based approach defines resilience as the ability of human communities to anticipate, absorb, accommodate, or recover from the effects of a disturbance (IPCC, 2012). It assesses resilience in terms of the success or failure of a system to return to a state as good as, or better than, the pre-disaster status quo in the shortest feasible time (Gilbert, 2010; DFID, 2011). The process-based approach describes resilience as a mechanism of self-organization, the capacity to learn from experience, to process information and adapt accordingly (Resilience Alliance, 2005). This approach views resilience as a concept which is broader than just recovery and encompasses a system's ability to cope with the current hazard as well as its capacity to reduce exposure to hazards in general (Cutter et al., 2008a).

The cross-disciplinary conceptual divide that exists with regard to vulnerability and resilience manifests in an academic debate over the nature of their mutual links. The scholars supporting the narrowly defined paradigm suggest that vulnerability is the flip side of resilience (Galderisi et al., 2010; Cannon, 2008), i.e. 'high levels of vulnerability imply low resilience and vice versa' (Cannon, 2008; p. 10). The advocates of the broadly defined vulnerability paradigm dismiss the flip-side hypothesis, arguing that although a resilient system is less vulnerable than a non-resilient one, the relation is not necessarily symmetrical (Gallopi´n, 2006). They offer two alternative hypotheses: either (1) resilience is a subset of vulnerability or (2) resilience and vulnerability are fundamentally different concepts which nonetheless have some components in common (Gallopi´n, 2006; Cutter et al., 2008a; Sapountzaki, 2012).

Gallopı´n (2006) points out two fundamental conceptual differences between vulnerability and resilience. First, resilience relates to shifts in state (conditions) between domains of attraction, while vulnerability relates to structural changes within a system. Second, unlike vulnerability, resilience is an internal property of a system that does not include exposure to a disturbance. Vulnerability and resilience are considered to be linked to one another via response capacity, which is an integral part of vulnerability (Gallopı´n, 2006; Nelson et al., 2007). Whether that makes resilience a subset of vulnerability or a different yet overlapping concept depends on how response and adaptive capacity are defined, since resilience is determined by a system's adaptive and response capacity. Some scholars use these two terms synonymously (Adger, 2006; Smit and Wandel, 2006). This would imply that resilience is a subset of vulnerability. Turner et al. (2003) separated adaptive capacity from response capacity and defined them as relatively longer- and shorter-term strategies respectively. Adaptive capacity is considered a broader concept than the capacity of response, which refers mainly to the ability to just survive. Adaptive capacity refers to relatively longer-term or more sustainable adjustments that can modify a system's sensitivity and exposure to a disturbance (Turner et al., 2003; Gallopı´n, 2006). This latter view renders resilience and vulnerability two distinct concepts, with response capacity as a common component.

The debate surrounding the nexus between vulnerability and resilience clouds our understanding of the distributional consequences of natural disasters across different groups living within a community. The social vulnerability literature suggests that a household's socio-economic status lies at the heart of its vulnerability (see for example Adger, 1999; Adger, 2006; Brouwer et al., 2007). The poor and marginalized are more likely to live in poorly built settlements located in hazard-prone areas. As a result, they are more exposed and more sensitive to natural hazards. Further, they often possess inadequate capacity to reduce their exposure and sensitivity by moving to a safer location or to a strongly built settlement (i.e. lack of adaptive capacity) and to cope with the shock (i.e. lack of response capacity). Thus, socio-economic resilience is likely to correspond closely with the poverty dynamics of a community. The nexus between vulnerability and resilience plays an important role in determining the nature of that correspondence. For example, the 'flip-side' doctrine that suggests highly vulnerable communities (i.e. the poor and marginalized) are also less resilient would imply that the immediate impacts (physical, economic and structural damage) as well as the longer-term impacts (e.g. lower income, unemployment and lower standard of living) of hazards will be born disproportionately by the poorer segment of a society. If the opposite is true, i.e. high vulnerability does not necessarily lead to low resilience, then this would imply that the poor and marginalized may bear the larger share of the immediate impacts of a natural disaster but may equally be able to avoid its longer term consequences.

Empirical understandings of socio-economic resilience and its links with poverty and socio-economic vulnerability are limited (Gallopi´n, 2006; Cutter et al., 2008a). The handful of empirical studies that have addressed socio-economic resilience have confined themselves to the study of adaptive and response capacity (Tadele and Manyena, 2009; Sharma et al., 2009; Van den Berg, 2010; Alam and Collins, 2010; Paul and Routray, 2011). Some studies have focused on the role of a specific strategy (such as microfinance, out-migration or remittance) in determining households' ability to rebound after a disaster (Parvin and Shaw, 2012; Mallick and Vogt, 2012; Mohapatra et al., 2012). These studies treat resilience as an isolated concept without linking it to either poverty or vulnerability. Hence, there is currently no knowledge available regarding the way poverty and vulnerability map onto resilience in a real world setting. The general messages that emerge from the existing studies are that both the immediate and longer-term consequences of natural hazards for the livelihood strategies of rural households are substantial and adverse. In some cases, the commonly used response strategies such as microfinance, out-migration or sale of productive assets enable people to survive, but only just – namely, at a permanently lower welfare level than before.

In the context of the increased risk of natural disasters all over the world and the new paradigm of disaster risk management that centers on building resilient societies, an enhanced and in-depth understanding of the dynamics of socio-economic resilience and its links with poverty and vulnerability is eminent (Cutter et al., 2008a). In particular, three questions demand urgent attention: (1) How does resilience vary across the socio-economic groups (i.e. the poor and the non-poor) living within a community? (2) How does resilience vary across the vulnerability profile (i.e. from high to low) of a community? (3) What type of policy adjustment would be required to eliminate the discrepancy in resilience (if any) across the different groups? The current paper presents an empirical case study that examines these three questions by using household survey data collected from a tropical cyclone-prone low income coastal community in Bangladesh. Given the absence of a widely accepted framework for resilience assessment in the social sciences literature, we have applied an adapted version of the state-and-transition model – a model widely used in applied ecology – in this study. Assessing socio-economic resilience over a period of one year, we systematically examine the links among the different components of vulnerability and resilience across different definitional paradigms and between the poor and non-poor sections of the community.

The remainder of this article is organized as follows. Section 2 outlines the analytical framework used for resilience assessment. Section 3 describes the context of the case study followed by a description of the study area and the data. Section 4 presents the empirical findings and Section 5 discusses the results. Section 6 concludes the paper and outlines policy implications.

2. Analytical Framework

This section presents the analytical framework used for resilience assessment in our study. First we present an overview of the available frameworks. This is followed by a discussion of the state-and-transition model.

2.1. Existing Frameworks

The existing resilience assessment frameworks vary depending on whether they are oriented more towards the outcome or process realm. The outcome oriented frameworks assess resilience in terms of end outcome. For example, the resilience assessment framework used by DFID (2011) entails four possible states. The best case is 'bounce back better' which implies that the household is better able to deal with future shocks and stresses than it was in the past. The second best case is 'bounce back' to status quo or the pre-event condition. 'Recover, but worse than before' refers to a decreased capacity relative to pre-event status, and 'collapse' refers to the worst case scenario where the household exhibits a catastrophic reduction in their capacity to cope with future shocks.

Process orientated frameworks pose a challenge in terms of operationalizing the definition of resilience as they define resilience as a dynamic concept. The most noteworthy model of process based resilience is the Disaster Resilience of Place (DROP) model proposed by Cutter et al. (2008a). This model accounts for the pre-event conditions of a system (i.e. community or household) in the form of inherent vulnerability, and for post-event processes. The pre-event conditions are static snapshots of household characteristics at baseline determined by the social (race, ethnicity, age and economic status), structural (construction materials of housing units; the availability of lifelines such as the number of hospitals, schools, cyclone shelters and electric power facilities) and environmental (flood zone delineations, and the amount of water-resistant surfaces) indicators. The structural indicators measure a household's sensitivity while the environmental indicators reflect its exposure. The social indicators are measures of sensitivity (e.g. age, race)[1] and response/adaptive capacity (e.g. economic status)[2]. The post-event processes capture the dynamic notion of resilience by

[1] Racial and ethnic discriminations increase the vulnerability of racial and ethnic minorities. In addition, young children and the elderly people are unable to respond to disasters without outside support (Cutter et al., 2009).

[2] Richer people are better able to prevent and cope with damage.

accounting for factors such as early warning and emergency response plans (adaptive/response capacity).

Forgette and Boening's (2010) '4 Rs' model measures resilience by assessing household capacity in terms of risk recognition, resistance, redundancy and rapidity. Risk recognition is the degree to which households recognize the risk of a natural disaster. Resistance is the strength of a system to withstand disruptions (i.e. extent of damage). Redundancy is the extent to which structural, environmental and socio-economic conditions permit substitutes or resources for the replacement of critical goods and services (e.g. food, water, medical supply, credit), and rapidity is the amount of time required for individuals/groups within a community to access internal and external support (e.g. time to access aid).

2.2. The State-and-Transition Model

The frameworks discussed in the previous section form a spectrum in which pre- and post-event conditions lie at the left and right ends respectively while the DROP model (Cutter et al., 2008a) and Forgette and Boening's (2010) '4 Rs' model lie somewhere in the middle. There is currently no single model that covers the full spectrum of all of the scientifically accepted aspects of disaster resilience. For this reason we use the state-and-transition model, first developed by Westoby et al. (1989), as it accommodates a broader spectrum of resilience dynamics. We have modified this model to make it useful for understanding socio-economic resilience to natural disasters. We assume that households live close to a stable steady state at time t (i.e. pre-event). Exogenous environmental shocks (e.g. cyclones or floods) may invoke a level of devastation that exceeds households' capacity to maintain the characteristics of the pre-event steady state. If so, this triggers an irreversible transition as households cross the threshold and move from one steady state to another.

Thresholds can be categorized into two general groups: structural and functional (Briske et al., 2005). In applied ecology literature, the former refers to changes in community composition or spatial distribution of vegetation, while the later implies positive or negative changes in various ecological processes (e.g. soil physical and hydrological properties, nutrient cycling and productivity). The concept of a structural threshold in a socio-economic context can be interpreted in terms of changes in structural characteristics (e.g. housing structure, access to water, sanitation and electricity). Likewise, a functional threshold can be viewed in terms of changes in fundamental socio-economic characteristics such as income, employment, inequality and so on.

In order to structure our analysis, we divide the state-and-transition process into five components by applying the logic commonly used in a disaster management cycle: pre-event steady state, adaptive capacity, resistance[3], recovery[4] and post-event steady state (Figure 1). Pre-event steady state is a set of household characteristics and hazard indicators at time *t* determining a household's exposure, sensitivity and response capacity to a specific hazardous event. The sequence of adaptive capacity, resistance and recovery can be compared with the notion of a trajectory that navigates the transition between the two steady states. Pre- and post-event steady states are separated by functional and structural thresholds. The capacity for recovery is exceeded when a threshold is crossed, triggering an irreversible transition to a different steady state at time *t+1*. If the thresholds remain intact, then households restore their pre-event steady state at *t+1*.

INSERT FIGURE 1 HERE

As shown in Figure 1, the different components and the sub-components of this process are likely to be interlinked. Previous research in the social vulnerability literature has revealed

[3] Resistance is the ability to withstand physical, structural and economic damage.
[4] Recovery is the ability to restore pre-cyclone steady state.

the links among poverty, sensitivity, exposure, response and adaptive capacity, i.e. the poor are more vulnerable (according to both narrow and broad definitions of vulnerability) and less prepared (Brouwer et al., 2007). However, the mutual links that serve to map pre-event characteristics to post-event conditions have not been explored before. Hence we focus our attention on these in this study. In particular, we examine the following three links. First, greater exposure and sensitivity combined with a lack of adaptive capacity is likely to cause higher damage (link 1). Second, households with less damage (high resistance) are better able to absorb it (high response capacity) (link 2). Finally, a system's inability to resist damage and the lack of adequate capacity to respond and adapt to it are the forces that breach the thresholds and initiate transition across steady states. In other words, resistance and response and adaptive capacity are the key determinants of recovery (link 3).

3. Materials and Methods

3.1. Study Area

The context of our case study is a tropical cyclone stricken coastal community located on the southwest coast of Bangladesh (Shyamnagar, a sub-district of Satkhira district) (Figure 2). Bangladesh, a low-lying deltaic country located in the northern Indian Ocean, is ranked as the most vulnerable country to tropical cyclone risk (Peduzzi et al., 2012). The southern part of the country borders the Bay of Bengal, forming a 600 km long coastline. The coastal belt comprises 30 percent of Bangladesh's geographical area and is home to a third of the country's population. In addition to high population density, the overwhelming majority of the coastal residents are poor people who live in structurally weak houses (BBS, 2011). Bangladesh's coast has witnessed 14 serious cyclones in the last 50 years and, of these, three (Bhola in 1970, Gorky in 1991 and Sidr in 2007) were catastrophic (Khan, 2008). Cyclone Bhola and Cyclone Gorky are among the two deadliest tropical cyclones on record.

The study area is situated within a unique geo-ecological setting which borders the Sundarbans, the largest mangrove forest reserve zone in the world, and the Bay of Bengal. The area has been listed as a UNESCO World Heritage Site since 1999.The district is around 2,000 km² in size and is home to three million people. Non-mechanized agricultural farming and aquaculture are the main livelihoods here. Villagers living closest to the mangrove forest (bordering the coast) are the poorest and depend on mangrove resources for their livelihood and income generation activities, such as timber harvesting, honey and wax production, eco-tourism, extraction of poles and posts for fuel wood (Hussaine and Badola, 2010). The Department of Forestry manages the reserve by allocating access permits in certain parts of the reserve and prohibiting access to specific areas during particular periods of the year.

INSERT FIGURE 2 HERE

On May 25 2009 the region was struck by a Category I tropical cyclone (Cyclone Aila) that generated a wind speed of 120 km/h and a storm surge three meters above the normal astronomical tide. Eleven out of the 19 coastal districts were severely affected. The cyclone claimed 190 lives, injured 7,000 people, killed 100,000 livestock and caused US$170 million worth of economic damage (UNDP, 2010). The central government distributed relief assistance including food, cash, drinking water, emergency medicines and other non-food materials to the affected communities. Ninety percent of the assistance was distributed under the Government's existing safety net networks, including Vulnerable Group Feeding, Vulnerable Group Development and Gratuitous Relief. Some of this assistance continued until 2010. The central Government also rolled out a 40-day 'Cash for Work' program in the affected districts to generate post-cyclone employment. Although no official appeal was made for international assistance, the international community extended their generous support by supplying relief and rehabilitation aid to the affected communities.

3.2. Data Collection and Analysis

We designed a cross-sectional household survey using a natural experiment framework to allow ‘before–after’ and ‘with (poor)–without (non-poor)’ comparison. The survey was administered a year after the devastation caused by Cyclone Aila (in 2010) and focused on 12 villages in one of the worst affected coastal sub-districts, Shyamnagar (Figure 2). The pre-cyclone year 2009 was treated as the baseline for before–after comparison. The information about the baseline was collected during the household survey by retrospective recalling – a method widely used to substitute high cost and limited availability of longitudinal data in social sciences research. Our key estimation approach is a standard difference-in-difference estimator which allows comparison of welfare outcomes (1) across the poor and non-poor (i.e. cross-sectional comparisons) and (2) before and after the cyclone.

The analysis plan was structured in three main steps. First, the linkages among the components of vulnerability and resilience (links 1 and 2) were examined using linear correlations and parametric and nonparametric testing procedures. Second, these linkages were cross-sectionally compared across the poor–non-poor to understand if they significantly or systematically vary across these groups. For before–after comparison (examination of link 3), a series of deterministic models were estimated. The models followed the standard difference-in-difference setting. For example, let $Y_{t+1,t}$ be the state of the functional and structural threshold indicators at t and $t+1$. $X_{t+1,t}$, $Z_{t+1,t}$ and $H_{t+1,t}$ are sets of variables representing resistance, response and adaptive capacity. μ is a set of unobserved household characteristics influencing the threshold indicators. □ is idiosyncratic error. The standard way to control for unobserved heterogeneity bias is to assume that they are not time varying. Therefore, they can be controlled with fixed initial (or baseline) household characteristics (e.g. religion, education, age, profession, land and non-land assets and location). The difference-in-difference specification for an income growth equation, for example, takes the following form:

$$\Delta lnY_{t+1,t} = \alpha + \beta X_{t+1,t} + \theta Z_{t+1,t} + \lambda H_{t+1,t} + \mu + \varepsilon_{t+1,t} \quad (1)$$

in which $\Delta lnY_{t+1,t}$ is the income growth α *(constant),* β*,* θ *and* λ are coefficients to be estimated.

Two hundred and eighty fully structured face-to-face interviews were conducted using local interviewers. A random sampling procedure was followed in which every 15th household along the village road was approached for an interview. A draft questionnaire was prepared first after two focus group discussion sessions and interviews with local experts (government and non-government workers, village leaders and school teachers). The questionnaire was finalized after two subsequent rounds of pre-tests in the study area. The final questionnaire consisted of around 30 questions which were divided between one general section and three specific sections. The general section contained questions about demographic characteristics and questions relating to current socio-economic conditions and standard of living (e.g. income, expenditure, land- and non-land assets, housing structure, access to sanitation and drinking water). This section was followed by a set of recall questions about economic conditions and standard of living before the area was battered by Cyclone Aila. Respondents were also asked about physical and economic damages incurred due to the cyclone, the ex-ante and ex-post measures employed to cope with it, and the nature and extent of the support received from government and non-government organizations (NGOs).

Eighty-nine percent of the sample was Muslim. Over one third (40%) of the respondents were unable to read and write and average per capita income (pre-cyclone) equaled US$15 per month, lower than the regional average rural per capita income of US$20 (BBS, 2011). Forty-one percent of sampled households were recorded as living below the upper poverty line before the cyclone[5]. Households living below the poverty line were significantly more likely to be illiterate, to be from a minority religious community, to have a significantly larger household size and a relatively smaller parcel of farmland. A significantly larger proportion of households living below the poverty line were day laborers and were significantly less likely to have access to electricity or own a television or private vehicle.

4. Results

This section presents the results and is divided into four sub-sections. The first presents a brief discussion about the mutual links observed among poverty, pre-event steady state and adaptive capacity. The remaining sub-sections present the results related to the key links of interest to us, which are outlined in Section 2.2. Table 1 summarizes the indicators used to measure the core components of vulnerability and resilience.

INSERT TABLE 1 HERE

4.1. Poverty, Pre-event Steady State and Adaptive Capacity

Table 2 presents the correlation coefficients, Chi-square test and mean-difference test results of the key indicators of pre-event steady state and adaptation across the poor and non-poor. Consistent with the findings documented in the social vulnerability literature, the results suggest that sensitivity, exposure and adaptive capacity were closely linked with poverty. The poor were more likely to live in kacha houses (i.e. structurally weak houses built with mud, bamboo or golpata), closer to the shoreline and further away from the cyclone shelter. Poorer households were significantly and systematically less prepared. They were less likely to

[5] The poverty line measure was calculated by applying the Cost of Basic Need (CBN) income threshold (US$105 per capita per year) recommended by the Bangladesh Bureau of Statistics (BBS, 2005). The CBN income comprises the values of both food and non-food items needed to ensure minimum subsistence.

attend the cyclone preparedness training and were less likely to receive early warning. Interestingly, poverty appeared to have a positive relationship with response capacity (rapidity). Households living below the poverty line could access emergency food relief quicker than those who lived above the poverty line. Being from a minority religious community also increased the likelihood of receiving all types of emergency relief, particularly food (all relief: Z=2.50, $p<0.05$; food: Z=2.24, $p<0.05$).

INSERT TABLE 2 HERE

4.2. Exposure, Sensitivity, Adaptive Capacity and Resistance

Link 1: Higher exposure and sensitivity combined with a lack of adaptive capacity is likely to cause higher damage.

As expected, physical, economic[6] and structural damages were significantly positively correlated with exposure and sensitivity. On average, the kacha houses suffered significantly higher damage than the pucca houses (i.e. structurally robust houses built with concrete and wood) (Table 3). Further, households who lived in kacha houses were significantly more likely to experience fatality or physical injury as well as higher economic damage (Table 3). Households who lived below the poverty line incurred significantly higher relative economic damage (damage as a proportion of pre-cyclone income) (Z=5.70, $p<0.001$). Although no statistically significant relationship was observed between the number of children and elderly members and the number of deaths and injuries experienced by households, women were more likely to be injured in households that had a higher number of infants and elderly members (Z=2.30, $p<0.05$). This is because women are generally responsible for ensuring the safety of children and elderly household members. Their mobility during an emergency is also significantly impaired by traditional long clothing (*saree*) and long hair.

[6] Four observations containing outlier values of economic damage were eliminated from the data.

INSERT TABLE 3 HERE

Proximity to the shoreline had a statistically significant negative association with economic, structural and physical damage. Households who lived further away from the coast suffered from significantly lower absolute (r=-0.26, $p<0.001$) as well as relative economic damage (r=-0.24, $p<0.001$). The extent of house damage was also significantly lower for the households who lived away from the coast (r=-0.24, $p<0.001$). The correlation coefficient between physical damage and distance to the coast was also negative and significant at the ten percent level, implying that households who lived closer to the coast experienced higher cases of fatalities and injuries (r=-0.10, $p<0.10$).

Cyclone preparedness training and evacuation had no significant correlation with physical, economic or structural damage. However, a statistically significant negative relationship was observed between the failure to access a cyclone shelter and the likelihood of physical injury (Z=2.5, $p<0.05$). This implies that those who went to cyclone shelters but were not allowed entry due to a lack of adequate space were more likely to experience death or injury.

Only ten percent of those who suffered from economic, structural or physical damage borrowed money from microcredit organizations. All the households who borrowed money were acquainted with local NGO workers and 50 percent of them borrowed money even before the cyclone. No statistically significant difference was observed between the likelihood of borrowing money and the extent of physical, economic or structural damage incurred by households. Pre-cyclone income or assets also had no statistically significant correlation with the likelihood of borrowing or the size of the loan.

4.3. Resistance and Response Capacity

Link 2: Households who experience a lower damage are better able to absorb it.

We assess response capacity using two criteria, namely, the need (i.e. redundancy according to ‘4 Rs’ model) and rapidity to access external support. Not needing any external support points to a higher internal response capacity. The dependence on external assistance does not necessarily reflect a lack of response capacity as long as the assistance can be accessed with a reasonable degree of rapidity. Around 90 percent of the sampled households were in need of some form of external assistance to cope with the immediate aftermath of the cyclone. As expected, those households who experienced significantly lower economic, structural and physical damage were able to respond to the crisis by mobilizing internal resources. These households were also more likely to be from the non-poor group (see Table 2).

Emergency relief distribution varied significantly across administrative boundaries (i.e. unions), reflecting political economy-based biases as well as divergent post-cyclone infrastructural conditions (road-river network). The areas lacking a pucca road had limited accessibility due to wind and storm damages to the kacha roads. Controlling for the proximity to the pucca road and the administrative boundaries, the rapidity of accessing emergency relief was found to be significantly positively correlated with economic damage (both relative and absolute). Particularly, the households who experienced higher relative economic damage accessed food and medical assistance faster on average than the rest (food: $r=-0.20$, $p<0.001$; medical supplies: $r=-0.13$, $p<0.05$). A similar trend was observed in the case of rehabilitation aid (construction material for houses). Households who received rehabilitation aid suffered from a significantly higher proportion of house damage (86%) on average than those who did not receive it (73%) ($Z=3.5$, $p<0.001$). Contacts with government officials significantly increased the likelihood of receiving rehabilitation aid in the areas where aid was distributed by the central government (Chi-square=9, $p<0.01$). These results suggest that the link between resistance and response is not so obvious, i.e. low resistance does not necessarily lead to low response capacity.

4.4. Resistance, Response, Adaptive Capacity and Recovery

Link 3: Resistance, response and adaptive capacity are the key determinants of recovery.

This sub-section explores the deterministic relationship of resistance, response and adaptive capacity with recovery in terms of a number of functional and structural thresholds. First we present a comparison of the states of the structural and functional thresholds during the pre- and post-event steady states followed by a series of regression results that identify the drivers of their breaches.

4.4.1. Functional and Structural Thresholds

A range of socio-economic and household characteristics can be used as indicators of functional and structural thresholds. These indicators may vary depending on the case study context and the community in questions. For the purposes of this study we used income and employment as indicators of functional threshold, and housing structure and access to clean water, sanitation and electricity as indicators of structural threshold. Table 4 compares their status pre- and post-cyclone.

INSERT TABLE 4 HERE

The proportion of households living below the poverty line increased from 41 to 64 percent in 2010. Both average household income and income per person declined significantly after the cyclone. The poor experienced a significantly lower average income shock (-5%) than the non-poor (-28%) (Z=6, $p<0.001$). As expected, those who became unemployed after the cyclone experienced a significantly higher income shock (-30%) than those who maintained their employment status (-15%) (Z=3, $p<0.001$). Improvement was observed in terms of structural conditions, with over 20 percent of the kacha houses being rebuilt with wood after the cyclone. This positive change is likely to be the outcome of the central government led post-cyclone housing intervention named 'build back better' (Nadiruzzaman and Paul, 2013). No significant difference was observed across the poor and non-poor with regards to higher structural resilience (Chi-square=0.44, p<0. 50). However, structural and economic recovery did not go hand in hand. Households who exhibited higher structural resilience suffered from significantly higher income shocks (-28%) than those whose structural conditions remained unchanged (-16%) (Z=2.3, p<0.05).

Households' access to sanitation, clean water and electricity declined significantly after the cyclone. The loss of access to water and to sanitation was significantly positively correlated, implying that households who lost access to clean water were also more likely to lose access to sanitation (Chi-square=15, p<0.001). Households who lost access to sanitation experienced significantly higher structural damage (Z=3.5, p<0.001). Interestingly, the non-poor (23%) were significantly more likely to lose their access to clean water compared to the poor (9%) (Chi-square=10, p<0.01). Households who were acquainted with the local NGO workers were significantly more likely to restore their access to clean water after the cyclone (Chi-square=2.60, p<0.10)

4.4.2. Drivers of Change

This section presents the regression results. First, an ordinary least square (OLS) approach was applied to estimate Equation 1. The results are presented in Table 5.

INSERT TABLE 5 HERE

Among the resistance indicators, physical damage had a statistically significant negative impact on income growth. In particular, households where a male member was injured or killed experienced – on average and other things remaining the same – a significant decline in post-cyclone income. As expected, higher structural and economic damage led to lower income growth. However, the mean coefficients of structural and economic damage were not significantly different than zero. As for response capacity, households who lacked internal response capacity and hence relied on external support experienced significantly lower income growth than the rest. Among the indicators of adaptive capacity, only the coefficient of cyclone preparedness training had a significant positive impact on income growth. The coefficients of the other indicators (elite contacts, social safety nets, access to credit and availability of savings) were not significantly different than zero.

Among fixed initial household effects, the coefficients of the wealth indicators (both land and non-land), occupation, and distance from the mangrove forest significantly influenced post-cyclone income growth. Relatively wealthier households witnessed significantly lower income growth in the post-cyclone steady state. Self-employed households and salaried individuals experienced a significantly lower income growth compared to day laborers. A significant distance-decay relationship existed between income growth and proximity to the mangrove forests. With each kilometer increase in distance from the mangrove forest, average sampled household income declined by 8 percent. The slope of the decay function was positive, implying a weakening of the distance-income nexus with each additional kilometer increase in distance. This pattern is due to the availability of informal and ad-hoc income generation options available to the forest fringe dwellers. Such opportunities emerged as the local authorities relaxed the stringent restrictions to access the forest reserve after the cyclone (Zohora, 2011). Religion, age and education had no statistically significant influence on post-cyclone income growth.

Models 1 and 2 in Table 6 present the results of a similar difference-in-difference estimation to that depicted in Equation 1 and use unemployment and housing structure as dependent variables instead of income. The dependent variable in Model 1 is unemployment, coded 0 if the head of the household was employed before and after the cyclone and 1 if they were employed before the cyclone but became unemployed afterwards. The dependent variable in Model 2 is a stronger house, which was assigned a value 0 if households lived in a kacha house before and after the cyclone and 1 if they had a kacha house before the cyclone and a pucca house after.

INSERT TABLE 6 HERE

Consistent with the findings of the income growth model, the results presented in Table 6 (Model 1) reveal a positive relationship between physical damage and the likelihood of unemployment. Also consistent with the income growth model, day laborers were more likely to be employed relative to self-employed and salaried individuals. This is because day laborers are more flexible across different employment options than self-employed and salaried individuals. For example, an agricultural day laborer can work as a construction worker or in a shrimp firm while self-employed and salaried individuals are tied to a specific type of employment. Unlike the income growth model, the nature of damage (i.e. the loss of livestock and crop damage) influenced the likelihood of employment significantly negatively. Also, unlike the income growth model, access to post-cyclone credit and higher marginal propensity to save before the cyclone significantly curbed the likelihood of being unemployed.

As was observed in the case of income growth, a distance-decay relationship persisted between employment and mangrove forests although the direction of the relationship was the opposite. Households living closer to the mangrove forest periphery had significantly fewer employment opportunities than those who lived further inland. This apparent inconsistency can be explained by two opposing factors. The severely damaged road-river networks caused significant delays in the launch of the low paid (US$1.5 per day) post-cyclone employment generation programs run by the local government and NGOs in the villages close to the mangroves (Oxfam, 2012). As a result, households who lived closer to the mangrove did not have any formal employment, yet they managed to earn income through extraction of forest resources as the access restrictions to the forest were relaxed following the cyclone.

Model 2 in Table 6 examines the drivers of higher structural recovery. The decision to build a pucca house after the cyclone for those households who lived in a kacha house before was dictated, to a large extent, by households' willingness to protect their family, livestock and property (house) against future hazards. Elite contacts had a significant positive relationship with higher structural recovery, implying that households who had a stronger connection with the local elites had greater access to relief and rehabilitation aid that enabled them to rebuild better. Finally, a statistically significant positive relationship was identified between distance from the mangrove and higher structural recovery, implying that those who were the least exposed were significantly more likely to reduce their sensitivity to future environmental shocks.

5. Discussion

The poverty-vulnerability nexus may be differently understood depending on the definition of vulnerability. Using the narrow definitional paradigm (i.e. vulnerability is susceptibility/sensitivity), we found strong evidence in support of the hypothesis that the poor were more susceptible to tropical cyclone than the non-poor as they lived in weakly built houses and further away from the cyclone shelter. Under the broader definitional paradigm that considers exposure, sensitivity and response capacity as integral components of vulnerability, the poverty–vulnerability nexus appeared rather weak. Although the poorer households were significantly more exposed to the risk of tropical cyclone as they lived closer to the coast, their (ex-post) capacity to respond to the cyclone by rapidly accessing external support was significantly higher than the non-poor. Households below the poverty line as well as households from the minority religious community had quicker access to post-disaster relief and rehabilitation aid. Evidently, elite contact significantly influenced the relief and aid distribution process. Contacts with the local NGO workers helped restore clean water supply and allowed access to post-cyclone credit under circumstances when the credit market was confronted with acute liquidity shortage. However, we did not find any evidence to suggest that the poor had fewer or no contacts with social elites. This means that although households' response capacity was distorted by elite influence, the distortion did not cause any systematic bias against the poor.

Like the poverty–vulnerability nexus, the poverty–resilience nexus also varies depending on the definition of resilience. According to the outcome-based definition, our results suggest that the poor are more resilient than the non-poor as they exhibited a higher ability to restore their pre-cyclone steady state. First, poorer households experienced significantly higher income growth during the post-cyclone steady state. Second, day laborers, who tend to belong to the poorer segments of the society, were significantly more likely to experience positive income growth and find employment in the post-cyclone steady state. Third, poorer households were significantly more likely to restore their access to clean water after the cyclone compared to the non-poor. Finally, both the poor and non-poor were equally likely to build a stronger house during the post-cyclone steady state.

According to the process-based definition, the positive nexus between poverty and resilience slightly weakens due to the differences observed across the poor and non-poor with regards to 'hazard recognition' – a component of adaptive capacity. We found that the poorer households were less prepared in terms of attending cyclone preparedness training and reception of early warning. Although being more or less prepared did not cause any significant direct impacts on the incidence of physical, economic or structural damage, cyclone preparedness training had a significant positive impact on economic recovery. This implies that poverty has some significant (indirect) detrimental effect on socio-economic resilience.

Regardless of the definitional paradigm followed, our results do not provide evidence in support of the flip-side relationship hypothesis (i.e. vulnerability is the flip side of resilience). Within a narrow definitional paradigm, vulnerability and resilience appear to have a reasonable degree of overlap. Although sensitivity unequivocally led to higher economic, structural and physical damage, it did not necessarily translate into lower resilience. For example, structural and economic damage did not have any significant impact on post-cyclone income growth. Households whose members suffered death or physical injury earned significantly lower income and were significantly more likely to be unemployed. Nonetheless, these households were also significantly more likely to be structurally resilient, exhibiting signs of learning from experience and thereby taking preventive measures against such losses in the future.

Evidence favoring the flip-side relationship hypothesis weakens further as the definition of vulnerability becomes broader. Exposure to a tropical cyclone had a mixed influence in determining the post-cyclone steady state. On the one hand, households who lived further away from the coast were more likely to be employed and build a stronger house after the cyclone. On the other hand, households who lived closest to the coast were more income-resilient since the proximity to the mangrove reserves offered them higher income generation opportunities than the inland inhabitants. These findings point towards Sapountzaki's (2012) thesis regarding vulnerability–resilience interaction: Resilience is a process of vulnerability re-arrangement and a function of unequally distributed opportunities across communities.

6. Conclusions and Policy Implications

The main objective of this paper was to enhance our understanding of the nexus involving poverty, vulnerability and resilience in order to bridge the existing knowledge gap regarding resilience heterogeneity across households. Consistent with existing studies in the disaster risk literature, our results reveal that the tropical cyclone had significant negative medium-term impacts on coastal residents' lives and livelihoods, particularly in terms of income, employment and access to clean water and sanitation. The loss of productive assets, human capital shock, credit constraint and proximity to the forest reserve were the key factors explaining resilience heterogeneity across households. Although the poor were the most vulnerable and suffered from relatively higher economic, physical and structural damage, they exhibited a relatively better ability to respond to and recover from the shock compared to the non-poor. These findings imply that the increased risk of tropical cyclone is likely to reduce incomes and standards of living among the tropical coastal communities. However, the burden of these adverse impacts is unlikely to be disproportionally borne by the poorer segment of the society.

Three key policy implications can be drawn from the case study. First, the existing cyclone preparedness programs (i.e. cyclone preparedness training, early warning system and evacuation plan) seem to be systematically excluding the poor. The adequacy and effectiveness of the preparedness programs can be enhanced by reaching out to poorer households, increasing the capacity and facilities of the cyclone shelters, and making transportation available to encourage evacuation, especially for families with elderly household members and young children and for those who live further away from the cyclone shelters. Second, the post-disaster relief and recovery aid disbursement program appears to be quite well targeted. However, the inadequacy of the aid supply relative to the overwhelming demand for it seems to exacerbate competition, thereby creating opportunity for social elites to influence the system. A potential way to curb such influence could be to increase the volume of aid and enhance the monitoring of aid distribution. Finally, the government-operated social safety net programs do not appear to be acting as a shield against environmental shocks. The existing social safety nets need to be cast wider to prevent people from becoming unemployed and falling below the poverty line. Although post-cyclone credit schemes appear to have prevented some people from becoming unemployed, access to and the availability of such credit programs does not seem to be widespread. Increased access and availability of soft credits (with low interest rates) should be targeted towards self-employed individuals to help them restore their livelihoods.

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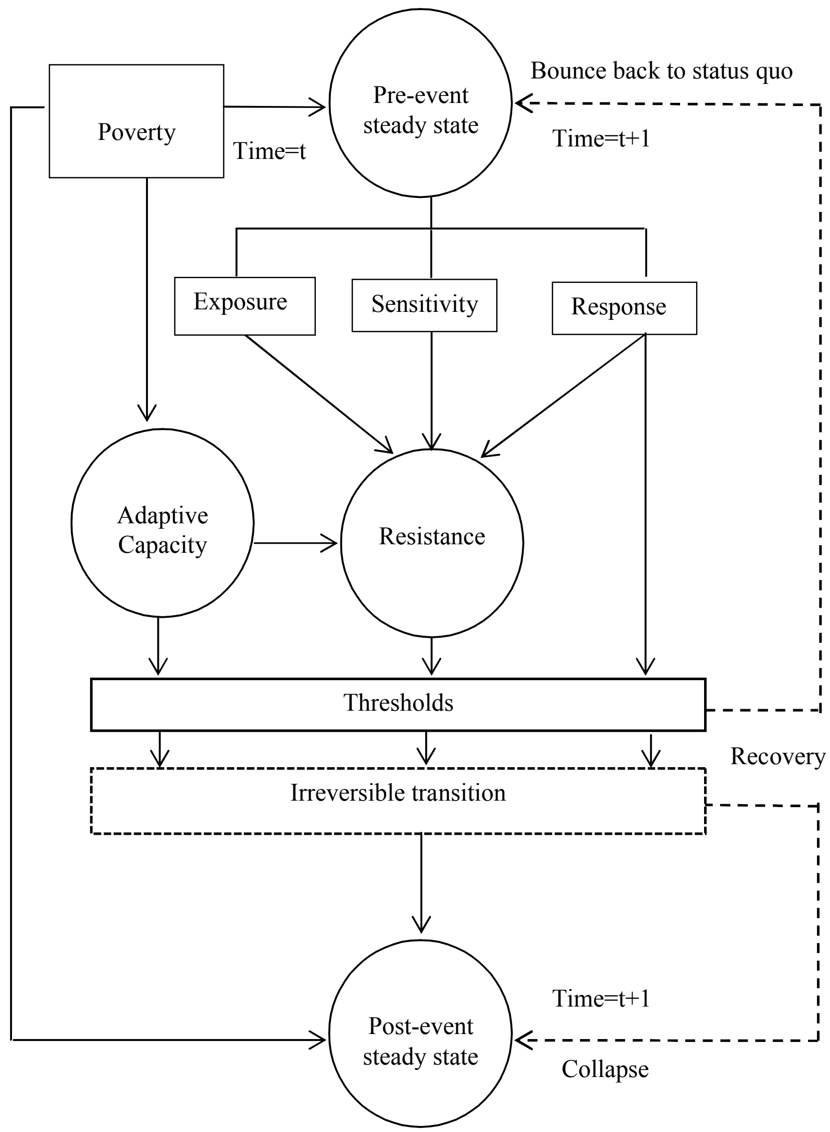
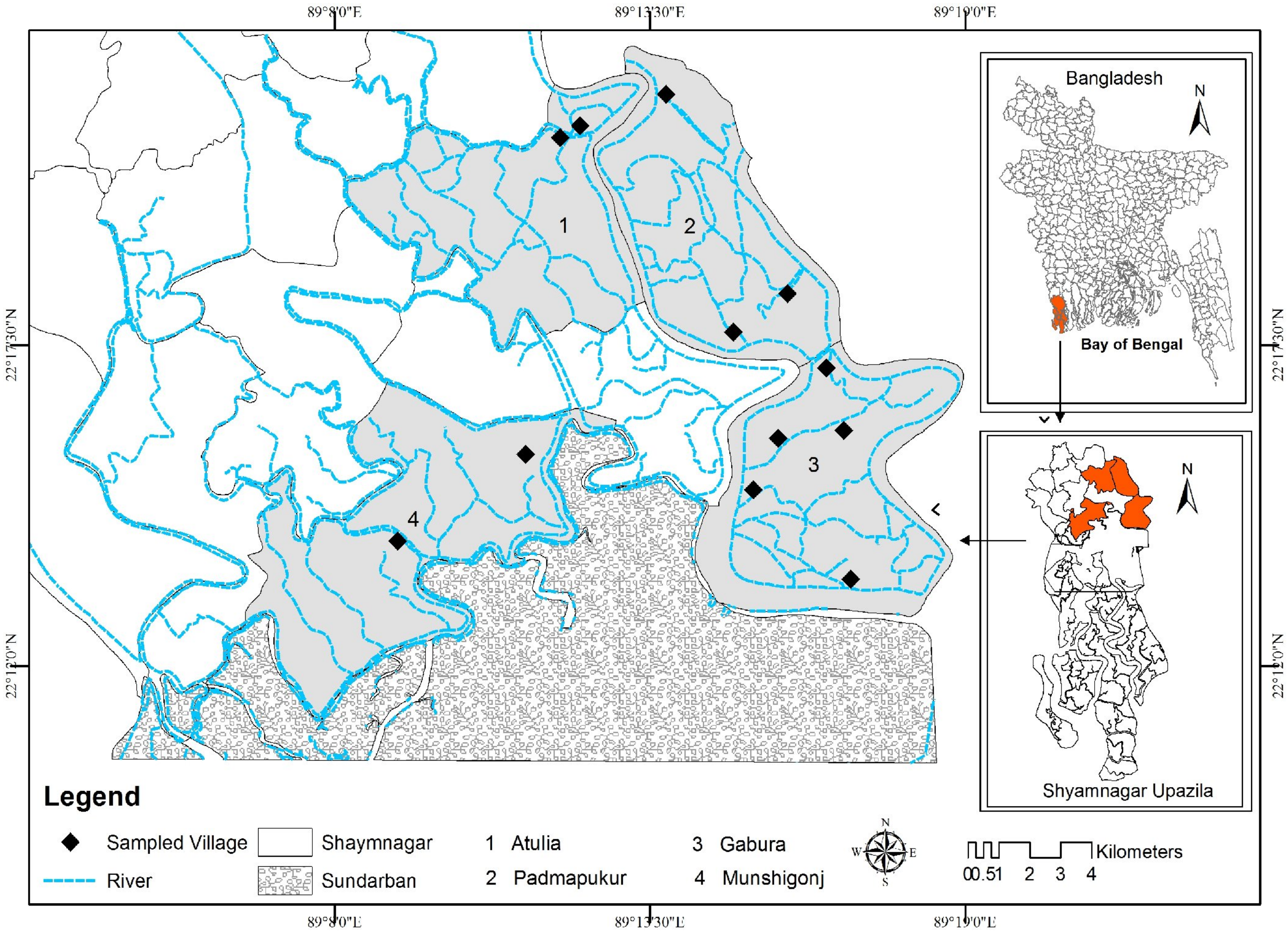
Figure 1 State-and-transition model for assessing socio-economic resilience to natural disasters



Source: Adapted from Westoby et al.'s (1989) state-and-transition model.

Figure 2 Location of the study area



Source: Generated by the authors using the data provided by the GIS unit of the Local Government and Engineering Department (LGED) of the Government of Bangladesh (2009).

Table 1 Components of vulnerability and resistance and associated indicators

Components	Indicators	Measurement	Reference for indicators
Sensitivity	Sex	-Number of female household members	Cutter et al. 2008a;
	Age	-Children (0 to 14) and elderly (60+) household members	Cutter et al. 2008b
	Religion	-Minority religious community (Hindu)	
	Housing Structure	-Construction materials used for roof and wall before Cyclone Aila (a: mud; b: concrete; c: bamboo; d: golpata; e: wood; f: tin/tally)	
	Proximity to the cyclone shelter	-Distance to the nearest cyclone shelter from household's location (walking distance in minutes)	
Exposure	Distance from the coast	-Distance measured using GPS coordinates of household's location (in km)	Brouwer et al. (2007)
Response Capacity	Need for relief, rapidity of accessing relief and rehabilitation aid	-Household needed assistance with food, shelter, medical supplies after the cyclone -Time taken for these needs to be addressed. (number of days) -Household received building materials as rehabilitation aid	Forgette and Boening (2010)
Adaptive Capacity	Hazard recognition	-Household attended disaster preparedness training before the cyclone -Household received early warning -Household evacuated before the cyclone	Forgette and Boening (2010)

	Credit	-Household borrowed money after the cyclone	Parvin and Shaw (2012)
	Propensity to save	-Computed using households' income and expenditure profiles	Heltberg et al. (2009)
	Social capital (elite[a] acquaintance)	-Friendships or acquaintances with the local elites	Pelling and High (2005)
	Social safety net	-Household is a part of government operated social safety net programs	Heltberg et al. (2009)
Resistance	Economic damage	-Value of economic damage	Forgette and Boening (2010)
	Structural damage	-House damage (in %)	
	Physical damage	-Number of family members killed or injured	

Note:
[a] In the case study context, elite refers to community leaders (e.g., school teachers, leader of the local mosque) and people with power (e.g., village chairman, GO and NGO officials).

Table 2 Poverty, pre-cyclone steady state and adaptive capacity

	Indicators	Poor[a]	Non-poor[a]	Test-statistics (p value)
Sensitivity	Household lived in pucca (concrete and wood) houses (%)	80	60	13[b] (p<0.001)
	Distance from the cyclone shelter (minutes)	50	37	2.4[c] (p<0.05)
	Religion (% Hindu)	12	10	0.5[b] (p<0.50)
	Number of children and elderly members	3	2	4.5[c] (p<0.001)
Exposure	Distance from the main river (km)	5.5	7	2.5[c] (p<0.05)
	Households live within 2 km distance from the coast (%)	25	14	5[b] (p<0.05)
Response Capacity	Household needed external help (%)	86	57	7[b] (p<0.01)
	Time to access food relief (days)	3	6	2.6[c] (p<0.05)
	Time to access medical help (days)	2.7	4	1.7[c] (p<0.10)
	Households received rehabilitation aid (%)	56	65	2.1[b] (p<0.15)
Adaptive Capacity	Household attended cyclone preparedness training (%)	6	15	5[b] (p<0.05)
	Household received early warning (%)	26	41	6[b] (p<0.05)
	Household evacuated (%)	75	73	0.1[b] (p<0.80)
	Households accessed credit (%)	9.6	10	0.03[b] (p<0.80)
	Social safety net (%)	95	95	0.003[b] (p<0.90)

Propensity to save[d]	0.03	0.09	30[c] (p<0.001)
Acquaintance with social elites (number of contacts)	1.34	1.30	0.36[c] (p<0.70)

Notes:

[a]Households below and above the upper poverty line before cyclone Aila.

[b]Chi-square statistics.

[c]Z-statistics for mean difference test.

[d]Marginal propensity to save=1-(yearly expenditure over income)

Source:

Household survey data collected by the authors (2010).

Table 3 Linkage between sensitivity and resistance

	Economic damage[a] (US$)	Structural damage (%)	Physical damage (# of people injured or killed)
Mud, bamboo and golpata wall	400	76	0.28
Concrete and wood	133	47	0.13
Z-statistics [b] (*p* value)	5.66 (p<0.001)	6 (p<0.001)	1.74 (p<0.10)
Muslim	389	68	0.24
Non-Muslim	312	53	0.20
Z-statistics [b] (*p* value)	1.25 (p<0.21)	2.04 (p<0.05)	0.277 (p<0.80)
Number of children and elderly members	–	–	0.08 [c] (p<0.21)
Distance from the cyclone shelter (minutes)	–	–	-0.09 [c] (p<0.14)

Note:
[a] Four observations containing outlier values of economic damage were eliminated from the data.
[b] Z-statistics for mean difference test.
[c] Pearson correlation coefficient.
Source:
Household survey data collected by the authors (2010).

Table 4 Structural and functional thresholds before and after Cyclone Aila

Indicators	Before (2009)	After (2010)	Z-statistics (p value)
Functional thresholds			
Households below poverty line (%)	41	63	4.4[a] (p<0.001)
Unemployment (%)	11	60	12[a] (p<0.001)
Monthly household income (US$)	81	54	6.0[b] (p<0.001)
Per capita income (US$)	15	10	7.3[b] (p<0.001)
Structural thresholds			
Kacha houses (%)	68	51	7.1[a] (p<0.01)
Access to sanitation (%)	86	72	5.1[a] (p<0.01)
Access to clean water (%)	83	66	7.3[a] (p<0.01)
Access to electricity (%)	19	17	1.7[a] (p<0.10)

Notes:

[a]Chi-square statistics.

[b]Z-statistics for mean difference test.

Source:

Household survey data collected by the authors (2010).

Table 5 Ordinary least square regression results for drivers of per capita income growth (Dependent variable: $\Delta \ln Y_{t+1,t}$)

Variable name	Variable description	Coefficients (SE)
Indicators of resistance ($X_{t+1,t}$)		
Economic damage[b]	Value of total damage (in 000' Tk)	-0.002 (0.001)
Structural damage	House damage (%)	-0.001 (0.001)
Injured or killed (Women)	Number of female household members injured or killed	0.05 (0.10)
Injured or killed (Men)	Number of male household members injured or killed	-0.22** (0.09)
Response capacity ($Z_{t+1,t}$)		
Redundancy	Households needed external support to cope with cyclone damage=1, otherwise=0	-0.20* (0.10)
Adaptive capacity ($H_{t+1,t}$)		
Preparedness	Household participated in disaster preparedness training before Cyclone Aila=1, otherwise=0	0.20** (0.03)
Elite contacts	Number of contacts with social elites	0.02 (0.02)
Social safety net	Receives help from the government operated safety net programs=1, otherwise=0	0.06 (0.12)
Credit	Borrowed money after the cyclone=1, otherwise=0	-0.01 (0.10)
Savings	Marginal propensity to save before Cyclone Aila	-0.07 (0.04)
Fixed initial household effects at baseline (μ)		
Religion	Muslim=1, otherwise=0	-0.13 (0.10)
Age	Head of household's age (in years)	-0.003 (0.002)
Literacy	Some literacy=1, illiterate=0	-0.10 (0.06)
Land (wealth indicator 1)	Size of cultivable land (in 100 decimal)	-0.001** (0.0004)
Television (wealth indicator 2)	Household owned television=1, otherwise=0	-0.15** (0.07)
Dependents	Number of family members aged 60+	-0.06 (0.04)
Day laborer[b]	Head of household is day laborer=1, otherwise=0	0.20** (0.08)
Self-employed[b]	Head of household is self-	-0.13*

	employed=1, otherwise=0	(0.07)
Distance coast	Distance from the coast (in km)	-0.08**
		(0.04)
Squared distance coast	Square of distance from the coast (in km)	0.007**
		(0.003)
Constant		0.05
		(0.24)
N		276
Adjusted R-squared		0.22

Notes:

***: p<0.01; **: p<0.05; *: p<0.10.

Standard error in the parenthesis.

[a]Four observations containing outlier values of economic damage were eliminated from the data.

[b]Baseline category is salaried individuals.

Source:

Household survey data collected by the authors (2010).

Table 6 Drivers of change in unemployment and housing structure

		Model 1 Unemployment[a]	Model 2 Stronger Settlement[b]
Variable name	Variable description	Coefficients (SE)	Coefficients (SE)
Indicators of resistance ($X_{t+1,t}$)			
Livestock	Loss of livestock=1, otherwise=0	1.4*** (0.38)	1.30*** (0.40)
Crop damage	Loss of crop damage=1, otherwise=0	0.97** (0.40)	–
Structural damage	House damage (%)	–	0.02*** (0.006)
Injured or killed	Number household members injured or killed	0.89** (0.36)	0.74*** (0.26)
Adaptive capacity ($H_{t+1,t}$)			
Elite contacts	Number of contacts with social elites	0.03 (0.15)	0.50*** (0.16)
Social safety net	Receives help from the government operated safety net programs=1, otherwise=0	-0.34 (0.71)	-0.11 (0.76)
Credit	Borrowed money after the cyclone=1, otherwise=0	-1.42** (0.71)	0.05 (0.58)
Savings	Marginal propensity to save before Cyclone Aila	-0.44* (0.27)	0.23 (1.30)
Fixed initial household effects at baseline (μ)			
Religion	Muslim=1, otherwise=0	-0.08 (0.60)	0.31 (0.84)
Day laborer[c]	Head of household is day laborer=1, otherwise=0	-1.00* (0.60)	-0.06 (0.60)
Self-employed[c]	Head of household is self-employed=1,	0.52	-0.12

	otherwise=0	(0.50)	(0.48)
Literacy	Some literacy=1, illiterate=0	0.51	-0.45
		(0.40)	(0.36)
Distance Coast	Distance from the coast (in km)	-0.11*	0.10*
		(0.05)	(0.06)
Model fit statistics			
N		202	196
Percentage correctly predicted		68	83
Nagelkerke R-squared		0.30	0.28
-2 Log likelihood		226	215
Chi-square		51, df=12	52, df=12

Notes:

***: p<0.01; **: p<0.05; *: p<0.10.

Standard error in the parenthesis.

Four observations containing outlier values of economic damage were eliminated from the data.

[a]1=employed before, unemployed after, 0=employed both before and after.

[b]1=kacha house before, pucca house after, 0=kacha house both before and after.

[c]Base line category is salaried individuals.

Source:

Household survey data collected by the authors (2010).