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Children's vulnerability to natural disasters: Evidence from natural experiments in Bangladesh†

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ABSTRACT

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Both developed and developing countries face natural disasters, but it is the poor areas in developing countries, particularly women and children, that are most affected by those disasters in terms of loss of lives and livelihoods. If the predictions climate change models bear out, Bangladesh could be affected by frequent and severe natural disasters such as the rise in sea level leading to floods, cyclones, etc. Natural disasters adversely affect employment opportunities and earnings of the most vulnerable households. Loss of employment and earnings can affect the nutritional intake of children in natural disaster affected regions. Since nutritional status in the early age of 0-60 months of a child determines the cognitive ability and other developments, hindrances that affect nutritional supply and result in low nutritional intake can have adverse lifetime effects on children affected by such events. Consequently, the frequency and severity of natural disasters due to climate change have intergenerational effects. In this study, we examine the effects of natural disasters – specifically, cyclones Sidr and Aila - on children's nutritional status in Bangladesh. We estimate the nutritional status of children below 60-months age who had been exposed to those extreme events in November 2007 and May 2009. Results show that children who had been exposed to such an extreme climate events from sometime in utero to newborn stages suffer significant reduction in height for age Z score and are more likely to be stunted and underweight. This is particularly important as among other nutritional outcome indicators, height for age Z score is regarded as a measure of the long-term consequence of nutritional intake. Our findings suggest that even a single extreme event such as super cyclone Sidr can exert long term detrimental effects to hinder development of children of a generation exposed to such disasters.

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Introduction

High income risks are a part of the lives of a significant proportion of poor people in developing countries. Such volatilities arise from different adverse shocks that range from disease to natural disasters which have been exacerbated by the climate change (Islam and Nguyen, 2018; Bartlett, 2009). While both developed and developing countries are prone to natural disasters, it is mostly the poor households in developing countries that are greatly affected by extreme events such as sea-level rising led floods and cyclones (World Bank & United Nations, 2010; Baez et al., 2010). Natural disasters not only cause volatilities in income and livelihoods, these extreme events have long term effects on the overall development of a generation through adverse changes in nutritional intake of children exposed to such events. Adverse shocks in early childhood can have substantial negative impacts on a person's life-time outcomes (Almond et al., 2018; Rodriguez-Llanes et al., 2016; Del Ninno and Lundberg, 2005; Akter, 2004; Godet et. Al., 2011). While the past research have shed lights on the impact of general negative shocks in early childhood life on outcomes in adult life (Almond et al., 2018), human capital (Baez and Santos, 2008), consumption volatility (Kazinga and Udry, 2006; Dercon, 2004; Fafchamps et al., 1998; Reardon and Taylor, 1996), school attendance and progression (Santos, 2007; Ureta, 2005; Stein et al., 2003; Skoufias, 1997), incidence of child labor (Beegle et al., 2008; Baez et al., 2007; Beegle et al., 2003), there are few studies that have investigated the impact of specific climate extreme events on child nutrition, particularly in the context of Bangladesh, one of the countries most vulnerable to climate change. In this paper, we examine the impact of a category-5 cyclone *Sidr* which was followed by a Category 1 cyclone *Aila*, on child nutrition in Bangladesh.

If the predictions climate change models bear out, Bangladesh could be affected by frequent and severe natural disasters such as floods due to rising sea levels and cyclones similar to *Sidr* and *Aila* that hit the coastal divisions-districts in 2007 and 2009 respectively. Women and children are the most vulnerable groups that are at risk of severe detrimental effects from such of natural disasters (Bartlett, 2009). More importantly, any adverse shocks in early childhood can have negative impacts on adult outcomes such as cognitive ability potentially lowering lifetime earnings and consequences that follow. Specifically, it has been shown that nutritional status in the early ages of 0-60 months of a child determines cognitive ability and other developments in adult life (Hoddinot, 2014). Therefore, events that potentially affect nutritional supply and result in low nutritional intake can have adverse lifetime effects on children exposed to such events.

Since natural disasters can cause negative shocks to households' income, these events can affect the nutritional status of the children in the affected households, particularly the rural poor. Consequently, the frequency and severity of natural disasters which are increasingly attributed to climate change could have intergenerational effects. In this paper, we examine the effects of cyclones *Sidr* and *Aila*, two of the major cyclones in last two decades, on children's nutritional status in Bangladesh. Since these types of extreme events are not predictable, we consider these as exogenous, random shocks to the households in affected areas. We study the nutritional status of children below 60 months of age who had been exposed to cyclones *Sidr and Aila,* and compare their nutritional status with children who were not exposed to those extreme events. The their birth month and those who were not.

The results show that climate events such as cyclone *Sidr* negatively affects nutritional gain of children exposed to the shocks. Our results show that cyclone *Sidr* significantly lowered Height for Age Z (HAZ) scores, and increased the likelihood of stunting and underweight among the exposed children. While the cyclone *Aila* apparently had no negative nutritional outcome, thorough analyses suggest that even a cyclone of significantly smaller scale compared to *Sidr* can have negative impact on the exposed children. Overall, the evidences suggest that events such as cyclones can adversely affect the three key nutritional scores – height for age (HAZ), weight for age (WAZ), and weight for height (WHZ). This is particularly important, as among other nutritional outcome indicators, lower height for age Z score is regarded as the long term consequence of lower nutritional intake. Our findings suggest that such extreme events can exert long term detrimental effects to hinder development of children of a generation exposed to such disasters.

The rest of the paper is organized as follows. Section 2 briefly summarizes the devastation cyclones *Sidr* and *Aila* caused in the affected areas, while section 3 briefly explains how such devastation can lower child nutrition. Section 4 discusses the related literature. In section 5 we describe the empirical strategies and the data. Results are presented in section 6. Finally, concluding remarks are made in section 7.

2. Cyclones *Sidr* and *Aila* and their devastations

Prone to natural disasters, Bangladesh experienced the devastation brought about by Super Cyclone *Sidr* – a category 5 on the saffir-simpson scale (BBC, 2007) equivalent tropical storm. *Sidr* made landfall on 15 November, 2007 in southwestern Bangladesh. It had wind speed of 240 km/hour peaking at 1-minute sustained winds of 260 km/hour (160 mph) and caused flood-storm surges estimated between 5 to 6 meters. *Sidr* caused severe damage in four southwestern districts (Bagerhat, Barguna, Patuakhali, Pirojpur) and moderate damage in another eight adjoining districts (Khulna, Madaripur, Shariatpur, Barisal, Bhola, Shatkhira, Jhalakati, and Gopalganj). *Sidr* was responsible for 3,500 deaths (another 1,000 missing) and over 55,000 injuries. In all, it affected 2.3 million households, approximately 1 million severely. The same general area was hit by Cyclone *Aila* on May 25, 2009. A Category 1 storm, *Aila* had wind speed of almost 120 km/hr and storm surges of 6 meters. *Aila* caused extensive damage in two southwestern districts (Khulna and Shatkhira), and damage in another seven adjoining districts (Barisal, Bhola, Pirojpur, Patuakhali, Barguna, Jhalakathi, Bagerhat). It caused 190 deaths and 7000 injuries. In all, *Aila* affected almost 1 million households, one hundred thousand severely.[3]

The two cyclones severely affected the lives and livelihoods of a large number of people in the southwestern part

[3] See Appendix B for the maps of *Sidr* and *Aila* affected areas

of Bangladesh. Table 1 provides estimates of damage to infrastructure, educational and hospital facilities, and production of goods and services from the cyclone *Sidr*. The dozen or so districts affected by *Sidr* and *Aila* had a population of almost 19 million in 2007 with a per km population density of 800. The affected districts had some of the highest poverty rates in the country. Bangladesh as a whole had a poverty rate of 40% (upper poverty line) in 2005. Khulna division, in contrast, had a 2005 poverty rate of 45.7% and the poverty rates in adjoining southwestern districts were similar if not higher. Thus, the two cyclones had a disproportionate impact on some of the most impoverished areas of the country. Damage from Cyclone *Sidr* was estimated at Bangladesh Taka (BDT) 116,000 million ((US$1.7 billion). The damage was concentrated with the housing sector losses accounting for almost half the total damages. Loss of physical infrastructure accounted for two-thirds of the damage. Housing and agricultural crop losses accounted for 75% of the estimated losses.

Of the approximately one million households severely affected, about two-thirds owned land, while a third received their primary income through production from the land. For most of these marginal land owners, income from land had to be supplemented by income from other sources, including livestock and paid labor in agriculture, fisheries and forestry. A large proportion also depended on non-farm businesses for livelihood. With a significant percentage of the region's population described as vulnerable (38%) or ultra-poor (17%), loss of agriculture related production, damage to infrastructure, and to non-farm businesses resulted in job and income losses. It was estimated that 75,000 wage workers lost jobs in the non-farm business sector. With employment losses of marginal land owners and those who depended on wage labor in the agriculture sector, plus the additional job losses in the non-farm business sector, it was estimated that 567,000 individuals (436,000 households) lost employment and income due to *Sidr*. This included 80,000 farm workers, 160,000 in non-farm business (owners/family, wage-workers), and 134,000 self-employed workers. The loss of housing, employment, and income specially exposed the vulnerabilities of the poorest of the population: marginal farmers, landless wage workers, and female headed households (Paul et. al., 2012). These vulnerabilities include malnutrition and increased susceptibility to air and water borne diseases. Extent of losses from *Aila* was less severe overall, but significant in the two districts of Khulna and Shatkhira. It was estimated that these two districts lost almost 143,000 homes (Table 2). Overall, almost 9000 miles of roads were damaged, and crops were fully or partially lost in over 320,000 acres of land. Though smaller than *Sidr*, effect of *Aila* is magnified by the fact that it affected the same general region as *Sidr*, and despite post *Sidr* relief efforts, people in this area were still struggling to overcome the impact of *Sidr*.

3. *Sidr* and *Aila*'s connection with child nutrition

In addition to exerting a negative impact on infrastructures and the overall economy, natural disasters can adversely affect households through negative income shocks. Consequently, natural disasters such as *Sidr* and *Aila* can cause significant damages to the nutritional outcome of the affected people (del Ninno and Dorosh, 2002; O'Donnell et. al., 2002). Studies report that *Sidr* in Bangladesh caused harm in general health outcomes by increasing prevalence of infectious diseases such as diarrhea, skin disease, hepatitis (jaundice) as well as mental health of the affected people (Kabir, 2014). Children, women, and the older adults have been identified as among the most vulnerable in the affected area. The death and damage caused by Cyclone *Sidr* resulted in household food insecurity and increased post-cyclone nutritional insecurity (Paul et. al., 2012).

Possible channels through which the natural disasters affect the household's investment in children which, in turn, affects child nutrition are: (*i*) the disruption of health services and damage to complementary infrastructure which is termed as the direct effects; (*ii*) the loss of assets and inventories and the death or illness of family members; (*iii*) the change in the income of the households damaged by the natural disasters. Loss of crops, jobs, and/or businesses caused by the disasters can reduce income[4]; and (*iv*) indirect effects are also felt by affected households due to sluggish regional macroeconomic activities that often follow such natural disasters.

Since natural disasters potentially reduce the households' consumption set through reduced permanent income of the affected households, natural disasters lead to a lower nutritional intake by children in the affected households. The situation~~s~~ worsen as the new limited household budget allocations predominantly favor adult males in the households because they are the main income earners (Harris-Fry, et. al., 2017). . Interruptions in health services, along with the loss of household assets as well as infrastructures lead households to lower investment expenditures on children. This in turn lowers children's nutrition intake resulting in poorer nutritional outcome. The effects of such disasters are magnified by the increased marginal costs of the goods and services associated with health outcomes. Damage to physical facilities, lack of health supplies, and availability of trained personnel to provide needed services are likely to worsen the situation. Similarly, the incapacity of a productive parent, the loss of crops, jobs or business lead to a fall in income that, in an environment of incomplete capital markets, can further tighten the household's budget constraint.

4. Related Literature

In addition to causing negative impact on wealth generation, natural disasters have important consequences for human health amongst the affected population. Approximately 2.4 percent of global diarrhea, 6% of malaria in middle income countries are claimed to be caused by climate change (WHO). More importantly, the most vulnerable groups that are affected by the extreme events are women and children (Bartlett, 2009). Natural disasters have been identified

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[4] Income, on the other hand, can also increase due to reconstruction initiatives that might arise from higher levels of public investment which might not be realized immediately

as a direct or indirect determinants of child nutrition in Bangladesh (Ahmed et al., (2015). Children's cognitive ability and other development are mostly determined by the nutritional status in their early age of 0-60 months (Hoddinot, 2014). Therefore, hindrances such as natural disasters that affect nutritional supply to and hence result in low nutritional intake by children of that age group can have adverse lifetime effects through lowered lower nutritional outcomes.

A number of studies focus on economic shocks caused by specific large events (Bustelo et al., 2012; Ninno and Lundberg, 2005; Foster, 1995; Santos 2010; Bustelo 2011 among others). Bustelo, Arends-Kuenning, Lucchetti (BAL, 2012) studied the effects of the 1999 Colombian earthquake on child nutrition and schooling. Using two cross sectional surveys before the earthquake and two (one and six years) after the earthquake, the authors concluded that there are strong effects on both schooling and nutrition in the short term, particularly in the most severely affected areas (Quindio Department), and also persistent weaker medium term, primarily on boys, effects. The weaker medium term effects could be due to the mitigating effects of very successful aid and reconstruction effort by the Colombian government following the earthquake.

Earlier studies estimating the effects of natural disasters include Foster (1995) and del Ninno and Lundberg (2005) respectively studying the impact of the 1988 and 1998 floods respectively in Bangladesh, Baez and Santos (2007) studying the impact of Hurricane Mitch in Nicaragua, Xiong et al (2008) of Hurricane Katrina in the United States, Santos (2010) on impact of earthquakes in El Salvador, and Bustelo (2011) examining the impact of Tropical Storm Stan in Guatemala. Later studies include Caruso (2015) of the 1993 floods in Tanzania, Danysh et al (2014) of El Nino in Peru. Baez and Santos and Kousky (2016) discuss the pathways through which natural disasters can have both short term and long term effect on children's health and educational status. For example, when a natural disaster destroys crops or reduces employment opportunities, credit constrained households may try to cope by reducing calorie intake, and/or by redirecting funds spent supporting child nutrition, schooling, and health. Because disasters damage roads, schools, and healthcare facilities, lack of access to health care can further intensify the effect of the disaster. Baez and Santos (2007) report that Hurricane Mitch destroyed one third of the country's crops, 300 schools, and rendered unusable dozens of health centers. The adverse effect on children may be further exacerbated by the need for children to go out and work to make up for lost family income. Santos and Baez report that children in areas affected by Hurricane Mitch were 30% less likely to receive medical care, the incidence of malnutrition among children in Mitch affect areas quadrupled, children's labor force participation increased and twice as many children were both enrolled in school and working after Hurricane Mitch than before. Regarding schooling and labor force participation, school enrollment in both Tanzania and Ivory Coast dropped about 20% following natural disasters. If such extreme event occurs more frequently, that will not only have short term effect on the children but can also have persistent long term effect. Effects of climate change leading to natural disasters are not limited to developing countries. Xiong et al (2008) in a study of 300 pregnant women exposed to Hurricane Katrina in the USA concluded that they were more likely to have pre-term births and low birth weight children. Dechenenes et al., (2009) examine 37.1 million US births to conclude that exposure to extreme hot temperatures result in low birth weight babies. Natural disasters in low income countries, which lack the institutional capacity to respond quickly to large natural disasters by mobilizing needed resources, are likely to see stronger adverse effects on child outcomes.

In the Bangladesh context, Foster reported that following the 1988 floods, children in credit constrained households were born with low birth weights. del Ninno and Lundberg (2005) examined the impact of the 1998 flooding in Bangladesh. In 1998, floods in Bangladesh over a significant area of the country affected 30 million people and caused over 1,000 deaths. It caused extensive damage to infrastructure. Over 15,000 miles of roads were lost, 140,000 schools were destroyed and many thousands of bridges and culverts were also lost. Two rice crops were partially affected. Almost 500,000 homes were also lost. With severe losses to income, assets, and employment opportunity, many households had to look for alternative resources to smooth consumption. As Foster had documented earlier, credit constraint households often fared worst in these situations with significant negative impacts on children health status. del Ninno and Lundberg (2005) point out that the consequences of such disasters could be completely short run. Suppose that households reallocate resources from children to other members of the family on the belief that once the acute period is over and distribution of household resources is normalized, children will catch up (grow faster than children unaffected by adverse effect) and attain normal health status. Alternatively, it is possible that affected children attain the same growth rate as unaffected children, but along a lower steady state path, with possible long term consequences on socioeconomic outcomes.

del Ninno and Lundberg use a three round balanced panel data set collected from seven thanas (sub-districts/police stations), involving 117 villages and 757 households. The data was collected over a one-year time period to study the health outcomes of children affected by flooding. Their dependent variable was alternatively height and weight-for-age z-scores. Their findings suggest that children affected by flooding had immediate adverse health impact, and that their health status did not catch up to the status of flood unaffected children within the study period of 1 year. For example, they report that height of flood affected children were .2 standard deviations or about 1 inch smaller than height of flood unaffected children. Using their panel data set the authors also estimated the growth rates for both flood exposed and unexposed children. The authors report that there is no evidence that exposed children grow faster to catch up to unexposed children. Exposed children grow at the same rate but along a lower steady state path relatively to unexposed children.

Lessons from India could be pertinent to Bangladesh due to proximity and similarities in socio-economic conditions. Datar et al (2011), instead of studying the health impact of one major event, focuses on the impact of a series of smaller adverse natural events that occurred over time in India. Smaller events are more frequent, and attract less attention, and hence attract less international and local public resources to mitigate the effects of these smaller events. They identify 228 smaller natural disaster events in the various states of India from 1992 to 2006. Their results suggest that exposure to a disaster has significant short run and medium term effect. If the exposure is during the past month, the likelihood of being affected by disease (diarrhea, fever, respiratory illness) increases by 9-18%. Exposure within the past year reduces height-for-age and weight-for-age z-scores between .12 and .15 standard deviations. Interestingly, though Datar et. al (2011) study a series of smaller events, the magnitude of the changes in the height-for-age z-scores are comparable to the scores reported by Ninno and Lundberg for a single large event in Bangladesh. Kabir (2014) reports that *Sidr* and *Aila* had caused harm in general health by increasing prevalence of infectious diseases such as diarrhea, skin disease, hepatitis (jaundice). More importantly, children, women, and the older adults have been identified the most vulnerable groups in the affected area.

In summary, there is a considerable evidence that natural disasters have many adverse effect on children. Children are more likely to work, less likely to go to school, and are more likely to experience adverse growth (height and weight) effects because of change in nutritional status.

5. Empirical Strategy

The objective of this paper is to examine whether cyclones *Sidr* and *Aila*–lowered investments in children leading to a deteriorated nutritional status of children living in areas affected by those extreme events. An ideal set-up is to estimate children's differential well-being by comparing the actual outcome of the affected child with what that outcome would have been in the absence of the shock, the counterfactual. Since we have a cross-sectional data set which does not allow us to have the same household in both affected and unaffected areas at the same time, construction of a proper counterfactual to assess the impact of the cyclones is not feasible. Existing literature on estimating effects of natural disasters on different outcomes suggests using difference-in-difference (DiD) estimation technique (Islam and Nguye, 2018; Chen and Zhou, 2007; Ureta, 2005; Jacoby and Skoufias, 1997). DiD is used by comparing outcome of children from two different regions both before and after the event to artificially construct a counterfactual. In order to construct a proper counterfactual to carry out the evaluation, mapping and distinguishing the observations of the affected area from that of unaffected area in the dataset is often intuitive. We follow this approach to study the effect of the two cyclones (events) on the development of children using standard outcome measures such as Height for Age (HAZ), Weight for Age (WAZ), and Weight for Height (WHZ) Z scores. While HAZ, WAZ, and WHZ are continuous scores, we also estimate the likelihood of stunting, underweight, and wasting. In order to calculate such under-nutritional statuses – stunted, underweight, and wasting – we use the World Health Organization (WHO) new reference variable provided in the Bangladesh Demography and Health Survey (BDHS).

Stunted, underweight, and wasting are defined if each of HAZ, WAZ, and WHZ, respectively, is lower than -200. In some cases, it is noticeable that reference point of those Z-scores is -2 instead of -200 which is just a scale down by dividing the Z-scores by 100.

We estimate the effect of the events using the standard recommendation in the similar studies: the difference in difference (DiD) estimation procedure. We observe children, 0-60 months, born both around the *Sidr* (event date T_1) and *Aila* (event date T_2) affected and non-affected areas ($Area_i$) before and after the cyclones (event). We utilize the Bangladesh Demographic and Health Survey (BDHS) 2011 dataset to estimate the effects of the two cyclones. The unique feature of the DHS data that it records the month of each child's birth which allows us to create a counterfactual for estimating the impact using the DiD approach. Our model specification is:

$$y_i = \alpha + \beta_1 T_{1i} + \beta_2 Area_i + \beta_3 interaction_{1i} + \beta_4 T_{2i} + \beta_5 Interaction_{2i} + \beta_6 \boldsymbol{X} + \epsilon_i \qquad (1)$$

Where y_i, is the dependent variable HAZ (or WAZ and WHZ respectively) that estimates the difference in Z-scores pre and post event (cyclone) in cyclone affected area minus the difference in HAZ (WAZ, WHZ) scores pre and post event in the areas not affected by the two cyclones. T_{1i} (T_{2i}) is a binary variable equal to 1 for observations after the event *Sidr* (*Aila*) and Area is a binary variable equal to 1 for observations in the *Sidr* (Alia) affected areas, 0 otherwise. The interaction terms (T X Area) is equal to 1 for observations in affected areas post event, 0 otherwise. **X** is the set of explanatory variables that includes child's gender, mother's characteristics (age at the time of survey, age at first birth, education level, employment status, height for age Z-score to indicate mother's long-term nutritional outcome), mother's empowerment indicators represented by the status of mother's being a victim of domestic violence, if the mother had the mobile phone to give access to information and connectivity, and household characteristics – household size, income level reported in different categories such as poorest, poor, middle-class, rich and richest. Our coefficients of interest are the two interaction terms, β_3 and β_5 which pick up the differential effect of the two cyclones on our measure of interest. We repeat the same model with Stunting (Underweight and Wasting) as the dependent variable, except that we use logistics regression for the latter cases.

Since we have data on birth months, we can deduce approximate conception months for the observed children. We subdivide our sample based on the conception month into three distinct sub-groups: children born before the events *Sidr* and *Aila* (neonatal), children born after the events to mothers who were pregnant during the events (in-utero), and children born to mothers who conceived after the events (pre-utero). While estimating equation (1) using the month of birth, the cyclone event times, and affected areas to create artificial counterfactuals within the whole sample, these sub-groups provide us with scopes to test any potential effects exposure to cyclones might have exerted on children exposed directly (neonatal) and indirectly (in-utero, and pre-utero). While the interaction represented by Utero indicates those children who were born to mothers exposed to the cyclone, we also created three subgroups of children in Utero group by the trimester of their mothers' pregnancy when the cyclone hit – first, second, and third trimester. Neonatal, Utero, and Pre-utero are the interaction terms in the model, and the coefficients β_3 (β_5) respectively pick the differential effect of *Sidr* (*Aila*) on the health status of the children in the event affected areas.

6. Data

We used the 2011 Bangladesh Demographic and Health Survey (BDHS 2011) data for estimating equation (1). The Demographic and Health Surveys (DHSs) are nationally representative surveys of women age 15-49 and their households. In addition to collecting socio-economic characteristics of households and its members, the DHS surveys collect data on anthropometric indicators to provide outcome measures of nutritional status of under-five children. The study only considers data on children age 0-59 months belonging to interviewed, de facto women. The 2011 BDHS reported information about 17,749 ever-married women and 3,997 ever married men aged 15-49 years. The survey also collected detail information about 7,861 children those who were born in January 2006 or later. We used the unique feature in the BDHS data that it collects the birth month of each child in the century year month code – CMC. The *CMC* in the BDHS survey indicates the month and year of birth of a child and is used to track the date of birth of each child in the survey. CMC in BDHS 2011 ranges from 1280 to 1344, where CMC=(YY*12)+MM, YY indicates the last two digits of the year, and MM is the month code. Month and year can be retrieved from the CMC using the following formulae: YY=int((CMC-1)/12); MM=CMC-(YY*12). CMC for dates 2000 and afterward is calculated as follows: CMC=(YYYY-1900)*12)+MM for month MM in year YYYY. Year and month can be retrieved from the *CMC* using the following formulae: $YYYY = int((CMC - 1)/12) + 1900$, and $MM = CMC - ((YYYY - 1900) * 12)$ respectively. Using the formulae, T_1=1 for $CMC > 1295$ ($CMC = 1295$ for *Sidr*) indicates the child was born post-*Sidr* that took place in the first half of November 2007; and T_1=0 without the cyclone shocks ($CMC \leq 1295$). On the other hand, the corresponding threshold time for exposure to cyclone *Aila* shock is represented by T_2=1 for $CMC > 1313$ ($CMC = 1313$ for *Aila*) indicates the child was born post-*Sidr* that took place in the May 2009; and T_2=0 without the exposure to cyclone *Aila* ($CMC \leq 1313$). Table 2 presents the summary statistics of key information associated with the households in our sample. The sampled households had a little over 1 child per family while average household size had 5.8 members per family, the mother of the family had the first child around 18 years of age, and about 40% of the households come from the lowest income groups (poor+poorest) - the group of households most vulnerable to extreme events like cyclone and floods. About half the children in our sample is male and the remaining half female. About two-thirds reported to include family planning in their conjugal lives, while 81% female had mobile phone for communication.

7. Results

Effects of two cyclones on HAZ and likelihood of stunting are reported in Table 3. Tables 4 and 5 report the corresponding results associated with the effects on WAZ and likelihood of wasting, and on WHZ and likelihood of underweight, respectively. The HAZ score is a long-term measure of nutritional outcome. Columns numbered (1)-(4) indicate the model where months corresponding to birth related different stages (such as birth, conception before and after the cyclones) and the months cyclones *Sidr* and *Aila* hit in the districts of two divisions have been used to create counterfactuals: (1) considering children's birth after the cyclones hit; (2) children who were already in their first 12 months of age at the time the cyclones hit and those born after the cyclones; (3) mothers of children were at different trimesters of their pregnancy during the cyclones hit; and (4) and mothers of children conceived after the cyclones hit as those children were born at least 10 months after each cyclone hit. Household's economic status and key characteristics related to mothers have been controlled for such as mothers' age, age at first birth, education level, employment, height-for-age standard deviation indicating mother's long-term health outcome, number of child at home, child's sex, incidence of domestic violence, whether mother has a mobile phone for communication, household's location (rural or urban), and different economic status – poorest, poor, middle-class, rich and the richest, and upazila (sub-district) fixed effects. Clustered (at upazila level) standard errors have been used. Household level weight provided by the BDHS has been used to estimate the corresponding model.

HAZ and likelihood of stunting

The results, reported in Table 4, suggest a significant drop in HAZ scores for children in the *Sidr* affected areas, contrary to that in cyclone *Aila* affected areas. while cyclone *Sidr* on an average lowered HAZ score (by 31 z-scores) and raised the stunting probability by 12%, evidence for children exposed to *Aila* are opposite – increased HAZ score by 34 and lowered stunting probability by 10%. However, children born before the cyclone *Aila* are on average have 22 less HAZ scores and are more likely (by 8%) to be stunted. In addition, the children whose mothers were exposed to cyclones either in-utero or pre-utero time led the children to lower HAZ scores and were more likely to be stunted. Results indicate that children whose mothers were exposed to cyclones *Sidr* lowered HAZ score if exposed during the second and third trimesters (by 30 and 46 HAZ scores, respectively). However, it did not alter the likelihood of stunting if exposed to *Sidr* in-utero. Households exposed to back-to-back cyclones led the HAZ and stunting likelihood to a worse direction. That is, if women were exposed to the cyclone *Aila* during any of the trimesters of their pregnancy, their children had lower HAZ scores (74, 31, and 45 for exposure in the first, second, and third trimester respectively). In addition, children were 22 percent more likely to be stunted if their mothers had exposure to the cyclone *Aila* in the first trimester of their pregnancy. Our results suggest that effects of exposure to *Sidr* and *Aila* like severe natural disasters continue to exert negative impact over an extended time period. Regression results (Model 4) suggest that children whose mothers were exposed to those extreme events even before conception have been associated with lowered HAZ scores (-37 and -48 due to *Sidr* and *Aila* respectively) and increased likelihood of stunting (11% and 10% due to *Sidr* and *Aila* respectively.

The results suggest significant adverse long-term health effect of *Sidr* and *Aila* on children in the hurricane affected areas with HAZ scores dropping by 26-49 HAZ scores. Results for *Aila* show that health status on average, considering the counterfactual based on children's birth pre-and post-*Aila*, improved since the HAZ scores are significantly positive. However, estimation based on different definitions of counterfactuals show that mothers of children having exposure to each cyclone had dropped HAZ scores and increased incidence of stunting for children who were in their first 12 months of age when the cyclone *Aila* hit. This might indicate that the impact of *Sidr* prolonged at least 18 months which was compounded due to two consecutive mega cyclones hit.

WAZ and the likelihood of underweight

WAZ scores are reported in Table 5, and exhibit a pattern similar as the of HAZ scores reported in Table 4. As in the case of HAZ scores, Cyclone *Sidr* resulted in a significant drop of 26 in the WAZ score, but the WAZ score went up by 48 and the likelihood of underweight dropped by 16% for children born in post Cyclone *Alia*. Results are quite different for children born before *Aila* (Table 5, Column 2). For this group of children, exposure to *Aila* lowered the WAZ score by 36 and increased the likelihood of being underweight by 13%. Children born before *Aila* were directly or indirectly affected by *Sidr* which might be the possible source of drop in WAZ score and increased likelihood of underweight due to exposure to *Aila*. That being said, even though the super cyclone *Sidr* was not damaging to those children who were in their first 12 months of age at the time *Sidr* hit, frequent incidence of such events even at a smaller scale might make the affected children vulnerable. Column 3 provides further evidence of the detrimental effects of the two cyclones. Results show that children, who were born to mothers exposed to *Sidr* any time during their pregnancy and to mothers exposed to *Aila* during the first trimester of their pregnancy, had significantly lowered WAZ score. Further, results reported in Column 4 of Table 5 show that children conceived and born after the two cyclones had significantly lower WAZ scores. The HAZ and WAZ scores reported in Tables 4 and 5 suggest that along with the exposure of children to extreme climate effect, exposure of expectant mothers and near expectant mothers are as important factors in explaining the detrimental impact on children. It is quite possible that lack of employment opportunities and lower income, destruction of infrastructure, including health facilities, significantly lowers nutritional intake and access to healthcare of child bearing age women, particularly women who are pregnant. Therefore, children born to women exposed to these extreme climate effects have higher incidence of stunting and are underweight.

WHZ and the likelihood of wasting

Cyclone *Sidr* had no significant impact on WHZ and wasting on those children born after the cyclones hit in the affected area relative to those outcomes of their counterfactuals, children exposed to *Aila* had on average 41 higher WHZ score and were 6% less likely to be wasted (Table 6). However, children born before the cyclones *Sidr* and *Aila* had lower WHZ scores (by 19 and 35 attributed to *Sidr* and *Aila* respectively), while only those exposed to cyclone *Sidr* in the first year after their birth were more likely to be wasted. Mothers' exposure to *Sidr* at different trimesters led to reduction in WHZ scores without any change in likelihood of wasting, while cyclone *Aila* had exerted no impact on WHZ scores. Mothers' exposure to cyclones during pregnancy did not exert any impact on the likelihood of wasting except to reduce the likelihood of wasting of the children whose mothers were exposed to *Aila* during the third trimester of their pregnancy. *Sidr* effects on WHZ scores, as had on HAZ and WAZ, lasted over a much longer time period by lowering the WHZ scores for children whose mothers were victims of the cyclone *Sidr* even before their pregnancy period.

Heterogeneity of cyclones effects

While we have consistently found that exposure to super cyclone *Siddr* has largely negative nutritional outcomes of the children exposed directly or indirectly, effects of *Aila* has not been found to be consistent in any direction. The possible reason might be the heterogeneity of cyclones might exert effects differently on different groups based on children's gender, their households' economic status, etc. In-order to check for heterogeneity, we also estimated the impacts of the cyclones with respect to several socio-economic characteristics. This will help us identify the specific groups that are more vulnerable to such natural disasters. We have utilized the DHS's classification of household's economic status – poorer, poor, middle-class, rich, and richer – to estimate the differential nutritional outcome, if any, of children from households of different economic statuses that are due to exposure to cyclones. We combined the DHS's five economic categories into three – poor (combination of poorer and poor), middle-class, and rich (combination of rich and richer). Tables 7-12 present the related results that report only the key coefficients: β_3 and β_5 in equation 1. In Table 7, we report the overall impact of the cyclones on children from different economic groups that is comparable to table 4. HAZ and WAZ shows a detrimental effect on children from middle and upper income groups following *Sidr* but that the same scores go up for all income groups following *Aila*. But when the sample is restricted to the very young (Children 1 – 12 months old), results reported in Table 8 show HAZ and WAZ scores are lower for children coming from the lowest income class following both *Sidr* (-32 and -25) respectively) and *Aila* (-46 and -49 respectively). The incidence of stunting and underweight were, as a result, higher among children 1-12 months old. WHZ scores were lower for this age groups, but the lower scores were statistically significant only following *Aila*. While all the numbers indicated higher wasting incidence, the numbers were not statistically significant. Therefore, there is no change in the likelihood of wasting following exposure to either of the cyclones which might be due to the fact that, among all three nutritional outcome indicators, HAZ is the longer term indicator compared to the other two.

Results reported in Table 9 are for children born to mothers who were at various stages of pregnancy during the two cyclone (in-utero). Except for a handful of statistically insignificant increase in HAZ, WAZ, and WHZ scores, the reported numbers provides strong evidence that children born to mothers who were pregnant at the time of the extreme events suffered because of the events. Almost all the reported HAZ, WAZ, and WHZ scores are lower. Results show that for those in the middle income and upper group, HAZ scores were lower if the mother was in second trimester of pregnancy following *Sidr* (-64, -24), and the first and third trimester of pregnancy following *Aila* (1st Trimester (-53, -101), 3rd Trimester (-83, -41). Following *Sidr*, WAZ scores are also lower for children born to mothers from: i. middle and upper income groups who were in the 2nd trimester of pregnancy; ii. All three income groups who were in the 3rd trimester of pregnancy. Following *Aila*, WAZ scores were lower for children born to mothers from: i. upper income groups in their first trimester of pregnancy, and, ii. Middle income group in their second trimester of pregnancy.

In Table 10, we report the effects of the two cyclones who were conceived after the cyclones. For all three income groups, there is strong evidence irrespective of the measure used, HAZ, WAZ, and WHZ, the two cyclones had significant negative nutritional impact on children conceived and born after the two events. The drop in the scores are more pronounced for the children conceived after *Sidr*, the larger of the two cyclones. Finally, in Table 11-12, we report the impact of the two cyclones based on the gender of the affected child. Since HAZ score indicates the nutritional intake for a longer term compared to other two measures, we report only the results of the effects of cyclones on HAZ scores for the children of both outcomes. Lower HAZ scores are observed for both Male and Female children affected by *Sidr*, for Male children born before *Aila*, for Male (Female) children whose mothers were in 3rd (2nd) trimester of pregnancy during *Sidr* and for Male (Female) children whose mothers were in the 1st and 3rd (1st) trimester of pregnancy at the time of *Aila*. For both Male and Female children conceived and born after the two cyclones, the HAZ scores are significantly lower and the likelihood of stunting significantly higher.

Overall, we find that super cyclone *Sidr* has caused negative impacts on households' ability to provide improved nutritional supply to their children of age from before birth to 60 months old, while *Aila* exhibits mixed results. A possible reason for having improved outcomes those born after *Aila* might be the active engagement of government and non-government agencies' post-cyclone relief activities. This is specially more important that Yang (2008) report that, relative other natural disasters such as floods, developing countries realize more financial flows after hurricanes that might lead to such positive outcomes after *Aila*. However, we also observed negative impact of the smaller scale cyclone *Aila* for a certain groups of children. In particular, since children born before or after *Aila* were directly or indirectly affected by *Sidr* that might make them more vulnerable to even a smaller shock This suggests that despite massive assistances from home and abroad cyclones, children from affected households are more vulnerable to even a much smaller climate shock. For example, even though the super cyclone *Sidr* was not damaging to those children who were in their first 12 months of age at the time *Sidr* hit, frequent incidence of such events even at a smaller scale might make the affected children vulnerable.

8. Conclusion

Natural disasters do not only cause volatilities in income and livelihoods, those extreme events have long term effects on the overall growth and welfare of a generation through the reduction in nutritional intake of children who are exposed to such events. More importantly, adverse shocks in early childhood can have substantial negative impacts on a person's life-long outcomes. If the predictions of the climate change models bear out, Bangladesh could be affected by frequent and severe natural disasters. Such natural disasters include, but is not limited to, floods due to rising sea levels and cyclones such as the Category 5 *Sidr* that hit the coastal divisions-districts in 2007. Women and children are the most vulnerable group that are at risk of severe detrimental effects from such of natural disasters. Adverse shocks in early childhood life causes negative impacts in adult outcomes such as cognitive ability leading to lower lifetime earnings, and to a life-long sustained negative impacts. Specifically, it has been shown that nutritional status in the early ages of 0-60 months of a child determines cognitive ability and other developments in adult life (Hoddinot, 2014). Using month of birth information in Bangladesh Demographic and Health Survey (BDHS) 2011 data, we examined the impact of a category-5 cyclone *Sidr* and a less severe cyclone *Aila* on child malnutrition in Bangladesh. The results show climate events such as cyclone *Sidr* and *Aila* negatively affects nutritional gain of children exposed to the shocks. We find that *Sidr* significantly lowered Height for Age Z (HAZ) scores, and increased the likelihood of stunting and underweight among the exposed children. The evidence suggests that events such as cyclones can have adverse long term development of the exposed children as, among three key nutritional scores – height for age (HAZ), weight for age (WAZ), and weight for height (WHZ). This is in particularly important as among other nutritional outcome indicators, height for age Z score is regarded as the consequence of long-term nutritional intake. Our findings suggest that such extreme events can exert long term detrimental effects to hinder development of children of a generation exposed to such disasters. Our findings also suggest that despite massive assistance from home and abroad after a natural disaster, affected households are much more vulnerable to climate shock of even a much smaller scale.

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Table 1: *Sidr* Damage and Loss Assessment, BDT (2008) (116m BDT; US$1.7b)

		Damage and Loss Effects			Ownership	
Sector	Subsector	Damage	Losses	Total	Public	Private

Infrastructure		71,064	2,130	73,194	15,758	57,436
	Housing	57,915		57,915		57,915
	Transport	8,006	1,725	9,731	8,006	1,725
	Electricity	576	359	935	935	
	Water and Sanitation	157	46	203	203	
	Urban and Municipal	1,696		1,696	1,696	
	Water Resource Control	4,918		4,918	4,918	
Social Sectors		4,482	1,453	5,934	5,485	449
	Health and Nutrition	169	1,038	1,206	1,188	18
	Education	4,313	415	4,728	4,297	431
Productive Sectors		1,734	32,083	33,817	19	33,798
	Agriculture	1,472	28,725	30,197	19	30,178
	Industry	262	2,035	2,297		2,297
	Commerce		1,258	1,258		1,258
	Tourism		65	65		65
Cross-Cutting		420	0	420	420	0
	Environment	420		420	420	
Total		79,904	35,665	115,569	21,682	93,888

Source: Government of Bangladesh Report (2008), "Cyclone Sidr in Bangladesh: Damage, Loss and Needs Assessment for Disaster Recovery and Reconstruction. https://reliefweb.int/sites/reliefweb.int/files/resources/F2FDFF067EF49C8DC12574DC00455142-Full_Report.pdf Last accessed on July 2, 2019.

Table 2: *Aila* Damage and Loss Assessment

Sector		Total	Fully	Partially
Infrastructure	Houses (no. KS**only)	142,706	94,609	48,097
	Roads (km)	8,854	2,233	6,621
	Embankments (Km)	1,794	237	1,557
	Bridges	157	157	
	Tube Wells (no. KS only)	1,038	1,038	
Institutions		5,033	445	4,588
Productions	Crops (acres)	323,454	77,486	245,968
	Livestock	100,000		

Table 3: Summary statistics of households' socio-economic characteristics

Variable	Mean	Std. dev.
Household size	5.80	2.18
Number of children in house	1.22	0.65
Child (Male=1)	0.51	0.50
HH head's age	42.55	14.52
Father's age	34.43	8.24
Father's education (years of schooling)	3.44	1.56
Agriculture as the main profession	0.27	0.45
Mother's age	25.35	5.88

Mother's education (years of schooling)	3.17	1.59
Mother’s age at first birth	18.18	3.42
Family planning (1=Yes)	0.73	0.44
Woman has a mobile phone (1=Yes)	0.81	0.39
Poor	0.41	0.41
Middle-class	0.19	0.39
Rich	0.40	0.49
Rural households	0.69	0.46

Table 4: Effects of cyclones *Sidr* and *Aila* on height for age z-score (HAZ) and likelihood of stunting

	HAZ scores				Likelihood of stunting			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Post-*Sidr* X Affected area	-30.93***				0.12***			
	(9.69)				(0.04)			
Post-*aila* X Affected area	33.50***				-0.10***			
	(8.69)				(0.03)			
Neonatal during *Sidr*		5.76				-0.06		
		(10.14)				(0.04)		
Neonatal during *Aila*		-21.67**				0.08**		
		(9.91)				(0.03)		
Trimester 1 during *Sidr*			-10.47				0.05	
			(17.26)				(0.07)	
Trimester 2 during *Sidr*			-30.43**				0.05	
			(12.10)				(0.06)	
Trimester 3 during *Sidr*			-45.66***				0.10	
			(15.61)				(0.07)	
Trimester 1 during *Aila*			-74.37***				0.22***	
			(14.34)				(0.07)	
Trimester 2 during *Aila*			-30.88*				0.02	
			(16.18)				(0.06)	
Trimester 3 during *Aila*			-45.28***				0.08	
			(15.73)				(0.06)	
Pre-utero during *Sidr*				-36.76***				0.11***
				(7.51)				(0.03)
Pre-utero during *Aila*				-48.37***				0.10***
				(9.47)				(0.04)
N	6124	6117	6117	6117	6117	6124	6117	6117

Notes: Numbers in parentheses are cluster (clustered at sub-district level) standard errors. (1), (2), and (3) are the corresponding specifications. ***, **, and * indicate statistically significant at 1%, 5%, and 10% respectively.

Table 5: Effects of cyclones *Sidr* and *Aila* on weight for age z-score (WAZ) and likelihood of underweight

	WAZ score				Likelihood of being underweight			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Post-*Sidr* X Affected area	-26.17***				0.06			
	(8.93)				(0.04)			
Post-*aila* X Affected area	48.49***				-0.16***			
	(6.68)				(0.03)			
Neonatal during *Sidr*		-9.80				0.05		
		(8.90)				(0.03)		
Neonatal during *Aila*		-35.69***				0.13***		
		(8.48)				(0.04)		
Trimester 1 during *Sidr*			-32.27**				0.05	
			(14.48)				(0.07)	
Trimester 2 during *Sidr*			-36.17***				0.04	
			(11.18)				(0.05)	
Trimester 3 during *Sidr*			-49.34***				0.12**	
			(10.65)				(0.05)	
Trimester 1 during *Aila*			-31.55**				0.04	
			(15.06)				(0.06)	
Trimester 2 during *Aila*			-12.47				0.05	
			(12.63)				(0.05)	
Trimester 3 during *Aila*			-16.66				-0.05	
			(13.01)				(0.06)	
Pre-utero during *Sidr*				-43.01***				0.11***

				(6.58)				(0.03)
Pre-utero during *Aila*				-19.73**				0.02
				(8.61)				(0.04)
N	6124	6117	6117	6117	6117	6124	6117	6117

Notes: Numbers in parentheses are cluster (clustered at sub-district level) standard errors. (1), (2), and (3) are the corresponding specifications. ***, **, and * indicate statistically significant at 1%, 5%, and 10% respectively.

Table 6: Effects of cyclones *Sidr* and *Aila* on weight for height z-score (WHZ) and likelihood of wasting

	WHZ score				Likelihood of wasting			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Post-Sidr X Affected area	-12.12				-0.01			
	(8.5)				(0.03)			
Post-aila X Affected area	41.33***				-0.06**			
	(6.83)				(0.02)			
Neonatal during Sidr		-18.8*				0.06*		
		(9.91)				(0.03)		
Neonatal during Aila		-34.76***				0.04		
		(7.56)				(0.03)		
Trimester 1 during Sidr			-40.06**				0.04	
			(15.63)				(0.06)	
Trimester 2 during Sidr			-27.13*				0.01	
			(15.48)				(0.04)	
Trimester 3 during Sidr			-32.23**				0.06	
			(14.39)				(0.04)	
Trimester 1 during Aila			-1.67				0.01	
			(19.69)				(0.06)	
Trimester 2 during Aila			-2.8				-0.03	
			(12.86)				(0.05)	
Trimester 3 during Aila			4.62				-0.11**	
			(13.78)				(0.05)	
Pre-utero during Sidr				-32.16***				0.05
				(9.32)				(0.03)
Pre-utero during Aila				-0.39				-0.03
				(8.82)				(0.03)
N	6124	6117	6117	6117	6117	6124	6117	6117

Notes: Numbers in parentheses are cluster (clustered at sub-district level) standard errors. (1), (2), and (3) are the corresponding specifications. ***, **, and * indicate statistically significant at 1%, 5%, and 10% respectively.

Table 7: Effects of exposure to cyclones *Sidr* and *Aila* on children from different economic groups

	HAZ score			Likelihood of stunting		
	Poor	Middle class	Rich	Poor	Middle class	Rich
Sidr effect[a]	-10.81	-40.01*	-39.56***	0.09	0.24***	0.11*
	(14.69)	(20.97)	(13.84)	(0.07)	(0.09)	(0.06)
Aila effect[b]	43.04***	43.15**	13.61	-0.17***	-0.11*	-0.02
	(14.17)	(18.35)	(14.23)	(0.05)	(0.06)	(0.05)
N	2095	1269	2760	2087	1253	2750
	WAZ score			Likelihood of underweight		
Sidr effect[a]	-13.00	-35.41**	-32.67**	0.02	0.11	0.06
	(13.95)	(16.88)	(15.19)	(0.06)	(0.08)	(0.06)
Aila effect[b]	46.14***	60.29***	45.04***	-0.16***	-0.19***	-0.14***
	(9.83)	(13.41)	(12.59)	(0.05)	(0.06)	(0.05)
N	2095	1269	2760	2087	1254	2749
	WHZ score			Likelihood of wasting		
Sidr effect[a]	-12.92	-14.38	-12.97	-0.01	0.00	-0.01
	(15.14)	(19.90)	(16.71)	(0.05)	(0.07)	(0.06)
Aila effect[b]	28.75***	47.61***	53.22***	-0.05	-0.06	-0.05
	(9.90)	(15.05)	(12.22)	(0.04)	(0.05)	(0.03)
N	2095	1269	2760	2049	1140	2662

Notes: [a] interaction: Post-*Sidr* X Affected area; [b] interaction: Post-*Aila* X Affected area Numbers in parentheses are clustered (clustered at sub-district level) robust standard errors. ***, **, and * indicate statistically significant at 1%, 5%, and 10% respectively.

Table 8: Effects of exposure to cyclones *Sidr* and *Aila* on children of 1-12 months old during the cyclones: different economic groups

	HAZ score			Likelihood of stunting		
	Poor	Middle class	Rich	Poor	Middle class	Rich
Sidr effect[a]	-31.54**	25.80	30.66**	0.06*	-0.23	-0.10*
	(15.65)	(21.11)	(13.99)	(0.07)	(0.09)	(0.06)
Aila effect[b]	-45.99***	-8.48	-2.77	0.18***	-0.00	0.05
	(14.52)	(19.93)	(16.95)	(0.05)	(0.07)	(0.06)
N	2095	1269	2760	2087	1253	2750
	WAZ score			Likelihood of underweight		
Sidr effect[a]	-24.85*	-2.70	-0.76	0.11	-0.03	0.03
	(14.50)	(16.76)	(14.88)	(0.06)	(0.08)	(0.05)
Aila effect[b]	-48.56***	-39.09**	-22.97	0.19**	0.11	0.09*
	(12.71)	(16.63)	(14.97)	(0.06)	(0.07)	(0.05)
N	2095	1269	2760	2087	1254	2749
	WHZ score			Likelihood of wasting		
Sidr effect[a]	-5.39	-27.69	-27.55	0.02	0.08	0.08
	(13.80)	(19.08)	(16.77)	(0.05)	(0.07)	(0.05)
Aila effect[b]	-33.20***	-50.14***	-31.96**	0.03	0.05	0.03
	(12.32)	(16.16)	(12.97)	(0.04)	(0.06)	(0.05)
N	2095	1269	2760	2049	1140	2662

Notes: [a] interaction: Post-*Sidr* X Affected area; [b] interaction: Post-*Aila* X Affected area Numbers in parentheses are clustered (clustered at sub-district level) robust-standard errors. ***, **, and * indicate statistically significant at 1%, 5%, and 10% respectively.

Table 9: Effects of exposure to cyclones *Sidr* and *Aila* on children who were in utero (different trimesters) during the cyclones: different economic groups

	HAZ score			Likelihood of stunting		
	Poor	Middle class	Rich	Poor	Middle class	Rich
Trimester 1 during Sidr	7.14	-26.88	-8.34	-0.04	0.10	0.05
	(32.38)	(29.65)	(18.58)	(0.12)	(0.14)	(0.07)
Trimester 2 during Sidr	-6.50	-63.88*	-23.85	-0.01	0.19	0.01
	(24.61)	(35.49)	(16.25)	(0.10)	(0.13)	(0.09)
Trimester 3 during Sidr	-24.38	-82.65*	-35.52*	0.11	0.21*	-0.00
	(21.85)	(42.00)	(19.40)	(0.08)	(0.12)	(0.11)
Trimester 1 during Aila	-62.98	-53.36*	-101.51***	0.19	0.07	0.37***
	(40.65)	(32.36)	(16.37)	(0.12)	(0.15)	(0.10)
Trimester 2 during Aila	-33.86	-18.26	-24.89	0.12	-0.02	-0.04
	(31.18)	(41.91)	(19.45)	(0.11)	(0.13)	(0.08)
Trimester 3 during Aila	-30.01	-82.55***	-41.33*	-0.00	0.16	0.10
	(28.16)	(29.08)	(24.12)	(0.11)	(0.10)	(0.08)
N	2095	1269	2760	2087	1253	2750
	WAZ score			Likelihood of underweight		

Trimester 1 during Sidr	-29.79	-52.58	-21.66	-0.02	0.29**	0.05
	(19.22)	(32.63)	(26.10)	(0.12)	(0.14)	(0.11)
Trimester 2 during Sidr	-6.95	-54.24***	-53.84***	-0.02	0.12	0.04
	(19.62)	(18.96)	(20.21)	(0.08)	(0.11)	(0.08)
Trimester 3 during Sidr	-32.89*	-67.19***	-62.73***	0.02	0.22*	0.19***
	(17.10)	(18.10)	(16.80)	(0.10)	(0.12)	(0.07)
Trimester 1 during Aila	-8.61	-20.55	-69.03***	0.07	-0.19	0.13
	(25.24)	(38.86)	(21.81)	(0.10)	(0.19)	(0.08)
Trimester 2 during Aila	-29.09	-11.04	1.51	0.24**	0.01	-0.02
	(22.27)	(38.31)	(16.30)	(0.12)	(0.11)	(0.09)
Trimester 3 during Aila	-27.09	-51.40**	4.74	-0.01	-0.03	-0.02
	(20.27)	(23.18)	(25.05)	(0.10)	(0.12)	(0.09)
N	2095	1269	2760	2087	1254	2749
		WHZ score			Likelihood of wasting	
Trimester 1 during Sidr	-51.60**	-51.83	-24.24	0.07	0.10	0.01
	(22.75)	(32.29)	(29.33)	(0.11)	(0.16)	(0.10)
Trimester 2 during Sidr	-2.74	-18.99	-59.22**	-0.00	-0.15	0.10*
	(23.37)	(29.50)	(28.61)	(0.07)	(0.11)	(0.05)
Trimester 3 during Sidr	-27.18	-22.77	-58.68***	0.06	0.13	0.05
	(23.83)	(33.51)	(21.48)	(0.08)	(0.09)	(0.07)
Trimester 1 during Aila	18.67	3.20	-37.41	-0.00	0.01	0.04
	(29.29)	(32.25)	(31.70)	(0.08)	(0.15)	(0.08)
Trimester 2 during Aila	-30.17	-8.55	16.22	0.06	-0.02	-0.13*
	(27.81)	(37.02)	(15.42)	(0.09)	(0.11)	(0.08)
Trimester 3 during Aila	-24.75	-15.52	31.48	-0.05	-0.25**	-0.08
	(18.69)	(21.86)	(30.91)	(0.09)	(0.12)	(0.08)
N	2095	1269	2760	2049	1140	2662

Numbers in parentheses are clustered (clustered at sub-district level) robust-standard errors. ***, **, and * indicate statistically significant at 1%, 5%, and 10% respectively.

Table 10: Effects of exposure to cyclones *Sidr* and *Aila* on children whose mothers conceived them after the cyclones: different economic groups

	HAZ score			Likelihood of stunting		
	Poor	Middle class	Rich	Poor	Middle class	Rich
Sidr effect[a]	-22.22*	-72.79***	-24.56*	0.09*	0.27***	0.02
	(12.85)	(21.17)	(12.73)	(0.05)	(0.08)	(0.06)
Aila effect[b]	-45.88***	-39.14*	-52.50***	0.09	0.07	0.13***
	(16.89)	(22.70)	(12.30)	(0.07)	(0.08)	(0.05)
N	2095	1269	2760	2087	1253	2750
	WAZ score			Likelihood of underweight		
Sidr effect[a]	-24.25***	-70.61***	-46.34***	0.07*	0.23***	0.08*
	(8.90)	(14.73)	(11.20)	(0.05)	(0.08)	(0.05)
Aila effect[b]	-18.21	-28.20	-16.98	0.10	-0.01	-0.00
	(14.25)	(19.10)	(11.26)	(0.06)	(0.07)	(0.06)
N	2095	1269	2760	2087	1254	2749
	WHZ score			Likelihood of wasting		
Sidr effect[a]	-16.81	-36.93*	-47.26***	0.04	0.05	0.06
	(13.30)	(21.22)	(15.37)	(0.05)	(0.07)	(0.04)
Aila effect[b]	-3.83	-18.28	6.72	-0.02	0.01	-0.03
	(13.81)	(16.09)	(13.99)	(0.05)	(0.06)	(0.04)
N	2095	1269	2760	2049	1140	2662

Notes: [a] interaction: Post-*Sidr* X Affected area; [b] interaction: Post-*Aila* X Affected area Numbers in parentheses are clustered (clustered at sub-district level) robust-standard errors. ***, **, and * indicate statistically significant at 1%, 5%, and 10% respectively.

Table 11: Effects of cyclones *Sidr* and *Aila* on male children: HAZ score and likelihood of stunting

	HAZ score				Likelihood of stunting			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Post-Sidr X Affected area	-49.13***				0.20***			
	(13.66)				(0.05)			
Post-aila X Affected area	37.70***				-0.14***			
	(13.71)				(0.04)			
Neonatal during Sidr		18.69				-0.09		
		(14.09)				(0.05)		
Neonatal during Aila		-32.35**				0.16***		
		(14.03)				(0.05)		
Trimester 1 during Sidr			-21.20				0.06	
			(21.11)				(0.09)	
Trimester 2 during Sidr			-16.33				-0.03	
			(19.67)				(0.08)	
Trimester 3 during Sidr			-69.74***				0.15**	
			(20.68)				(0.07)	
Trimester 1 during Aila			-95.47***				0.35***	
			(19.55)				(0.11)	
Trimester 2 during Aila			-33.39				-0.06	
			(25.91)				(0.07)	
Trimester 3 during Aila			-60.26***				0.05	
			(22.29)				(0.08)	
Pre-utero during Sidr				-34.96***				0.11***
				(11.84)				(0.04)
Pre-utero during Aila				-55.61***				0.10*
				(14.78)				(0.05)
N	3142	3140	3140	3140	3136	3138	3136	3136

Notes: Numbers in parentheses are clustered (clustered at sub-district level) robust-standard errors. ***, **, and * indicate statistically significant at 1%, 5%, and 10% respectively.

Table 12: Effects of cyclones *Sidr* and *Aila* on female children: HAZ score and likelihood of stunting

	HAZ score				Likelihood of stunting			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Post-Sidr X Affected area	-21.98*				0.08			
	(13.26)				(0.06)			
Post-aila X Affected area	31.76***				-0.06			
	(9.02)				(0.04)			
Neonatal during Sidr		-2.23				-0.06		
		(14.27)				(0.06)		
Neonatal during Aila		-11.56				-0.02		
		(12.20)				(0.05)		
Trimester 1 during Sidr			-6.54				0.06	
			(26.90)				(0.10)	
Trimester 2 during Sidr			-56.90***				0.19**	
			(17.37)				(0.08)	
Trimester 3 during Sidr			-23.71				0.06	
			(26.72)				(0.09)	
Trimester 1 during Aila			-57.94***				0.11	
			(20.49)				(0.09)	
Trimester 2 during Aila			-24.82				0.06	
			(20.72)				(0.07)	
Trimester 3 during Aila			-34.81				0.15	
			(24.87)				(0.09)	
Pre-utero during Sidr				-44.53***				0.13*
				(13.40)				(0.05)
Pre-utero during Aila				-45.49***				0.12***
				(13.39)				(0.05)

N	2982	2977	2977	2977	2977	2982	2977	2977

Notes: Numbers in parentheses are clustered (clustered at sub-district level) robust-standard errors. ***, **, and * indicate statistically significant at 1%, 5%, and 10% respectively.

Appendix B

Figure B1: Division-wise administrative map of Bangladesh.

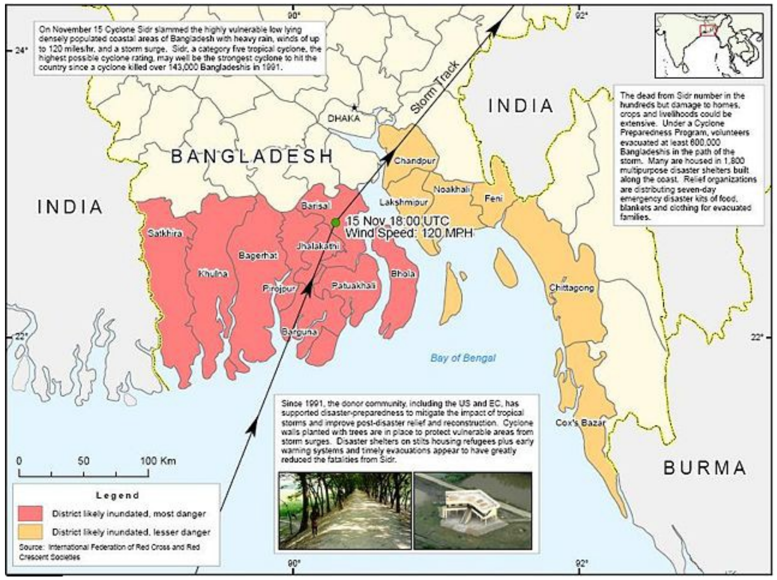

Figure B2: *Sidr* Storm track by the Humanitarian Information Unit (HIU), U.S. Department of State.

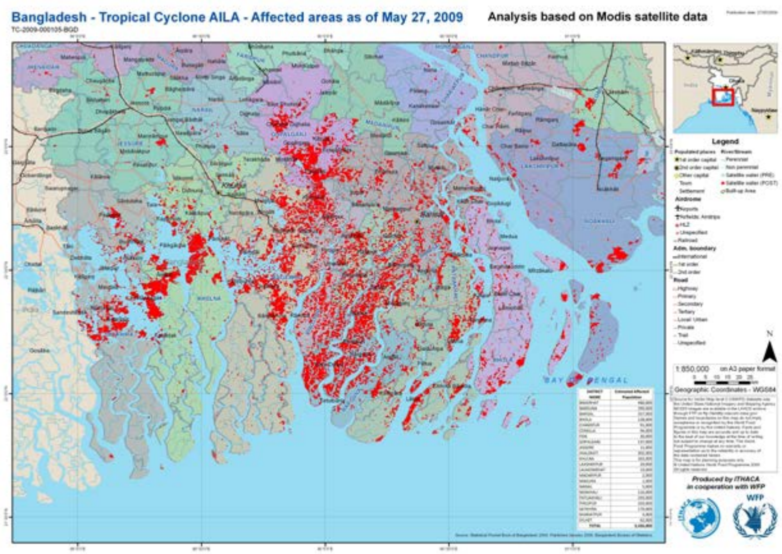

Figure B3: Map of Aila affected area.

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