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The Impact of Natural Disasters on Child Health and Investments in Rural India

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Abstract

Natural disasters are becoming more frequent worldwide and there is growing concern that they may adversely affect short- and long-term health outcomes in developing countries. Prior research has primarily focused on the impact of single, large disaster events but very little is known about how small to moderate disasters, which are more typical, affect population health. In this paper, we present one of the first investigations of the impact of small and moderate disasters on childhood morbidity, physical growth, and immunizations by combining household data from three waves of the Indian National Family and Health Survey with an international database of natural disasters (EM-DAT). We find that exposure to a natural disaster in the past month increases the likelihood of acute illnesses such as diarrhea, fever, and acute respiratory illness in children under 5 year by 9-18%. Exposure to a disaster in the past year reduces height-for-age and weight-for-age z-scores by 0.12-0.15 standard deviations, increases the likelihood of stunting and underweight by 7%, and reduces the likelihood of having full age-appropriate immunization coverage by nearly 18%. We also find that disasters' effects vary significantly by gender, age, and socioeconomic characteristics. Most notably, the adverse effects on growth outcomes are much smaller among boys and infants.

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1. Introduction

Natural disasters are a common occurrence in many developing countries, and there is a growing concern that they may become more frequent due to climate change (Van Aalst, 2006). Disasters result in significant economic damage: for example, in 2009, 335 natural disasters were reported worldwide, killing over 10,000 people and causing damages totaling over 41 billion USD (Vos et al., 2010). They can result in large-scale death, such as the 2004 Indian Ocean earthquake and tsunami that registered a death toll of well over 150,000 (Liu et al., 2005), and are frequently followed by epidemics (Watson, Gayer, and Connolly, 2007). It is likely that such disasters also result in more indirect, long-term health effects, in particular on children when they are exposed during critical growth phases. Indeed, adverse conditions in childhood have been consistently shown to have significant impact on long-term outcomes (Alderman, Hoddinott and Kinsey, 2006; Victora et al., 2008; Case and Paxson 2006, 2009, 2010).

Prior research examining the effects of natural disasters on children's health generally focuses on single, large disaster events. For example, studies show that the 1994-1995 drought in Zimbabwe slowed the growth of children under two (Hoddinott and Kinsey 2001), forest fires in Southeast Asia increased child mortality (Frankenberg et al., 2004; Sastry, 2002; Jayachandran, 2006), and Hurricane Mitch in Nicaragua had negative effects on children's health and nutrition and increased their labor force participation[1] While understanding the effects of large disaster events is important, nations are more frequently affected by several smaller-scale disasters, which may also impact children's health. In fact, large disasters typically attract greater international aid and resources to the affected regions (Stroemberg 2007), potentially mitigating

[1] Other studies of this kind have studied forest fires in Singapore (Emmanuel 2000), drought in Indonesia (Rukumnuaykit 2003), floods in the U.K. (1970), and other disasters in Bangladesh (Rousham 1996). Other health outcomes, such as post-traumatic stress disorder, have also been shown to be higher after Hurricane Mitch (1998) in Nicaragua (Goenjian et al., 2001) and the earthquake in Ano Liosia, Greece, in 1999 (Roussos et al., 2005).

some of the adverse effects. In contrast, smaller disasters often do not receive as wide attention and may lead to significant detrimental effects on child health and access to heath care, even though the immediate effects on mortality may be small. Consequently, impacts of large-scale disaster events may not be generalizable to the majority of disasters, particularly for developing countries. Only one recent study (Pörtner 2010) has examined the impact of several different natural disasters of varying types on child health using data from Guatemala.[2] The study found that most disasters had negative and often large effects on children's long-term health; each disaster occurrence reduced children's height-for-age by 0.1-0.2 standard deviations.

In this paper, we examine the effects of exposure to natural disasters on children's health and critical health investments using data from rural households in India over three periods of time. The focus on India is useful for several reasons. First, it is the second most populous country in the world, after China, with nearly 1.2 billion people and ranks among the lowest in terms of key child health indicators, including malnutrition and under-5 mortality. The UN estimates that 2.1 million Indian children die before reaching the age of 5 every year, mostly from preventable illnesses such as diarrhea, typhoid, malaria, measles and pneumonia (United Nations 2008). Every day, 1,000 Indian children die because of diarrhea alone. Second, the country is annually struck by several natural disasters of varying intensity and types causing significant damage to life and property. From 1992 to 2006, the period of time spanning our data, there were 228 natural disasters reported in India that led to over 96,000 fatalities and affected several million people. While a majority of these disasters did not result in large fatalities, there has been no systematic examination of whether exposure to these disasters affected morbidity, nutrition, and immunization against vaccine-preventable diseases.

[2] Pörtner (2010) estimates the impact of frost, hurricanes, storms, heavy rains, and floods on child health as measured by height-for-age, weight-for-height, and the occurrence of fever, diarrhea, or acute respiratory infections during the two weeks preceding the interview.

We use data on over 80,000 children from three waves of India's National Family and Health Surveys (1992-93, 1998-99, 2005-06) linked to EM-DAT, a database of natural disaster occurrences. Our analytical approach is similar to that of Pörtner (2010) in that we include year and state fixed effects to control for time trends as well as time-invariant heterogeneity across states which can confound identification in a cross-sectional setting. We find that exposure to disasters has significant short- and medium-term impacts on children. A natural disaster in the past month significantly increases the likelihood of diarrhea, fever, and acute respiratory illness (ARI) by 9-18%. In addition, exposure to a disaster in the past year reduces height-for-age and weight-for-age z-scores by 0.12-0.15 standard deviations, increases the likelihood of stunting and underweight by 7%, and reduces the likelihood of having full age-appropriate immunization coverage by nearly 18%.

However, we find important differences in the impacts of natural disasters by gender and age of the child, mother's education, and between Northern and Southern Indian states, but not by scheduled caste or tribe (SC/ST) status. Although no differences by gender are found in the likelihood of coming down with an acute illness (diarrhea, fever, ARI), boys are significantly less likely to be stunted and underweight after being exposed to a disaster relative to girls. This suggests that there may be little difference in biological susceptibility to the effects of disasters, but that there may be some preferential treatment by parents towards investments for sons. We also find that the youngest children— those under age one—are more likely to have acute illnesses such as diarrhea immediately after a disaster but are less likely to be stunted, underweight, and wasted after being exposed to a disaster relative to older children. The attenuated effects on infants' growth suggests that breastfeeding practices—over 97% of children under one are breastfed—may protect the nutritional intake of infants in the aftermath of a disaster. With respect to maternal education, we find that children of uneducated mothers are more likely to be stunted and underweight after a disaster occurs. Finally, children in the southern states of India weigh significantly more and are more likely to be vaccinated than those in the rest of the country following a disaster, which is consistent with relatively greater economic development among southern states.

The remainder of the paper proceeds as follows. Section 2 outlines the conceptual framework for understanding how disasters impact child health. Section 3 describes the data used in the empirical analysis, Section 4 outlines the methods, and Sections 5 describes the results. Finally, Section 6 concludes with a discussion of our findings.

2. Conceptual framework

Natural disasters can affect children's health in three main ways. The first is a direct effect on children's morbidity and mortality (e.g., a child drowns in a flood, illnesses from contamination of food or water). Family disruption due to the loss of a parent or other caretaker can also result in poor health outcomes after a disaster occurs.

The second effect is through the disaster's impact on the supply of health care. By destroying, damaging, or straining health infrastructure, natural disasters might affect access to health care. Increased search or travel costs following health infrastructure destruction increases the marginal cost of health investments.[3] For example, damage to hospitals or health clinics may result in reduced prenatal care, fewer births under the supervision of an obstetrician or nurse, less

[3] In response to large disasters, foreign aid and medical emergency teams often come to affected areas, potentially mitigating the negative health consequences of disasters. Unfortunately, data about emergency response to natural disasters is not currently being systematically collected and we are unable to explicitly account for these types of post-disaster interventions that would likely reduce estimated effects. As such, we believe that our results represent a lower bound for the health consequences of natural disasters in the presence of unobserved emergency response. Furthermore, most disasters in our study are relatively small-scale in terms of mortality and hence are unlikely to spark large emergency responses.

postnatal care, and incomplete immunization. In addition, disasters may also compromise other infrastructure that can have an impact on child health, such as disruption of clean water supply or appropriate disposal of waste.

The third effect is through the disaster's impact on the demand for health inputs, mainly through loss of income as well as increased expenditures needed to cope with a disaster. In agricultural societies, such as much of rural India, disasters such as droughts and floods may lead to significant income shocks from the damage to crops and livestock, in turn reducing the demand for health inputs. The need to relocate or reconstruct housing, replenish food reserves or replace lost livestock may crowd out critical early childhood health investments (e.g., nutrition and immunization). Disasters may also reduce the marginal returns to health investments. For example, the benefits of immunizing children may be less in the event of a famine if the risk of dying from hunger is high.

The impacts of natural disasters are also likely to vary by child and household characteristics, such as child's gender and age, mother's education, a household's SC/ST status, and between northern and southern Indian states. Differential investments across boys and girls is a well-documented fact in developing countries (for a review, see Miller 1997), particularly in India (e.g. Rosenzweig and Schultz 1982; Das Gupta 1987; Behrman 1988). One of the main hypotheses for gender discrimination is that boys have larger returns to human capital investments relative to girls. In this situation, one might expect that the crowding out of health inputs due to a disaster may be larger for girls than boys, resulting in attenuated effects of disasters among boys relative to girls. The differential impact of disasters by a child's age is less clear. On the one hand, infants may be less prone to nutritional deficiencies or adverse health effects from water or food contamination because of exclusive breastfeeding. On the other hand, they may be more vulnerable to diseases and other environmental hazards due to less-developed immune systems. Similarly, differential impacts by SC/ST status are also not clear *a priori*. One the one hand, SC/ST households may not be able to smooth consumption due to lack of access to credit markets or other informal mechanisms, leading to greater adverse effects of disasters. On the other hand, the effects on SC/ST households might be smaller if health outcomes are already much worse than the general population, and shocks brought about by natural disasters represent only one among a large set of health shocks to the child. Mother's education has been shown to be critical for determining a variety of child health outcomes across developing countries (Desai and Alva 1998), and these effects may be more pronounced after a natural disaster when critical decisions regarding disease management and prevention, and nutrition must be made. Finally, wide regional disparities in economic and human development exist in India with Southern states (Kerala, Karnataka, Andhra Pradesh, and Tamil Nadu) having more favorable socioeconomic and child health indicators than Northern states (Murthi, Guio, and Dreze 1995; Mishra, Roy, and Retherford 2004; Rani, Bonu, and Harvey 2008). As a result, children in Southern states may be expected to fare somewhat better than their Northern counterparts in the aftermath of a disaster.

3. Data

This study combines child health data collected in three waves of the National Family Health Surveys conducted in India with information on occurrences of natural disasters in the Emergency Events Database (EM-DAT). This effort represents the first time that the EM-DAT data have been linked to micro-level household survey data, enabling a comprehensive assessment of the impact of natural disasters across different types of disasters.

Emergency Events Database

Since 1988, the World Health Organization Collaborating Center for Research on the Epidemiology of Disasters has collected data on the nature, magnitude, scale, and basic human impact of over 12,800 disasters that have occurred since 1900. The EM-DAT includes an event as a disaster if at least 10 persons were reported killed, 100 persons were reported to be affected (i.e. requiring immediate assistance during a period of emergency), or the affected state either declared a state of emergency or made a call for international assistance. For a given disaster, EM-DAT provides information on where the disaster occurred, the type of disaster[4], the beginning and ending dates, and the damage incurred (i.e. number of people killed, injured, and rendered homeless, and estimated damages in dollars). Geographic specificity of the disaster includes identifiers such as name of a city, village, department, province, state, or district depending on the relevance. These data have been used extensively in disasters and public health journals, and also underlie a number of papers in the economics literature (see, for example, Kahn (2005), Toya and Skidmore (2007), or Strömberg (2007)).

All disasters occurring in India were downloaded from this database and categorized by date. To enable merging of the disasters data with NFHS data, the occurrences of disasters were aggregated to the state level, the lowest level of geographic identifiers consistently available across all the NFHS waves.[5] Although the EM-DAT provides detail on the type of disaster, we

[4] EM-DAT categorizes natural disasters into the following types: droughts, earthquakes, epidemics, extreme temperatures (both high and low), floods, mass movements (i.e. landslides, avalanches), storms (including hurricanes and tsunamis), and wildfires.

[5] There are currently 29 states in India. Three new states were created in 2000: Jharkhand, Uttaranchal, and Chhattsgarh. This analysis uses Indian state units as defined by their pre-2000 boundaries because it is impossible to assign boundaries which did not previously exist to these new states. However, exposure of children to disasters is based on the state-level identifiers existing at the time of the survey; children in the 2005-06 NFHS are linked to the EM-DAT according to the post-2000 state boundaries whereas children in the 1992-93 and 1998-99 NFHSs are linked according to the pre-2000 state boundaries..

do not distinguish between different types for two reasons. First, a string of disaster events may be serially correlated (e.g., floods as a result of storms, epidemics as a results of floods), making it difficult to attribute or apportion resulting impacts across each of these types. Second, there is wide variation in geography and climate in India, and some regions are particularly prone to specific types of disasters (e.g., typhoons in the southeast, avalanches in the northern mountainous states). Examining disasters by type is likely to capture much of these regional differences rather than the overall effect of a given disaster. Furthermore, we exclude epidemics from our disaster measure as disease outbreak is often triggered by the occurrence of a disaster and not an independent event in of itself. Therefore, we focus on the occurrence of any non-epidemic disaster in any state in order to generalize across all disasters in India.

The geographic distribution of natural disasters across India during the one-year exposure window prior to the NFHS survey month is displayed in Figure 1. As we describe in further detail later, most of the disasters in our exposure window were floods, droughts, and extreme temperatures. There is considerable variation in the occurrences of unique disaster events both within states over time and across states. Moreover, the increase in the number of events occurring over time is not unique to any single state, but appears to affect most states in India. We will exploit these sources of variation in our difference-in-difference estimation approach.

National Family Health Surveys (NFHS)

Data on child health status and investments are obtained from the National Family and Health Surveys conducted in 1992-93, 1998-99, and 2005-06. Each woman aged 15-49 is asked to provide a full birth history for up to 20 children. For all children under five years of age, NFHS collects information on specific health conditions during the two weeks prior to the survey—diarrhea, fever, and acute respiratory infection or cough. We create a binary indicator for the occurrence of any one of these conditions, as well as an indicator for whether any medication was obtained to treat these health conditions. Due to the narrow reference window for which these indicators were collected, these measures will only reflect the immediate effects of disasters.

Medium- and longer-term effects of disasters can be analyzed through physical growth measurements. Anthropometrics are important indicators of nutritional status during childhood. Stunting, or low height-for-age, is caused by long-term insufficient nutrient intake and frequent infections, and its effects are largely irreversible. Wasting, or low weight-for-height, is a strong predictor of mortality among children under five. It is usually the result of acute significant food shortage and/or disease. NFHS collects objective height (length for infants) and weight measurements which are age-standardized according to World Health Organization growth charts and converted to z-scores. We examine the continuous measures of height-for-age, weight-for-age, and weight-for-height z-scores as well as binary indicators for stunting, underweight, and wasting, identified as those children who are less than two standard deviations below the reference median in height-for-age, weight-for-age, and low weight-for-height, respectively.

Finally, we examine child health investments by looking at immunizations. Mothers interviewed in the NFHS are asked about different vaccinations for each of her eligible children and, when possible, this information was verified against the child's vaccination card. Specifically, the survey asked whether the child had been vaccinated against tuberculoses (BCG), diphtheria (DPT, all doses), polio (all doses) and measles. Since the questions are asked retrospectively, we classify a child as having the "age-appropriate" vaccination if the child has received the recommended doses of each immunization regimen according to the Government of India's Recommended Immunization Schedule (see Table 1). For example, a child who is three months old at the time of survey who has received BCG would thus be classified as being current for BCG vaccine. However, if she has not received polio dose 2, she would be classified as not having age-appropriate polio vaccine. Hence, separate indicators are created for each immunization regimen. In addition, a composite indicator is created to identify whether a child is current on all immunization regimens. For example, a child who is 3 months old would only be categorized as "fully current" if she has received BCG, DPT doses 1 and 2, and polio doses 1 and 2. Since many diseases require multiple doses to provide full immunization coverage across a range of strains of the disease (e.g., polio) we use this classification scheme to distinguish between children who are fully protected against childhood infectious diseases and those who may have been vaccinated at one point in time, but who only have partial immunological protection.

Other individual and household characteristics collected in the NFHS are used to control for observable differences across children. These include the child's age, sex, birth order, age of the mother at the time of birth, the mother's and father's highest level of educational attainment, schedule caste or tribe, and religion.

Defining exposure

Exposure to disasters is calculated relative to the month the NFHS interview was conducted. Because acute illnesses (fever, ARI, diarrhea) are only recalled for the two weeks prior to the interview, the length of exposure for these short-term outcomes is defined to be the month preceding the interview, including the interview month. For longer-term health and investment outcomes—anthropometrics and immunizations—exposure to disasters is defined to be the 11 months leading up to the interview date, including the month of the interview. Although we show the 11-month exposure period in the main results, we also test the sensitivity of the regression specification to the definition of this exposure period and find the results to be robust to different exposure lengths (e.g., 6 months).

The exposure variable is coded as a dummy indicator for having been exposed to any disaster in the 11 months (one month for acute illnesses) prior to and including the month of the interview. The dummy variable definition avoids double-counting a disaster that may have occurred over multiple months and facilitates interpretation of the results. There is also reason to believe that length of disaster is not necessarily indicative of its severity, as some disasters are short in duration, such as earthquakes. However, we also explore the use of a continuous variable that reflects the months of exposure to a disaster. While estimates generally showed that exposure to more disaster months was also significantly related to child health outcomes, there were no significant differences observed by disaster length. Therefore, we report the dummy variable estimates in our main results. Findings from additional robustness checks examining non-linear effects of disasters are discussed in the results.

Sample

The final sample is comprised of all children in rural households who were less than five years of age and for whom health questions were asked. We further limit the analysis to only to children from singleton births and exclude those with extreme anthropometric scores (i.e. beyond five standard deviations of the reference mean).[6] The final analytic sample includes over 80,000

[6] Children of multiple births are often underweight at birth and are likely to proceed on a different growth trajectory during their formative years compared to children of singleton births. Therefore, we drop these 604 children from

children with valid information on acute illnesses and over 59,000 children with valid height and weight measurements. For vaccination outcomes, the sample is further restricted to only children who were eligible to receive the vaccination within the previous 11-month disaster exposure period. For example, because children should receive a complete polio immunization regimen by four months of age, only children up to 15 months of age at the time of survey would have been "at risk" of not receiving the vaccination during the prior 11 months. For assessing whether children are "fully current" for all scheduled immunizations, the sample is restricted to children who are 20 months of age and younger since the last scheduled vaccination, measles, should be obtained by 9 months of age.

Table 2 summarizes the individual and household characteristics for the largest sample of children analyzed for recent acute illnesses (N_{1993}=31,973, N_{1999}=21,688, N_{2006}=27,475). The proportion of children experiencing acute illnesses during the last two weeks varies across type of illness and wave, ranging from 9-35%. Of those with illnesses, at most about 60% of children are given medication. Indian children are more than 1.6 standard deviations shorter and lighter than the reference population. This translates into about 45-50% being stunted and underweight, and about 17% being wasted. Obtaining the age-appropriate vaccination appears to improve over survey waves. By 2006, 86% of children have ever been vaccinated with 40% being fully current compared to only 49% being ever vaccinated and 30% being fully current in 1993.

Table 3 describes the exposure to disasters in both the previous one month for children included in the analysis of acute illnesses and 11 months for children included in the analysis of anthropometric outcomes. From one month before the survey, there were seven unique state-level disasters that occurred in the 1992-93 NFHS, exposing 26% of children to a disaster. These

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our sample. We also drop 2131 children who have extreme z-score values for anthropometric measurements to reduce the possibility that outliers skew estimated results.

were mostly droughts and floods. Five and eight disasters occurred in the 1998-99 and 2005-06 surveys, respectively, (mostly extreme temperature) each exposing about 25-28% of children. When the exposure time is extended to the year leading up to the survey, 10 state-level events occurring in the 1992-93 survey round (mostly floods and droughts) exposed 71% of children, 13 events leading up to the 1998-99 survey (mostly extreme temperature) exposed 60% of children, and 28 events leading up to the 2005-06 survey (mostly floods and extreme temperature) exposed 82% of children.

4. Methods

The general econometric model used to estimate the effect of natural disasters in the month or year leading up to the survey on our outcome measures of interest is as follows:

$$(1) \qquad Y_{ist} = \alpha + \beta_1 D_{st}^{-1} + \beta_2 X_{it} + \eta_s + \mu_t + \varepsilon_{ist}$$

where Y_{ist} stands for the health variable of child *i* in state *s* observed at time *t*; D^{-1}_{st} captures whether there was a natural disaster in the child's state within the last month or year; and X_{it} includes controls for child and family characteristics (male, quadratic in mother's age at birth, mother's education, father's education, Muslim religion, SC/ST, birth order, and gender-specific month of birth quartic polynomial). The primary coefficient of interest is β_1, which captures the effect of exposure to natural disasters on child health within the first month or year after the occurrence of the disaster. In order to examine whether the impact of natural disasters varies by child's gender, age, and socioeconomic status of the child's family, we estimate the model in equation (1) using an interaction of D^{-1}_{st} with child's gender, age (0-1 year versus greater than 1 year), scheduled caste or tribe (SC/ST) status, maternal education, and indicator for residing in a South India state.

As mentioned earlier, there may be unobserved differences across affected and unaffected areas within countries that might bias the estimated effect of disasters on health outcomes. In order to address this concern, we employ all three available waves of NFHS data for India. The availability of repeated cross-sections of data allows us to estimate difference-in-difference models. This approach essentially compares *changes* in health outcomes in disaster affected states to *changes* in health outcomes in unaffected states. Specifically, η_s in the above equation represents a vector of state fixed-effects and μ_t survey (wave) time fixed-effects. The state fixed effects control for all unobserved state-level confounders that are constant over time. In other words, the parameter β_1 in equation (1) will be estimated by using each state as its own control group. In addition, the time fixed-effects will control for any general time trend in disasters and child health that affects all regions equally. All regressions for binary outcomes are estimated using a linear probability model. Standard errors in all models are adjusted for clustering at the level of the primary sampling unit, a group of approximately twenty households living in close vicinity.

5. Results

5.1 Immediate Effects on Acute Illnesses

Table 4 summarizes the estimates for predicting the likelihood of illnesses occurring in the last two weeks. Each row is estimated with a separate regression. Row one displays the main effect of disasters, showing that a disaster in the past month significantly increases the likelihood of diarrhea, fever, and ARI by about two to three percentage points. Given the mean rate of illnesses between 13-23% within the sample, these effect sizes represent a 18%, 9%, and 15%

increase in diarrhea, fever, and ARI, respectively. However, experiencing a disaster in the past month is not significantly related to receiving medication to treat the condition.

5.2 Effects on Nutrition-Related Outcomes

For longer-term anthropometric outcomes displayed in Table 5, exposure to a disaster in the year leading up to the survey month is significantly related to worse height and weight outcomes (row 1). Height-for-age is reduced by 0.15 standard deviations and weight-for-age by 0.12 standard deviations. Stunting and underweight are each significantly higher by three percentage points or about a 7% increase. Given that estimates for height are larger in magnitudes than for weight, the negative signs for the weight-for-height ratio and wasting make sense.

5.3 Effects on Immunization

Estimates for immunization outcomes are summarized in Table 6. For all vaccinations—BCG, DPT, polio, and measles—a disaster in the past year significantly reduces the likelihood of having received the age-appropriate doses. In fact, children are 4 percentage points less likely to have ever been vaccinated, and 5 percentage points significantly less likely to be fully current on all their vaccinations in relation to experiencing a disaster in the past year.

5.4 Heterogeneous Effects

Investigation of heterogeneous effects of disasters that may come about due to the reasons discussed in section 2 shows important differences in outcomes by gender and age of the child, as well as mother's education and between north and south India. No differences by gender are found for the likelihood of coming down with an acute illness. Although boys are more likely to be given medication if they become ill (Table 4, row 2), the estimate is not statistically significant. However, significant differences by gender are observed for physical growth outcomes (Table 5, row 2). Boys are significantly less likely to be stunted and underweight than girls. This suggests that there may little difference in biological susceptibility to the immediate effects of disasters, but that there may be some preferential treatment by parents towards investments for sons. In comparison, no differences in attainment of vaccinations by gender are found, suggesting that disasters' effects on immunizations may be operating mainly through supply-side shocks (e.g. inability of mobile health units to vaccinate children due to floods) instead of demand-side shocks.

Younger children—particularly those under age one—are more likely to be given medication in response to acute illnesses and to consistently have better growth outcomes. While there is suggestive evidence that children under one may be more susceptible to acute illnesses (i.e. significantly more likely to have diarrhea, but not other conditions), they are also significantly more likely to be given medication to treat the condition. These children are also less likely to be stunted, underweight, and wasted than older children. Considering that over 97% of children under age one are breastfed, these results suggest that breastfeeding practices may protect the nutritional intake of infants in the aftermath of a disaster.

We find few differences by SC/ST status in disasters' impacts on child health or immunizations, but other proxies for SES—mother's education, and northern versus southern India—do show some differential impacts. Adverse outcomes for children appear to be stronger among those born to uneducated mothers. These children are significantly shorter and weigh less after being exposed to a disaster than those born to more educated mothers. Children of uneducated mothers are also more likely to suffer from fever immediately after a disaster occurs; however, significant differences are not observed for other acute illnesses or for vaccination outcomes. Between north and south India, children in the south appear to do significantly better in terms of weight, are more likely to receive BCG vaccination as well as any vaccination, and are less likely to have diarrhea. These differences may reflect relatively better health care access and socioeconomic conditions in southern states.

5.5 Robustness Checks

The above results are robust to a variety of sensitivity analyses (Table 7). First, since the choice of a one-year disaster exposure period was somewhat arbitrary, we rerun our analyses using a six-month exposure period (Table 7, Column 1). While point estimates do change somewhat because this redefinition essentially narrows the window of any disaster lagged effects, the substantive results do not change. Second, we test for the possibility that the occurrence of any single large disaster may be driving our results. We separately drop disasters killing more than 1000 people (Table 7, Column 2) and disasters affecting more than one million people (Column 3) from our disasters exposure measure. These thresholds represent about the 95^{th} percentile of all disasters in India in the EM-DAT in terms of mortality and destruction. Resulting estimated coefficients for all outcomes do not substantively change. Third, we include interview month fixed effects in our regressions to account for potential seasonal trends that affect both disasters and health outcomes (Column 4) and find similar results. Fourth, we include urban children in our estimation sample (column 5) and find that some effect sizes become smaller, suggesting that effects for urban children are also generally smaller than those observed for rural children. However, additional investigation of potential interaction effects revealed few differences across urban and rural areas (results not shown). Finally, we restrict our sample to households who report residing in the current location for two or more years (Column 6) to limit bias due to migration. We find that exclusion of recent migrants does not change our results.

In additional analyses not reported here, we also tested for nonlinearities in the effects of disaster exposure. First, regressions using a continuous indicator of exposure to disaster months produce results that are consistent with those found with the dummy variable definition. Second, we investigate whether there may be nonlinear effects in being exposed to more months of disasters by using either a quadratic term or by specifying dummy variables at different thresholds (e.g., 1-2 disaster months, 3-9 disaster months). Resulting estimates show that there are no nonlinearities or thresholds of disasters that consistently predict different growth and immunization outcomes. We also tested for various ways to control for differences in age cohorts: birth year dummies, additional quartic age polynomials interacted with scheduled caste/tribe. Neither specification of age controls affects the point estimates in the main results.

6. Conclusions and Discussion

There is a growing concern that climate change will lead to more frequent natural disasters of increasing intensity. For example, a substantial increase in hazards related to heavy rain is expected over central India in the future (Goswami et al 2006). While the effects of specific, large disaster events (e.g Hurricane Mitch, Indonesian forest fires) on child health have been examined in several recent studies, not much is known about how natural disasters in general affect child health. In this paper, we examined the immediate and medium-run effects of natural disasters on child health and investments by linking three waves of household survey data from India to information on all natural disasters that children were exposed to in the year prior to the survey to estimate difference-in-difference models. The vast majority of natural disasters during our study period were small or moderate in size; the median disaster led to 48 deaths, which is orders of magnitude smaller than the deaths caused by large events (e.g., over 16,000 deaths in India due to the 2004 Indian Ocean Tsunami).

Our results show that even small-to-moderate disasters can have significant short- and long-term effects on health. Several robust findings emerge from our results. First, disasters have significant immediate effects on morbidity, as measured by fever, ARI, and diarrhea. Failure to treat these illnesses effectively and promptly can lead to serious consequences. Both ARI and diarrhea are the leading causes of mortality among children under five, together responsible for almost 40 percent of the child mortality in this age group each year (UNICEF/WHO 2009). Second, exposure to a disaster in the past year is associated with significantly worse nutrition-related outcomes, including a greater likelihood of stunting and underweight among exposed children. Malnutrition in childhood has been linked to adverse health and socioeconomic outcomes in the long run (for a review, see Victora, Adair, Fall, et al. 2008). Finally, exposure to a disaster significantly lowers the likelihood of receiving age-appropriate immunization against vaccine-preventable diseases such as polio, tuberculosis, and measles, placing children at greater risk for these infectious diseases.

The magnitude of disasters' effects on morbidity, physical growth, and immunizations are fairly large. Exposure to a natural disaster in the past month increases the likelihood of acute illness by 9-18%. Exposure to a disaster in the past year reduces height-for-age and weight-for-age z-scores by 0.12-0.15 standard deviations, increases the likelihood of stunting and underweight by 7%, and reduces the likelihood of having full age-appropriate immunization coverage by nearly 18%. These effects are comparable to those of maternal education on the same outcomes. For example, children in our sample born to uneducated mothers are 5-8% more likely to be stunted or underweight and are 13-16% less likely to receive age-appropriate doses of BCG, polio, and measles vaccinations.

Our findings pertaining to the differential effects of disasters by gender, age, maternal education and region have important implications for policy. We show that, while there is little difference in biological susceptibility to the effects of disasters between boys and girls, there appear to be important gender differences in the behavioral responses of parents to disasters. We find that the adverse effects of disasters on nutrition-related outcomes are significantly attenuated among boys relative to girls, suggesting that disasters' effects on children's growth may largely result from demand-side shocks that reduce the households' resources. These findings are consistent with a vast literature documenting gender discrimination in India and suggest the need for policies that counter these effects. In contrast, we did not find any gender differences in disasters' effects on immunizations, suggesting that the mechanisms through which disaster exposure affects immunizations may operate largely through supply side shocks that influence girls and boys similarly. For example, community outreach workers are an important component of vaccine delivery in India, particularly in remote areas (Datar, Mukherji and Sood 2007), and natural disasters such as floods may significantly impair the ability of such workers to access vulnerable populations.

With respect to a child's age, we find that the adverse effects of disasters on infants' nutrition-related outcomes are significantly attenuated relative to older children. These findings highlight the critical role that breastfeeding plays in the event of disasters. Exclusive breastfeeding may shelter infants from food- or waterborne illnesses relative to their peers who are not exclusively breastfed. However, young children who are no longer breastfeeding may be particularly vulnerable after disasters, highlighting the need for programs that support their nutritional needs.

Finally, our results suggest that the negative effects of disasters are stronger among children living in lower socio-economic conditions (northern states and less maternal education). To the extent disaster relief efforts are targeted towards less developed areas or vulnerable subpopulations, the true effects of disasters may be even larger than what we estimate since we are unable to control for these policy responses. This also suggests, however, that existing policy efforts in response to disasters have been inadequate in mitigating large negative effects on children's health.

Our results should be interpreted in light of additional caveats. While our difference-in-differences strategy controls for time-invariant unobserved heterogeneity across states, we cannot rule out with certainty the influence of other unobservable factors (unrelated to disasters) on child health outcomes in the state (e.g. state-specific maternal and child health investments). As we also cannot account for emergency response to disasters, our estimated effects may represent a lower bound for the true effect of natural disasters. In addition, measuring disaster exposure at the state level ignores within-state heterogeneity in exposure, contributing to measurement error, particularly in large states. While recent waves of the Demographic and Health Surveys have been collecting detailed data on the geographic location of households, a similar level of geographic specificity is not yet consistently available for the EM-DAT natural disasters data. Lastly, our estimates capture the effects of disasters on households that remained in the same location after the disaster and among children who were alive at the time of the survey.

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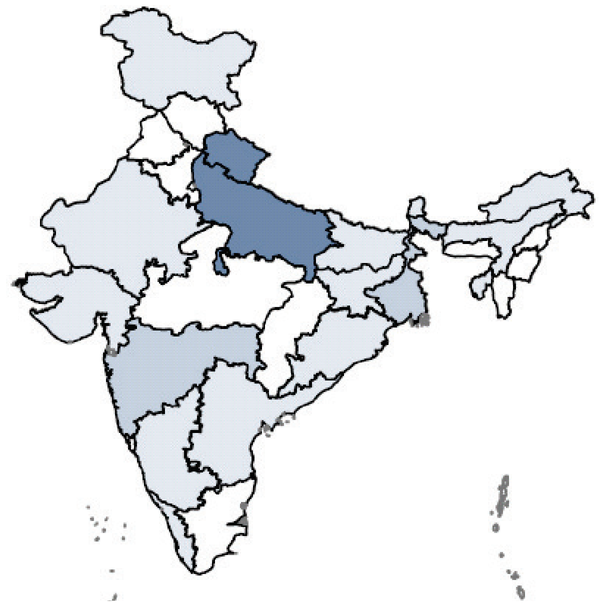
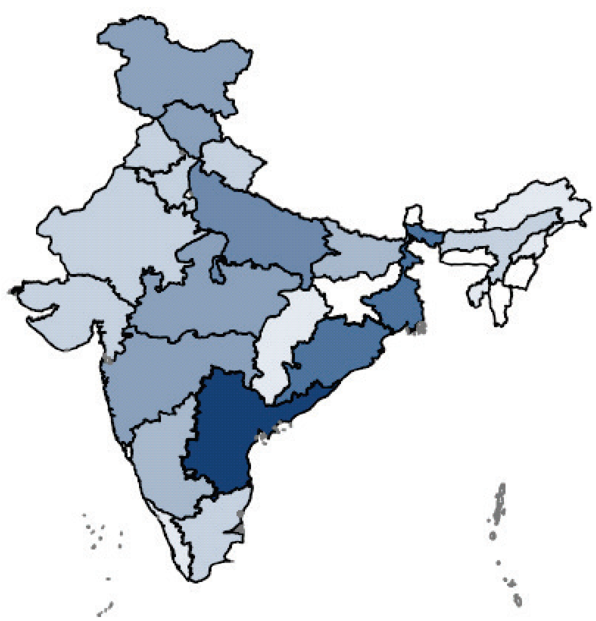
Figure 1. Natural disasters occurring in current and previous 11 months

a. 1992-93 NFHS

b. 1998-99 NFHS



c. 2005-06 NFHS



Unique Disasters in Contemporaneous Month and Previous 11 Months							
1	2	3	4	5	6	7	8

Table 1: Recommended Immunization Schedule

Age (weeks)	Vaccine (months)	BCG	DPT	Polio	Measles	Age Appropriate Coverage for all India
Birth	0	X		X		BCG
6 weeks	1.5		X	X		BCG + DPT1 + Polio1
10 weeks	2.5		X	X		BCG + DPT1-2 + Polio1-2
14 weeks	3.5		X	X		BCG + DPT1-3 + Polio1-3
36 weeks	9.0				X	BCG + DPT1-3 + Polio1-3 + Measles

Source: Universal Immunization Program Division, Department of Family Welfare, Min. of Health & Family Welfare http://cbhidghs.nic.in/hii2003/12.01.htm [accessed 23rd February 2011]

Table 2: Child Characteristics in the Indian National Family and Health Surveys

	1992-93 NFHS (N=31,973)		1998-99 NFHS (N=21,688)		2005-06 NFHS (N=27,475)	
	Mean	SD	Mean	SD	Mean	SD
Illness in last 2 weeks						
Diarrhea	0.11	0.31	0.20	0.40	0.09	0.29
Fever	0.21	0.41	0.30	0.46	0.15	0.35
Cough	0.19	0.39	0.35	0.48	0.17	0.38
Any medication given	0.63	0.48	0.61	0.49	0.42	0.49
Anthropometrics						
Height-for-age	-1.87	1.61	-1.72	1.57	-1.62	1.51
Stunted	0.49	0.50	0.45	0.50	0.42	0.49
Weight-for-age	-1.93	1.27	-1.74	1.28	-1.81	1.15
Underweight	0.52	0.50	0.45	0.50	0.47	0.50
Weight-for-height	-0.92	1.18	-0.84	1.22	-1.05	1.08
Wasted	0.17	0.37	0.16	0.36	0.17	0.38
Age-appropriate vaccination						
BCG	0.54	0.50	0.62	0.49	0.72	0.45
Polio	0.46	0.50	0.53	0.50	0.74	0.44
DPT	0.45	0.50	0.47	0.50	0.53	0.50
Measles	0.53	0.50	0.62	0.49	0.64	0.48
Ever vaccinated	0.49	0.50	0.69	0.46	0.86	0.35
Fully current	0.30	0.46	0.31	0.46	0.40	0.49
Individual characteristics						
Age (months)	22.49	13.90	16.78	10.35	29.42	17.32
Male	0.51	0.50	0.52	0.50	0.52	0.50
First born	0.25	0.44	0.26	0.44	0.27	0.45
Second born	0.23	0.42	0.24	0.43	0.25	0.43
Third born	0.18	0.38	0.17	0.38	0.16	0.37
Fourth born	0.12	0.32	0.11	0.32	0.10	0.31
Fifth born	0.08	0.27	0.08	0.27	0.07	0.26
Sixth born or higher	0.14	0.35	0.14	0.34	0.14	0.34
Mother's age at birth	24.47	5.65	24.42	5.47	24.69	5.42
Mother: no education	0.67	0.47	0.57	0.49	0.49	0.50
Mother: primary school	0.16	0.37	0.17	0.37	0.16	0.36
Mother: secondary school	0.16	0.37	0.21	0.41	0.32	0.47
Mother: higher education	0.01	0.10	0.05	0.21	0.03	0.17
Father: no education	0.38	0.48	0.31	0.46	0.29	0.46
Father: primary school	0.26	0.44	0.18	0.39	0.16	0.37
Father: secondary school	0.32	0.46	0.37	0.48	0.47	0.50
Father: higher education	0.05	0.22	0.14	0.35	0.07	0.26
Muslim religion	0.12	0.32	0.13	0.33	0.11	0.32
Scheduled caste/tribe	0.29	0.46	0.36	0.48	0.40	0.49

Table 3: Exposure to Natural Disasters by Survey Wave

	Exposure in current and past 1 month		Exposure in current and past 11 months	
	Number of unique state-level events	Proportion of children exposed	Number of unique state-level events	Proportion of children exposed
<u>1992-93 NFHS</u>				
Any disaster	7	0.26	10	0.71
Drought	1	0.15	1	0.20
Earthquake	0	n/a	0	n/a
Extreme temperature	0	n/a	0	n/a
Flood	6	0.11	6	0.51
Mass movement	0	n/a	1	0.01
Storm	0	n/a	2	0.20
<u>1998-99 NFHS</u>				
Any disaster	5	0.28	13	0.60
Drought	0	n/a	0	n/a
Earthquake	1	0.01	1	0.01
Extreme temperature	2	0.24	2	0.39
Flood	1	0.02	3	0.14
Mass movement	0	n/a	4	0.14
Storm	1	0.06	3	0.18
<u>2005-06 NFS</u>				
Any disaster	8	0.25	28	0.82
Drought	0	n/a	0	n/a
Earthquake	0	n/a	0	n/a
Extreme temperature	1	0.16	2	0.51
Flood	7	0.08	21	0.78
Mass movement	0	n/a	1	0.03
Storm	0	n/a	4	0.11

Table 4: Effects of Disasters on Acute Illnesses in the Last Two Weeks

		(1) Diarrhea	(2) Fever	(3) ARI	(4) Any medication
(1)	Any disaster in past month	0.023	0.020	0.035	0.005
		(0.004)***	(0.005)***	(0.005)***	(0.010)
	Interaction Effects of Disaster Exposure				
(2)	X male	0.006	0.006	0.010	0.023
		(0.006)	(0.007)	(0.007)	(0.015)
(3)	X scheduled caste/tribe	-0.003	-0.001	0.001	0.010
		(0.007)	(0.008)	(0.009)	(0.017)
(4)	X age 0-1	0.019	-0.007	0.004	0.037
		(0.007)***	(0.007)	(0.008)	(0.015)**
(5)	X no education	0.008	0.017	0.008	0.017
		(0.006)	(0.008)**	(0.008)	(0.016)
(6)	X South	-0.038	-0.008	0.010	0.047
		(0.011)***	(0.016)	(0.017)	(0.026)*
Observations		81136	81122	81126	22230
Sample mean(y)		0.127	0.212	0.228	0.598

95% confidence interval in parentheses.
Standard errors are corrected for heteroskedasticity and clustered by primary sampling unit; * significant at 10%; ** significant at 5%; *** significant at 1%.
Each cell is estimated with a separate regression; binary outcomes are estimated using linear probability models.

All regressions include the following controls: male, quadratic mother's age at birth, mother's education, father's education, Muslim religion, scheduled caste/tribe, birth order, gender-specific month of birth quartic polynomial, survey wave, and state fixed effects.

Table 5: Effects of Disasters on Physical Growth

		(1) Height-for-age	(2) Stunted	(3) Weight-for-age	(4) Underweight	(5) Weight-for-height	(6) Wasted
(1)	Any disaster in past year	-0.148	0.031	-0.123	0.032	-0.045	-0.014
		(0.033)***	(0.009)***	(0.026)***	(0.008)***	(0.026)*	(0.007)**
				Interaction Effects of Disaster Exposure			
(2)	X male	0.037	-0.027	0.061	-0.018	0.044	-0.003
		(0.029)	(0.009)***	(0.022)***	(0.009)**	(0.024)*	(0.007)
(3)	X scheduled caste/tribe	0.011	-0.015	-0.022	0.008	-0.065	-0.007
		(0.042)	(0.012)	(0.032)	(0.011)	(0.032)**	(0.009)
(4)	X age 0-1	0.079	-0.054	-0.032	-0.043	0.121	-0.051
		(0.028)***	(0.008)***	(0.021)	(0.008)***	(0.023)***	(0.007)***
(5)	X no education	-0.024	0.032	0.119	0.010	0.324	-0.026
		(0.077)	(0.022)	(0.052)**	(0.020)	(0.058)***	(0.018)
(6)	X South	-0.020	0.029	0.109	0.014	0.300	-0.021
		(0.077)	(0.022)	(0.052)**	(0.020)	(0.058)***	(0.018)
Observations		59145	59145	65650	65650	59346	59346
Sample mean(y)		-1.727	0.448	-1.839	0.483	-0.950	0.166

95% confidence interval in parentheses.
Standard errors are corrected for heteroskedasticity and clustered by primary sampling unit; * significant at 10%; ** significant at 5%; *** significant at 1%.

Each cell is estimated with a separate regression; binary outcomes are estimated using linear probability models.

All regressions include the following controls: male, quadratic mother's age at birth, mother's education, father's education, Muslim religion, scheduled caste/tribe, birth order, gender-specific month of birth quartic polynomial, survey wave, and state fixed effects.

Table 6: Effects of Disasters on Immunizations

		(1) BCG	(2) DPT	(3) Polio	(4) Measles	(5) Any vaccination	(6) Fully current
(1)	Any disaster in past year	-0.053	-0.019	-0.042	-0.034	-0.037	-0.049
		(0.012)***	(0.010)*	(0.010)***	(0.008)***	(0.012)***	(0.009)***
		Interaction Effects of Disaster Exposure					
(2)	X male	0.005	-0.012	-0.014	0.001	-0.005	-0.004
		(0.014)	(0.012)	(0.012)	(0.009)	(0.013)	(0.010)
(3)	X scheduled caste/tribe	0.008	0.015	0.026	-0.006	0.009	0.011
		(0.018)	(0.014)	(0.015)*	(0.012)	(0.017)	(0.013)
(4)	X no education	-0.014	0.003	0.013	-0.011	0.022	-0.018
		(0.016)	(0.013)	(0.014)	(0.010)	(0.015)	(0.012)
(5)	X South	0.086	0.020	-0.009	-0.024	0.096	0.004
		(0.030)***	(0.028)	(0.028)	(0.021)	(0.028)***	(0.027)
Observations		21746	29119	29246	37517	25579	38195
Sample mean(y)		0.515	0.424	0.467	0.669	0.564	0.276
Sample ages (months)		0-11	0-15	0-15	0-20	0-20	0-20

Standard errors are corrected for heteroskedasticity and clustered by primary sampling unit; * significant at 10%; ** significant at 5%; *** significant at 1%.

Each cell is estimated with a separate regression; binary outcomes are estimated using linear probability models.

All regressions include the following controls: male, quadratic mother's age at birth, mother's education, father's education, Muslim religion, scheduled caste/tribe (SCST), birth order, gender-specific month of birth quartic polynomial, survey wave, and state fixed effects.

Table 7: Robustness Checks

	(1) Any disaster in past 6 months[a]	(2) Excluding disasters killing>1000 people[a]	(3) Excluding disasters affecting>1 million people[a]	(4) Including interview month fixed effects[a]	(5) Including urban areas[b]	(6) Limited to residents[a, c]
Diarrhea[d]		0.023	0.024	0.022	0.019	0.022
		(0.004)***	(0.005)***	(0.004)***	(0.003)***	(0.004)***
Fever[d]		0.019	0.025	0.015	0.019	0.020
		(0.005)***	(0.006)***	(0.005)***	(0.004)***	(0.006)***
ARI[d]		0.034	0.045	0.028	0.028	0.035
		(0.006)***	(0.007)***	(0.006)***	(0.004)***	(0.006)***
Any medication given[d]		0.005	0.017	-0.006	-0.001	-0.000
		(0.010)	(0.011)	(0.010)	(0.008)	(0.010)
Height-for-age[d]	-0.092	-0.130	-0.126	-0.135	-0.111	-0.158
	(0.027)***	(0.029)***	(0.030)***	(0.032)***	(0.025)***	(0.035)***
Stunted[d]	0.016	0.027	0.025	0.029	0.020	0.035
	(0.007)**	(0.008)***	(0.008)***	(0.009)***	(0.007)***	(0.009)***
Weight-for-age[d]	-0.066	-0.126	-0.085	-0.112	-0.084	-0.138
	(0.021)***	(0.024)***	(0.022)***	(0.025)***	(0.020)***	(0.027)***
Underweight[d]	0.014	0.029	0.017	0.029	0.025	0.036
	(0.007)**	(0.007)***	(0.007)**	(0.008)***	(0.006)***	(0.009)***
Weight-for-height[d]	-0.043	-0.061	-0.048	-0.040	-0.003	-0.061
	(0.020)**	(0.023)***	(0.023)**	(0.025)	(0.020)	(0.027)**
Wasted[d]	-0.003	-0.000	-0.009	-0.014	-0.018	-0.013
	(0.005)	(0.006)	(0.006)	(0.007)**	(0.005)***	(0.007)*
BCG[e]	-0.044	-0.043	-0.007	-0.057	-0.053	-0.055
	(0.011)***	(0.011)***	(0.011)	(0.012)***	(0.010)***	(0.014)***
DPT[e]	-0.023	-0.009	0.008	-0.021	-0.012	-0.016
	(0.009)**	(0.009)	(0.009)	(0.010)**	(0.008)	(0.011)
Polio[e]	-0.032	-0.034	0.000	-0.041	-0.031	-0.046
	(0.009)***	(0.009)***	(0.009)	(0.010)***	(0.008)***	(0.011)***
Measles[e]	-0.022	-0.022	-0.018	-0.034	-0.034	-0.033
	(0.007)***	(0.007)***	(0.007)***	(0.008)***	(0.006)***	(0.008)***
Any vaccination[e]	0.007	-0.020	0.044	-0.032	-0.040	-0.045
	(0.011)	(0.011)*	(0.011)***	(0.012)***	(0.010)***	(0.013)***
Fully current[e]	-0.032	-0.033	-0.018	-0.049	-0.039	-0.049
	(0.008)***	(0.008)***	(0.008)**	(0.009)***	(0.008)***	(0.010)***

Standard errors are corrected for heteroskedasticity and clustered by primary sampling unit; * significant at 10%; ** significant at 5%; *** significant at 1%.

Each binary outcome is estimated using a separate linear probability model.

All regressions include the following controls: male, quadratic mother's age at birth, mother's education, father's education, Muslim religion, scheduled caste/tribe (SCST), birth order, gender-specific month of birth quartic polynomial, survey wave, and state fixed effects.

[a]Disaster exposure for diarhhea, fever, cough, and any medication given for such conditions is defined as the previous 1 month, including the month of interview. All other outcomes are predicted based on disaster exposure in the past 11 months, including the month of interview.

[b]Samples sizes are as follows: diarrhea (N=118,714); fever (N=118,696); cough (N=118,689); any medication (N=30,987); height-for-age, stunted (N=87,471); weight-for-age, underweight (N=96,077); weight-for-height, wasted (N=87,744); BCG (N=30,827); DPT (N=41,266); polio (N=41,413); measles (N=53,502); any vaccination (N=33,709); fully current (N=54,366).

[c]Residents are defined as mothers who report residing in the current location for two or more years.
[d]Sample is restricted to all children under 5 years of age at the time of survey. Samples for vaccination outcomes are restricted to ages 0-11 months for BCG, 0-15 months for DPT and Polio, and 0-20 months for measles and any vaccination.
[e]Samples are restricted to ages 0-11 months for BCG, 0-15 months for diphtheria and polio, and 0-20 months for measles, any vaccination, and being fully current on all vaccinations.