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

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Abstract

There is growing concern that climate change will lead to more frequent natural disasters that 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 and 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 on over 80,000 children 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 units, 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, infants, and families with more socioeconomic resources.

Keywords

India; natural disasters; child health; immunization; stunting; underweight

Introduction

Natural disasters are a common occurrence in developing countries, and there is growing concern that they may become more frequent due to climate change (Van Aalst, 2006). Disasters result in significant economic damage and can cause large-scale death. In 2009, 335 natural disasters were reported worldwide, killing over 10,000 people and causing damages over 41 billion USD (Vos et al., 2010).

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In addition to their immediate effects on health and mortality, disasters can have indirect, long-term, population health effects through various mechanisms, including income shocks to households and restricted access to health care. In particular, exposure to disasters during critical growth phases, such as childhood, could permanently alter health trajectories by interrupting important health investments. For example, disasters may prevent children from receiving timely immunizations or may induce households to divert resources away from children. Indeed, a large body of literature indicates that childhood socioeconomic (SES) conditions and health exhibit long-term influences on individuals' health and mortality (e.g., Haas, 2008; Victora et al., 2008; Case & Paxson, 2010; Galobardes, Lynch, & Smith, 2004). Exposure to severe environmental conditions, including epidemics, tropical diseases, and famines, during gestation and early years of life has been shown to significantly contribute to poor long-run outcomes (Bleakley, 2009; Chen & Zhou, 2007; Almond, 2006).

Prior research examining the effects of natural disasters on children's health generally focuses on singular large disaster events. For example, studies show that the drought in Zimbabwe slowed the growth of children under two (Hoddinott & Kinsey, 2001), forest fires in Southeast Asia increased child mortality (Frankenberg et al., 2004; Sastry, 2002; Jayachandran, 2009), and Hurricane Mitch in Nicaragua impaired children's health and nutrition and increased their labor force participation (Baez & Santos, 2007).

While understanding the effects of large disaster events is important, nations are more frequently affected by smaller-scale disasters, sometimes repeatedly. In fact, large disasters typically attract greater international aid and resources to the affected regions (Stroemberg, 2007), potentially mitigating some 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 health care, even if 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 has examined the impact of several different natural disasters on child health using data from Guatemala. Pörtner (2010) estimates the impact of frost, hurricanes, storms, heavy rains, and floods on child height-for-age, weight-for-height, and the occurrence of fever, diarrhea, or Acute Respiratory Infections (ARIs) within two weeks of the interview. 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 z-scores by 0.1-0.2 units.

In this paper, we examine the effects of exposure to disaster events, including small-to-moderate scale natural disasters on children's health and critical health investments using data from rural households in India. The focus on India is useful for several reasons. First, with nearly 1.2 billion people, India ranks among the lowest in terms of key child health indicators, including malnutrition and under-five mortality. The UN estimates that 2.1 million Indian children die before reaching the age of five every year, mostly from preventable illnesses such as diarrhea, typhoid, malaria, measles, and pneumonia (United Nations, 2008). Second, the country is annually struck by several natural disasters of varying intensity and types. 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. This includes some very large disasters, such as the 2004 Indian Ocean earthquake and tsunami (over 16,000 killed), the 1999 Orissa cyclone (nearly 10,000 killed), and floods in Gujarat and Maharashtra in 2005 (affecting over 20M people). However, a majority of these disasters did not result in large fatalities, and there has been no systematic examination of whether exposure to these disasters affected morbidity, nutrition, and health investments in childhood.

We use data on over 80,000 children from three waves of India's National Family and Health Surveys (NFHS; 1992-93, 1998-99, 2005-06) linked to EM-DAT, an international database of natural disaster occurrences containing information on all disasters affecting India during and around the period covered by the NFHS. 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 and not just single disaster events.

Conceptual framework

Natural disasters can affect children's health in three main ways. The first is a direct effect on family (either child and/or parent/caregiver) morbidity and mortality (e.g., a child drowns in a flood or contracts illness from contamination of food or water, death or illness of parent or caregiver).

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. For example, damage to hospitals or health clinics may result in reduced pre- and postnatal care, fewer births attended by a health professional and incomplete immunization. In addition, disasters may also compromise other water and sewage infrastructure that can have an impact on child health and increase exposure to vector-borne diseases.

The third effect is through the disaster's impact on the demand for health inputs, either through lost income or increased expenditures needed to cope with damage. In agricultural societies like much of rural India, disasters such as droughts and floods may lead to significant income shocks from damage to crops and livestock. Economic theory predicts that income shocks would reduce 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. 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 & Schultz, 1982; Behrman, 1988). One main hypothesis 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. While infant nutrition and health may be protected because of exclusive breastfeeding (e.g. from water contamination), 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 have fewer resources (e.g. access to credit markets) to smooth consumption, 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 from a natural disaster is 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 & 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 SES and child health indicators than Northern states (Mishra, Roy, & Retherford, 2004; Rani, Bonu, & Harvey, 2008). As a result, children in Southern states may be expected to fare better than their Northern counterparts in the aftermath of a disaster.

Data

Emergency Events Database

The World Health Organization (WHO) Collaborating Center for Research on the Epidemiology of Disasters maintains the Emergency Events Database (EM-DAT) of natural disasters that have occurred since 1900. The EM-DAT includes an event as a disaster if at least 10 persons were killed, 100 persons were affected (i.e. requiring immediate assistance during a period of emergency), or the affected state either declared a state of emergency or called for international assistance. For each disaster, EM-DAT provides information on where the disaster occurred, the type of disaster (i.e. droughts, earthquakes, epidemics, extreme temperatures, floods, mass movements, storms, and wildfires), the beginning and ending dates, and the damage incurred (i.e. people killed, injured, and rendered homeless, and estimated damages). Geographic specificity of the disaster includes identifiers such as name of a city, village, province, state, or district depending on the relevance. These data have been used extensively in disasters and public health journals, and also in the economics literature (Kahn, 2005; Toya & Skidmore, 2007; Strömberg, 2007).

All disasters occurring in India during the periods 1991-93, 1997-99 and 2004-06 were downloaded from EM-DAT. These periods were chosen because our focus is on disaster exposure during a 1-year period prior to the NFHS survey dates. 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 NFHS waves. Three new states were created in 2000–Jharkhand, Uttaranchal, and Chhattisgarh–making a current total of 29 states. Our analysis uses Indian state units as defined by their pre-2000 boundaries. However, disaster exposure 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.

Although the EM-DAT indicates type of disaster, we do not distinguish between different types for two reasons. First, a string of disaster events may be serially correlated (e.g., flooding following a storm), making it difficult to apportion resulting impacts across 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 disaster. Furthermore, we exclude epidemics from our disaster measure as disease outbreak is often triggered by another disaster and not an independent event in of itself. Therefore, we focus on the occurrence of any non-epidemic natural disaster by state.

Figure 1 displays the distribution of natural disasters across India corresponding to a one-year exposure window prior to the NFHS survey month. 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 occurrence 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 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 NFHS 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 children under five years old, NFHS asks about specific health conditions occurring two weeks prior to the survey–diarrhea, fever, and ARI or cough. We create a binary indicator for the occurrence of each of these conditions, and an indicator for whether any medication was given to treat the condition (conditional on occurrence). Due to the narrow reference window for these indicators, 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 nutrient deficiency 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 and is usually the result of acute significant food shortage and/or disease. NFHS collects height (length for infants) and weight measurements, which are age-standardized according to WHO growth charts and converted to z-scores. We examine z-scores for height-for-age, weight-for-age, and weight-for-height as well as binary indicators for stunting, underweight, and wasting, which are defined as having a z-score less than two for each indicator, respectively.

Finally, we examine child health investments by looking at immunizations. Mothers are asked about the following vaccinations for each child under five: tuberculosis (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 for a disease if the child has received the recommended doses of the immunization regimen for that disease according to the Government of India’s Recommended Immunization Schedule (see INSERT LINK TO ONLINE APPENDIX). Separate indicators are created for each immunization regimen and a composite indicator is created to identify whether a child is current on all immunization regimens. Since many diseases require multiple doses to provide full immunization coverage across different disease strains (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 included as control variables including child’s age, sex, birth order, mother’s age at the time of birth, mother’s and father’s highest level of educational attainment, SC/ST status, 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 before the interview, the period of exposure for these short-term outcomes is defined as the month preceding, and including, the interview month. For longer-term health and investment outcomes, i.e. anthropometrics and immunizations, exposure to disasters is defined based on the eleven months prior to the interview date, including the interview month. Although we show the 11-month exposure period in the main results, we also test the sensitivity of the results to an alternate definition of this exposure period and find the results to be robust to exposure length.

The exposure variable is coded as a dummy indicator that equals 1 if child was exposed to any disaster in the eleven months (one month for acute illnesses) prior to and including the interview month. The dummy variable definition avoids double-counting a disaster that may have occurred over multiple months. Furthermore, disaster length is not necessarily indicative of its severity as some severe disasters are short in duration, such as earthquakes. Findings from additional robustness checks examining alternate functional forms for exposure are discussed in the results.

Sample

The final sample is comprised of all children under five in rural households for whom health questions were asked (n=109,032). We drop 604 children from multiple births because their growth trajectories are likely to be markedly different from singletons. We also drop 2131 children with z-scores for anthropometric measurements greater than five in order to reduce the influence of outliers on estimated results. The final analytic sample includes over 80,000 children with information on acute illnesses and over 59,000 children with valid height and weight measurements. For vaccination outcomes, the sample is further restricted to children who were eligible to receive the vaccination within the previous 11-month 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 nine months of age.

Table 1 summarizes the individual and household characteristics for the largest sample of children analyzed for recent acute illnesses. The proportion of children experiencing acute illnesses during the last two weeks varies across illness type 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 in the WHO growth charts. Between 45-50% are stunted and underweight and 17% are 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 2 describes the exposure to disasters in the previous month, for children in the analysis of acute illnesses, and in the previous 11 months for children 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 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 previous year, 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.

Methods

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

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

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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 differential impacts of natural disasters by child's sex or gender, age, and SES status of the child's family, we estimate the model in equation (1) using an interaction of D^{-1}_{st} with child's sex or gender, age (0-1 year versus greater than one year), SC/ST status, maternal education, and indicator for residing in a South Indian state.

As mentioned, 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, we follow the approach used in Pörtner (2010) and employ all three available NFHS waves 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 ${}_t$ represents wave fixed effects. State fixed effects control for all unobserved state-level confounders that time-invariant. In other words, the parameter β_1 will be estimated using each state as its own control group. In addition, time fixed effects will control for any time trend in disasters and child health that affects all regions equally.

One concern may be that emergency teams are often mobilized in response to large disasters, potentially mitigating the negative health consequences of disasters. Unfortunately, data about emergency response is currently not being systematically collected and we are unable to account for post-disaster interventions. However, most disasters in our study are relatively small-scale in terms of mortality and would be unlikely to spark large emergency responses. As such, we believe that our estimates represent a lower bound for the health consequences of natural disasters in the presence of unobserved emergency response.

All regressions for binary outcomes are estimated using a linear probability model and standard errors are adjusted for clustering at the primary sampling unit (PSU) level, a group of approximately twenty households living in close vicinity. We considered clustering standard errors at the state level, the level at which our disaster exposure is coded, but the number of states (29) is much less than the suggested number of clusters needed for consistency (Kézdi, 2004). Nevertheless, we estimated these models and found that the standard errors with state clustering were generally lower than in models with PSU clustering.

Results

Immediate Effects on Acute Illnesses

Table 3 summarizes the estimates for predicting the likelihood of illnesses occurring in the previous two weeks. Each row is estimated using 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 an 18%, 9%, and 15% increase in the probability of diarrhea, fever, and ARI, respectively. However, experiencing a disaster in the past month is not significantly related to receiving medication to treat the condition.

Effects on Nutrition-Related Outcomes

For longer-term anthropometric outcomes displayed in Table 4, exposure to a disaster in the past year is significantly related to worse height and weight outcomes (row 1). Height-for-age and weight-for-age z-scores are reduced by 0.15 and 0.12 units, respectively. Stunting and underweight are each significantly higher by three percentage points, about a 7% increase. Given that estimates for height are larger in magnitude than weight, the negative signs for weight-for-height and wasting make sense. Similar results have been found by Pörtner (2010).

Effects on Immunization

Estimates for immunization outcomes are summarized in Table 5. For all vaccinations–BCG, DPT, polio, and measles–a disaster in the past year significantly reduces the likelihood of receiving age-appropriate doses. In fact, children are four percentage points less likely to have ever been vaccinated and five percentage points significantly less likely to be fully current on all their vaccinations if they experience a disaster in the past year.

Heterogeneous Effects

Investigation of heterogeneous effects of disasters 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 sex differences 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 3, row 2), the estimate is not statistically significant. However, significant gender differences are observed for growth outcomes (Table 4, row 2). Boys are significantly less likely to be stunted and underweight than girls. This suggests that there may be 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 sex or 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 if ill. 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 SES conditions in Southern states.

Robustness Checks

The above results are robust to a variety of sensitivity analyses (Table 6). 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 6, Column 1). While point estimates do change somewhat due to the narrower window for disasters' lagged effects, the substantive results do not change. Second, we include interview month fixed effects in our regressions to account for potential seasonal trends that affect both disasters and health outcomes (Column 2) and find similar results. Third, we include urban children in the sample (column 3) 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 exclude households who have resided in their current location for less than two years (Column 4) to limit bias due to migration; exclusion of recent migrants does not change results.

In additional analyses not reported here, we examined alternate functional forms for disaster exposure. Regressions using a continuous indicator of exposure to disaster months produce results that are consistent with those found with the dummy variable definition. For investigating potential nonlinear effects of disaster exposure, we separately included a quadratic term and dummy variables for different thresholds (e.g., 1-2 disaster months, 3-9 disaster months), but resulting estimates did not show any nonlinearities or thresholds that consistently predict growth and immunization outcomes. Finally, alternate ways to control for differences in age cohorts (e.g. birth year dummies, additional quartic age polynomials interacted with SC/ST) did not appreciably change point estimates in the main results.

Conclusions and Discussion

Our study contributes to the broader literature linking environment and population health (De Souza, Williams, & Meyerson, 2003) and to the literature on environmental effects on child health in particular (World Health Organization, 2005). There is growing concern that climate change will lead to more frequent natural disasters of increasing intensity worldwide. 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, little is known about how natural disasters in general affect child health. The vast majority of natural disasters tend to be small or moderate in size, similar to those we examine in our study; the median disaster in our data led to 48 deaths, which are orders of magnitude smaller than the deaths caused by large events. Our results show that even small-to-moderate disasters can have significant short- and long-term effects on population 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 SES outcomes in the long run (for a review, see Victora 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 units, 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 sex/gender, age, maternal education and region have important implications for policy. We show that, while there is little difference between boys and girls in the biological susceptibility to the effects of disasters, 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 large literature documenting disinvestments in girls' human capital in developing countries (Rose, 1999; Maccini & Yang, 2009; Chen, 2011; Anttila-Hughes & Hsiang, 2012) 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, & 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. Indeed, suboptimal breastfeeding is estimated to be the largest contributor to child mortality in low- and middle-income countries (Black et al., 2008) and the Government of India's policy guidelines promote continued breastfeeding for infants up to two years of age as a key intervention for reducing malnutrition (Ministry of Human Resource Development, 2004).

Finally, our results suggest that the negative effects of disasters are stronger among children living in lower SES conditions (Northern states and less maternal education). This is consistent with findings in from other developing countries that it is the poorest households that struggle to cope with natural disasters are at high risk of poverty traps (Carter et al., 2007). 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).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 do not include children who may have moved with their families due to the disaster, or children who were no longer alive at the time of the survey, therefore these findings are conservative

Several directions for future research emerge from our study, including examining the role of different types of disasters on child health and investments; understanding how households migrate in response to disasters of different scale and severity; and further exploring the precise mechanisms through which disasters influence population health.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Research Highlights

- Even small and moderate natural disasters had widespread effects on children's health in rural India during 1992-2006.
- Effects of natural disasters on child health varied significantly by child's gender, age and socioeconomic characteristics.
- Exposure to natural disasters increased the likelihood of acute illnesses in children under 5.
- Exposure to natural disasters in the past year increased the likelihood of stunting and underweight among children under 5.
- Exposure to natural disasters in the past year reduced the likelihood of timely immunizations among children.
- Exposure to small and moderate natural disasters has significant short and long term impacts on child health among affected populations.

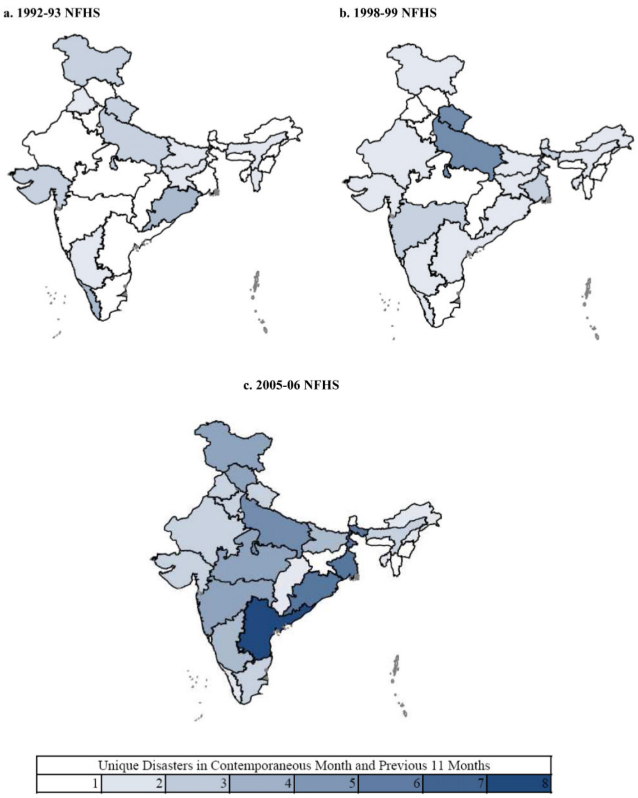

Figure 1.
Natural disasters occurring in survey month and previous 11 months

Table 1

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
Acute Respiratory Infection	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

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	1992-93 NFHS (N=31,973)		1998-99 NFHS (N=21,688)		2005-06 NFHS (N=27,475)	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
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 2

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**
1992-93 NFHS				
Any disaster	7	0.26	10	0.71
Drought	1	0.15	1	0.20
Flood	6	0.11	6	0.51
Mass movement	0	n/a	1	0.01
Storm	0	n/a	2	0.20
1998-99 NFHS				
Any disaster	5	0.28	13	0.60
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
2005-06 NFS				
Any disaster	8	0.25	28	0.82
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 3

Effects of Disasters on Acute Illnesses in the Last Two Weeks

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

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 controls for male, quadratic mother's age at birth, mother's education, father's education, Muslim religion, scheduled caste/tribe, 5 indicators for birth order, gender-specific month of birth quartic polynomial, survey wave, and state fixed effects. a This model is estimated conditional on occurrence of the illness.

[a]This model is estimated conditional on occurrence of the illness.

Table 4

Effects of Disasters on Physical Growth

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

Standard errors (in parentheses) are corrected for heteroskedasticity and clustered by PSU;

* 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 full set of controls.

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Table 5

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 (0.012)***	−0.019 (0.010)*	−0.042 (0.010)***	−0.034 (0.008)***	−0.037 (0.012)***	−0.049 (0.009)***
Interaction Effects of Disaster Exposure						
(2) X male	0.005 (0.014)	−0.012 (0.012)	−0.014 (0.012)	0.001 (0.009)	−0.005 (0.013)	−0.004 (0.010)
(3) X scheduled caste/tribe	0.008 (0.018)	0.015 (0.014)	0.026 (0.015)*	−0.006 (0.012)	0.009 (0.017)	0.011 (0.013)
(4) X no education	−0.014 (0.016)	0.003 (0.013)	0.013 (0.014)	−0.011 (0.010)	0.022 (0.015)	−0.018 (0.012)
(5) X South	0.086 (0.030)***	0.020 (0.028)	−0.009 (0.028)	−0.024 (0.021)	0.096 (0.028)***	0.004 (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 PSU;

* 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 full set of controls.

Table 6

Robustness Checks

Outcome[a]	(1) Any disaster in past 6 months	(2) Including interview month fixed effects	(3) Including urban areas	(4) Limited to residents[b]
Diarrhea		0.022 (0.004)***	0.019 (0.003)***	0.022 (0.004)***
Fever		0.015 (0.005)***	0.019 (0.004)***	0.020 (0.006)***
Acute Respiratory Infection		0.028 (0.006)***	0.028 (0.004)***	0.035 (0.006)***
Any medication given		−0.006 (0.010)	−0.001 (0.008)	−0.000 (0.010)
Height-for-age	−0.092 (0.027)***	−0.135 (0.032)***	−0.111 (0.025)***	−0.158 (0.035)***
Stunted	0.016 (0.007)**	0.029 (0.009)***	0.020 (0.007)***	0.035 (0.009)***
Weight-for-age	−0.066 (0.021)***	−0.112 (0.025)***	−0.084 (0.020)***	−0.138 (0.027)***
Underweight	0.014 (0.007)**	0.029 (0.008)***	0.025 (0.006)***	0.036 (0.009)***
Weight-for-height	−0.043 (0.020)**	−0.040 (0.025)	−0.003 (0.020)	−0.061 (0.027)**
Wasted	−0.003 (0.005)	−0.014 (0.007)**	−0.018 (0.005)***	−0.013 (0.007)*
BCG	−0.044 (0.011)***	−0.057 (0.012)***	−0.053 (0.010)***	−0.055 (0.014)***
DPT	−0.023 (0.009)**	−0.021 (0.010)**	−0.012 (0.008)	−0.016 (0.011)
Polio	−0.032 (0.009)***	−0.041 (0.010)***	−0.031 (0.008)***	−0.046 (0.011)***
Measles	−0.022 (0.007)***	−0.034 (0.008)***	−0.034 (0.006)***	−0.033 (0.008)***
Any vaccination	0.007 (0.011)	−0.032 (0.012)***	−0.040 (0.010)***	−0.045 (0.013)***
Fully current	−0.032 (0.008)***	−0.049 (0.009)***	−0.039 (0.008)***	−0.049 (0.010)***

Standard errors are corrected for heteroskedasticity and clustered by PSU;

* significant at 10%;

** significant at 5%;

*** significant at 1%.

Each cell represents a separate regression; each binary outcome is estimated using a separate linear probability model.

All regressions include the full set of controls.

[a] Disaster exposure for diarrhea, fever, cough, and any medication given for such conditions is defined as the previous 1 month, including the interview month. For all other outcomes, exposure is based on the past 11 months, including the interview month.

[b]Residents are defined as mothers who report residing in the current location for two or more years.