After the floods: Differential impacts of rainfall anomalies on childhood undernutrition in India

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Abstract

Childhood undernutrition is among the most challenging issues faced by low- and middle-income countries. In India, where over one-third of children are undernourished, this can hinder the achievement of sustainable development. The changing climate may aggravate malnutrition directly by reducing food availability and indirectly through affecting income and subsequent food security or increasing the spread of infectious diseases. The empirical evidence however remains unsettled, with too much rainfall increasing malnutrition in some contexts, but reducing the prevalence in some others. Based on the Demographic and Health Survey for India 2015-16 (n=228,747), this study examines the effect of rainfall anomalies on the prevalence of stunting among children under five in India. The findings suggest that exposure to floods, particularly during infancy and in-utero, increases the likelihood of moderate stunting and severe stunting by 12% and 14%, respectively. Girls, children from disadvantaged castes, and those living with poor and less educated mothers are at highest risk of stunting due to rainfall anomalies. Furthermore, we find that female empowerment through education can reduce the risk of flood-induced undernutrition in a similar magnitude as household wealth. This has important implication for sustainable development.

Introduction

The frequency and magnitude of floods is projected to increase in the next decades due to global warming, affecting up to 1.2% of the global population by the end of the century (Hirabayashi et al. 2013). India is in a high-risk zone, with floods already frequently causing serious damage in the country as evident in the recent flooding in Kerala during the 2018 monsoon season. Between 2001 and 2010, a two-fold increase in the number of floods was recorded in India compared to the previous two decades.[1] An estimated 3.8 million people were affected by floods in 2016 alone, with losses amounting to 1.5 billion US dollars.

Apart from economic loss and damage, floods bring about serious consequences on human health. Common short-term risks include mortality, injuries, and communicable diseases, including vector-borne and water-borne diseases (Ahern et al. 2005). Some studies have documented long-term health risks as well, including elevated risk of non-communicable diseases, psychosocial distress, malnutrition and poor birth outcomes (K. Alderman et al. 2012a; Zhong et al. 2018). However, to date the evidence on the long-term health effects of floods is limited and inconclusive.

The burden on children can be particularly heavy in the event of floods and other environmental disasters. Severe floods can damage vital infrastructure, disrupting food supplies in the short-run and undermining economic livelihoods in the medium to long-run. Households facing financial strains due to climatic shocks may have to reduce the quantity and quality of food consumed (Mazumdar et al. 2014; Mehar et al. 2016; Muttarak 2018). As a result, children's health can be compromised.

Experiencing undernutrition during childhood can have long-lasting implications, including lower school performance (H. Alderman 2006), reduced work capacity (Martorell et al. 2010), predisposition to chronic diseases, as well as mental health problems during adulthood (Adair et al. 2013; Black et al. 2008; Victora et al. 2008). Acute malnutrition also puts children's life at risk; Research shows that nearly half of child deaths worldwide under the age of two are caused by undernutrition (Black et al. 2013).

Children's health can be further aggravated by water contamination after heavy rainfalls. Outbreaks of infectious diseases, such as diarrhoea, leptospirosis, cholera and vector-borne diseases are common after flash floods (Ahern et al. 2005b; K. Alderman et al. 2012b) and can contribute to childhood undernutrition.

However, the implications of floods for childhood health are still unclear due to a limited number of empirical studies (Phalkey et al. 2015). Current evidence is based on few community-based surveys and seems to be context-dependent. While some report an increased risk of childhood undernutrition and diarrheal diseases among flooded communities in India (Rodriguez-Llanes et al. 2011, 2016), Bangladesh (del Ninno and Lundberg 2005) and Nepal (Gaire et al. 2016), others do not find such an association (Joshi et al. 2011; Stewart et al. 1990). It is important to improve the knowledge in this field because if floods do increase the incidence of undernutrition, relevant nutritional interventions will be called for to reduce the impacts of floods on childhood undernutrition.

Indeed, this line of research is particularly relevant for India. In spite of making some progress in the past decade, India remains among the countries with the highest levels of childhood undernutrition

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[1] Own estimates based on EM-DAT data (https://www.emdat.be/) of hydrological disasters (floods). 99 flood events were recorded in India in 2001-2010, compared to 46 in 1991-2000 and 33 in 1981-1990.

in the world; 38.3 % of boys and 37.4 % of girls in India aged under five had stunted growth in 2015 (UNICEF et al. 2018). With climate projections showing an increased risk of floods in South Asia over the coming decades (Goswami et al. 2006; Hijioka et al. 2014; Hirabayashi et al. 2013), progress towards reducing child undernutrition in the region could be slowed down or even reversed. In fact, a recent study has warned that the impacts of floods on childhood stunting are highly acute in southern India where the worst flood in nearly a century was experienced in the state of Kerala in August 2018 (Muttarak and Dimitrova (in press)).

It is crucial not only to understand how floods can affect child health, but also who is vulnerable to the impacts of floods. The demographic differential vulnerability approach thus is employed to investigate the differential impacts of floods on population subgroups (Muttarak et al. 2016). Socio-economic status has been identified as one of the most important determinants of climate vulnerabilities (Brouwer et al. 2007; Friel et al. 2008). A study on flood risks and vulnerabilities in Bangladesh found that poor households are not only less adaptive to floods, but also more likely to experience floods in the first place and less likely to receive assistance after the disaster (Brouwer et al. 2007). In India caste also plays an important role in determining social disadvantages.

Moreover, while boys are more likely to be stunted than girls due to higher energy use, floods can disproportionately affect girls by worsening poverty and reinforcing feeding preferences. In India, girls are generally more likely to be neglected than boys. Recent research shows that around 22% of female deaths under age of five in India are due to gender bias (Guilmoto et al. 2018). We investigate whether gender disparities are also present when it comes to flood vulnerabilities.

This study adds to the literature by exploiting data from a nationally representative household survey for India and geo-referenced climate data. We use the 2015-16 round of the Demographic and Health Survey (DHS) for India in combination with monthly rainfall data from the Climatic Research Unit (CRU) at the University of East Anglia. The GPS coordinates of household clusters, available in more recent DHS rounds, are used to match the survey and climate data. The focus of our analysis is on children under five years of age at the time of the interviews. Child health is measured through an indicator for stunting (low height-for-age), which is typically caused by infections and inadequate nutrition during a child’s early years of life.

We restrict the climate data to the monsoon months only (June to September), when the risk of floods in India is the highest. We then construct measures for rainfall anomalies – deviations in monsoon season rainfall from the location-specific long-term average. A multivariate logistic regression model is used to assess the relationship between stunting and exposer to rainfall anomalies in early childhood. More details on the data and methods used in this study are provided in the next section.

Data and methods

Health data

We use data from the most recent round of DHS for India, collected in 2015-16. DHS focuses on fertility, health and overall welfare of women in reproductive age and their children. The large sample size is representative at the national and sub-national level.

We focus our analysis on children under the age of five (n=228,747) and use anthropometric data to construct a binary outcome indicator for stunting and severe stunting. Children are classified as stunted if their height for age is more than two standard deviations (SD) below the WHO Child Growth Standards median (de Onis 2007). Severely stunted children have a height for age more than three standard deviations below the WHO Growth Standards median (Ibid.).

Stunting reflects the cumulative effect of undernutrition and infections since the child's birth and even during the in-utero period. It can thus indicate poor environmental conditions or other long-term restrictions to a child's physical development (WHO 2010). Severe stunting can impair not only the physical but also the mental development of a child, with long-lasting implications. Children who are severely stunted have been found to perform worse in school and have reduced intellectual capacity (Adair et al. 2013; H. Alderman 2006; Black et al. 2008). In adulthood, stunted women are likely to experience complications during labour and give birth to stunted children, which creates a 'vicious cycle' of malnutrition (Wells 2017; WHO 2010).

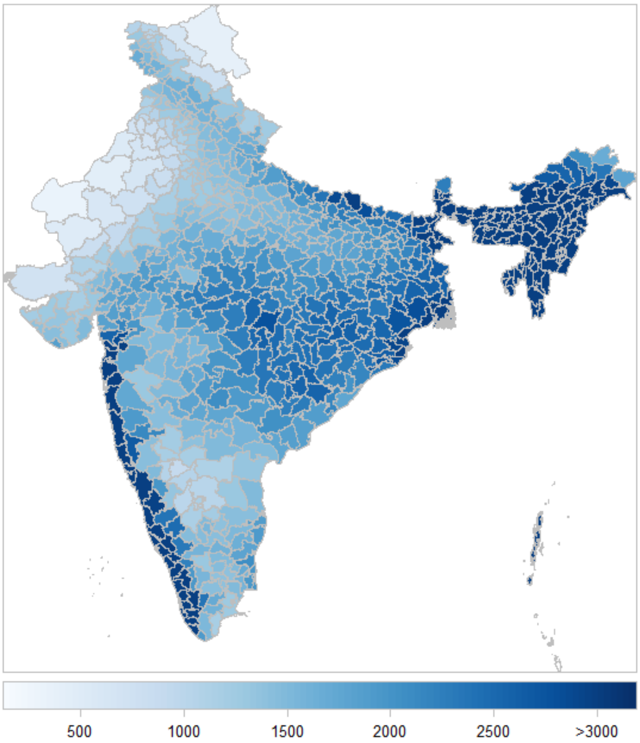
Climate data

Gridded precipitation data is retrieved from CRU (time-series 3.25), which is available for the whole globe at 0.5° spatial resolution and covers the period from 1901 to 2016 (Harris et al. 2014). The GPS coordinates of household clusters, provided in recent DHS rounds, is used to match the location of children with the gridded precipitation data. To keep the identity of survey participants confidential, DHS displaces household clusters in a random direction by 2km for urban areas, 5km for rural areas, and additional 10km for 5% of all clusters (Burgert et al. 2013). We account for this shift by creating a 10km radius around each cluster and averaging the climate information for all grid cells that fall within the buffer area.

We restrict the climate data to the monsoon season only (months June to September) and calculate the total monsoon rainfall for each buffered location and period. A measure of rainfall anomalies is then constructed as a deviation in monsoon rainfall from the location specific long-term mean (1970-2016).

Figure 1 below shows the distribution of total monsoon rainfall by district in India for the period 2010-2016. The different climate regimes in India can be clearly seen on the map; The arid and semi-arid zones in the east and central-south received under 500 mm of monsoon rainfall per year, while the tropical and sub-tropical zones in the east and south-west received over 3000 mm.

Figure 1: Total monsoon season rainfall (mm) by district in India (2010-2016 average)



Source: Own estimates based on CRU TS 3.25

Estimation strategy

We use multivariate logistic regression models to estimate the effect of precipitation on child's nutrition status. The basic model takes the following form:

$$\mathrm{logit}\ (\text{odds of } \mathrm{Y}_{\mathrm{i,g}} = 1) = \beta_1\, C_{g,t} + \delta_j\, \mathrm{Z}_j + \beta_1 f(a_6, \alpha_{12}\alpha_{18}, \alpha_{24}, \alpha_{36}\alpha_{48})_i + \alpha_g + \epsilon_{\mathrm{i,g}}$$

where *Y* is a dummy variable, taking the value of 1 if a child *i*, at age *a* and in grid cell *g* is stunted and 0 otherwise. *C* denotes exposure to rainfall anomalies in grid cell *g* during period *t. Z* is a vector of individual and household characteristics, which are expected to impact the child's nutrition status. These are grouped into individual, maternal and household variables. More details are provided in Table 1.

The equation also includes controls for grid cell fixed effects $\alpha_g$and period fixed effects for year of interview, quarter of interview, and quarter of birth. The grid cell fixed effects capture location-specific time invariant factors which can affect childhood undernutrition, while the period fixed effects capture yearly and seasonal factors. f is a restricted cubic age spline with knots at 6, 12, 18, 24, 36 and 48 months of age. Finally, errors (ϵ) are clustered at the district level.

We further examine the potential differential vulnerabilities across population sub-groups by including interaction terms between rainfall anomaly and selected individual and socio-economic variables. In particular, we are interested in differences by child's gender, household's level of wealth, mother's education and literacy, and caste groups. Looking into differences in climate vulnerabilities by partner's level of education would be highly relevant as well, however, the data is missing for a large number of observations in our sample.

Table 1: Description of individual, maternal and household variables

Variable	Description	Mean (SD)
Individual factors		
Sex of the child	Categorised into: (0) female (1) male	0.52 (0.50)
Child is twin	Categorised into: (0) no (1) yes	0.01 (0.12)
Maternal factors		
Mother's age at giving birth	Measured in years of age	25.15 (4.96)
Mother's height	Measured in cm	1517 (60.55)
Mother's media exposure	Categorized into: (0) no (1) yes	0.63 (0.48)
Mother's level of education	Categorised into: (0) no (1) primary (2) secondary (3) higher	1.33 (1.01)
Mother's literacy		1.58 (0.49)
Household factors		
Wealth quintile	Categorised into: (1) lowest (2) lower (3) medium (4) high (5) highest	2.68 (1.37)
Household head	Categorised into: (1) female (2) male	1.12 (0.32)
Number of under-five children in the household	Measured in number of children.	1.76 (0.93)
Caste	Categorised into: (0) other (1) scheduled caste (2) scheduled tribe (3) other backward class (OBC)	1.77 (1.18)

Results

Our data analysis shows that exposure to higher than usual monsoon rainfall can exacerbate malnutrition in India. We find that accumulative exposure to rainfall anomalies over the child's lifetime up to age 5 had a negative and statistically significant effect of children's HAZ score (Table 2, column 1). This means that children who have experienced higher rainfall that usual are more likely to be too short for their age group.

The results of the logistic regression model show that exposer to rainfall anomalies during the child's observed lifetime increased the odds of stunting by 12% and the odds of severe stunting by 14% (both at 99% confidence) (Table 2, columns 2 and 3).

We identify that exposure to positive rainfall anomalies is most critical for stunting when the child was in infancy (age between 0 and 1) and in-utero (period before birth); see Figure 2. Positive rainfall anomalies during these periods increased the probability of stunting by between 0.5 and 1 percentage point (99% confidence), while it was not significant for other single age periods.

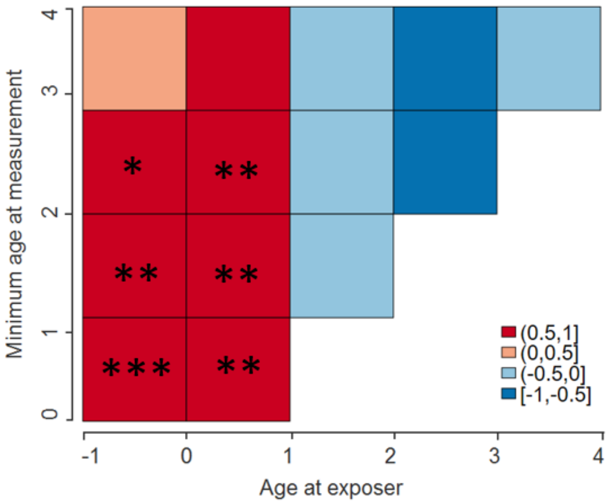
Table 2: Impacts of rainfall anomalies on moderate and severe stunting, children aged 0-5

	HAZ score (OLS coef.)	stunting (Odds ratio)	severe stunting (Odds ratio)
Average rainfall anomalies since in-utero	-0.05*** (0.02)	1.12*** (0.02)	1.14*** (0.02)
Individual controls			
Sex (female)	ref	ref	ref
Sex (male)	-0.09*** (0.01)	1.10*** (0.01)	1.16*** (0.01)
Twin (no)	ref	ref	ref
Twin (yes)	-0.40*** (0.04)	1.58*** (0.08)	1.66*** (0.10)
Maternal controls			
Age at birth	0.01*** (0.00)	0.99*** (0.00)	1.00 (0.00)
Height	0.00*** (0.00)	0.99*** (0.00)	0.99*** (0.00)
Education (no education)	ref	ref	ref
Education (primary)	0.06*** (0.01)	0.91*** (0.01)	0.85*** (0.02)
Education (secondary)	0.15*** (0.01)	0.79*** (0.01)	0.73*** (0.01)
Education (higher)	0.32*** (0.01)	0.62*** (0.02)	0.59*** (0.02)
Exposure to mass media (yes)	0.05*** (0.01)	0.94*** (0.01)	0.90*** (0.01)
Household controls			
Wealth (lowest)	ref	ref	Ref
Wealth (lower)	0.11*** (0.01)	0.86*** (0.01)	0.81*** (0.02)
Wealth (middle)	0.24*** (0.02)	0.73*** (0.01)	0.64*** (0.02)
Wealth (higher)	0.37*** (0.02)	0.59*** (0.01)	0.53*** (0.02)
Wealth (highest)	0.55*** (0.02)	0.47*** (0.01)	0.45*** (0.02)
Number of children under age 5	-0.05*** (0.00)	1.06*** (0.01)	1.06*** (0.01)
Household head (male)	ref	ref	ref
Household head (female)	-0.02 (0.01)	1.02 (0.02)	1 (0.02)
Caste (other)	ref	ref	ref
Caste (scheduled caste)	-0.14*** (0.02)	1.19*** (0.02)	1.16*** (0.03)
Caste (scheduled tribe)	-0.08*** (0.02)	1.14*** (0.03)	1.14*** (0.04)
Caste (other backward caste)	-0.07*** (0.01)	1.09*** (0.02)	1.07** (0.02)
Residence (urban)	ref	ref	ref
Residence (rural)	0.00 (0.01)	0.98 (0.02)	0.95** (0.02)
Age splines	YES	YES	YES
District FE	YES	YES	YES

Period FE	YES	YES	YES
Observations	228,747	228,747	228,744
Adj. R-squared	0.151	0.095	0.085

Notes: **p* <0.5, ***p* <0.01, ****p* <0.001. Coefficients are odds ratios with clustered standard errors reported in parenthesis.

Figure 2: Impact of positive rainfall anomalies on stunting (percentage points), children aged 0 to 5



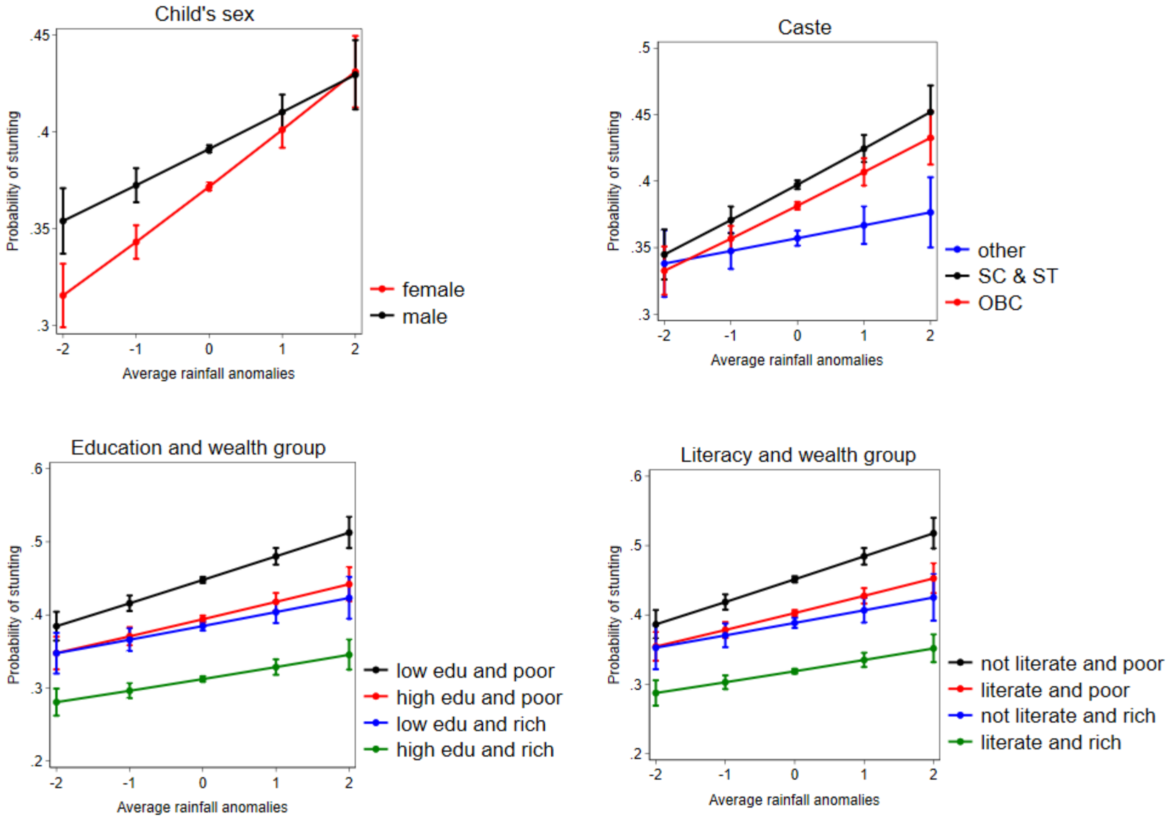
Notes: **p* <0.1, ***p* <0.05, ****p* <0.01. The figure shows average marginal effects based on a logistic regression model. Positive rainfall anomalies are dummy variables, which take the value 1 if total monsoon rainfall in a given period is 1 or more standard deviations above the long-term mean (1970-2016), and 0 otherwise.

In Figure 3, we further compare the likelihood of stunting due to rainfall anomalies for different population subgroups. Whilst boys are generally more likely to be stunted than girls given their higher energy usage, our data show that when experiencing positive rainfall anomalies, girls are equally likely to being stunted as boys. This might reflect gender-based discrimination in feeding practices in households struggling with food insecurity during climate shocks.
We find that children born to poor and less educated mothers are particularly vulnerable to rainfall excess exposure. Having an educated mother reduces the odds of stunting during excessive rainfall even for those children that are in the lower wealth quintiles. Not surprisingly, children born to wealthy and educated mothers have the lowest odds of stunting from rainfall anomalies.

We also look into possible differences by mother’s literacy instead of education to investigate whether literacy alone can reduce children’s vulnerabilities of stunting from rainfall excess. Indeed, the results look very similar to the above, with children born to illiterate and poor mothers having the highest odds of stunting during periods of excessive rainfall and those born to wealthy and literate mothers having the lowest odds.

Not surprisingly, caste also seems to play an important role in determining climate vulnerabilities in India. Children born in scheduled and backward castes and tribes are generally more likely to be stunted that children born in other caste. Experiencing excessive rainfall additionally increases the risk of stunting for socially disadvantaged castes and tribes, while it does not seem to affect the other caste.

Figure 3: Impacts of rainfall anomalies on stunting by individual and socio-economic characteristics, children aged 0-5



Notes: Figures show predicted probabilities and 95% CIs. Average rainfall anomalies refer to the period from in-utero up until child's measurement. Abbreviations: SC & ST – scheduled caste and scheduled tribe; OBC – other backward caste. Results tables are provided in the Annex.

Conclusions

We show that exposure to excessive rainfall during the monsoon months, which is an indication of flood developments, elevates the risk of childhood undernutrition in India. The most critical periods of exposer seem to be the period before birth (when the child was in-utero) and the first year of life. Indirectly, rainfall shocks could affect child health by undermining food security and elevating the risk of infectious diseases. The results of the present study warn on the urgent need to aid children and pregnant women in flood affected areas.

Most importantly, we show that health outcomes depend not only on the severity of floods but also on people's vulnerabilities. Experiencing rainfall shocks can deepen existing inequalities; We find that children born in disadvantaged castes, and to less educated and poor mothers are more likely to be affected by rainfall shocks than children borne in less socially disadvantaged groups.

The results of the present study can serve as a critical input to policy-makers, researchers, and health professionals working to improve children's wellbeing in disaster affected areas. In view of the global sustainable development agenda, we hope to shine a light on the potential obstacles to achieving the SDG target of eliminating childhood malnutrition.[2]

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[2] Sustainable Development Goal 2.2: „By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons"; source: https://sustainabledevelopment.un.org/topics/sustainabledevelopmentgoals.

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