# Impact of Rainfall Shocks on Child Health: Evidence from India*

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**Abstract**

While there is little evidence of discrimination against girls in the allocation of resources within a household under normal circumstances, it would be worthwhile to explore the effect of extreme conditions such as rainfall shocks on the outcomes of surviving girls and boys. In this paper, I estimate the impact of rainfall shocks in early childhood on the anthropometric outcomes of girls and boys aged 13-36 months in rural India. I find that adverse negative rainfall shocks negatively impact height for age and weight for age for both girls and boys. Further, I explore two channels through which rainfall affects child health: by affecting the relative price of parent's time in childcare (particularly breastfeeding and vaccinations) and through income (as rainfall generates variation in income through its effect on agricultural output). I find that average rainfall improves agricultural yield in India on the one hand and increases the demand on mother's time for performing agricultural tasks on the other. These two channels work in opposite directions– implying that the income effect outweighs substitution (of parental time) effect.

**Keywords**: Anthropometric outcomes, Rainfall, India.

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# 1 INTRODUCTION

The relative status of women in the developing world is poor, compared to developed countries. The literature has highlighted the existence of gender inequalities in South Asia, attributed to strong preferences for male child often the result of traditional customs. Further, households in India, as in much of the developing world, face substantial risk - an inevitable consequence of engaging in rainfed agriculture in a drought prone environment. This further affects the ability of households to provide for their families and invest in children. Investments in children and human capital are central to enhance the well being of households, break the intergenerational transmission of poverty and finally lead to the growth and development of a country.

The phenomenon of 'missing women', a term coined by Amartya Sen, was used to describe that the gender ratio is much lower than would be expected if women and men were subject to similar allocation of resources in a household (Sen, 1990). The comparative neglect of female health and nutrition, especially but not exclusively during childhood is largely responsible for such a phenomenon. Indeed, the most striking evidence on skewed sex ratios and gender bias in mortality comes from South Asia in general and India in particular. According to the gender statistics of the Census of India in 2001, out of the total population of India, 532 million or 52 percent are males and 497 million are females constituting the remaining 48 percent in the population. In sheer numbers, males outnumber females by 35 million in the population. Further, Kynch and Sen (1983) explain this difference by pointing out that "except in the period immediately following birth, the death rate is higher for women than for men fairly consistently in all age groups until the late thirties. This relates to higher rates of disease from which women suffer, and ultimately to the relative neglect of females, especially in health care and medical attention".

Given the literature on comparative neglect of women in India, one would expect to find evidence of discrimination against girls in the allocation of resources within a household under normal circumstances- however this is not observed (Subramanian, 1995); (Subramanian and Deaton, 1990). But it is conceivable that under abnormal circumstances like shocks faced by households, parents alter their behaviour in a way which leads to discrimination against girls. (Rose, 1999) establishes that mortality among girls in higher in the presence of a rainfall shock as compared to boys in India. In a similar spirit, I assess the impact of rainfall shocks on the health of surviving children and explore gender differences.

This paper contributes to the literature on the investigation of gender bias in India. Previous studies have pointed out that there is no gender based difference in anthropometric outcomes and food allocation in India, although there is sex selection in mortality in childhood. This paper contributes to the literature by seeking to address whether the existence of shocks changes the intra household allocation (in terms of nutrition, medical care and breastfeeding practice) to the disadvantage of the girl so that it leads to deteriorated health outcomes for her, as measured by anthropometric outcomes. In addition, I check for possible mechanisms through which shocks could affect child health outcomes.

### 1.1 Gender bias in South Asia

In India, child sex ratio (0-6 years) of the population has been registered as 914 in the 2011 Census. This ratio has been continually declining from 927 in 2001, 945 in 1991 and 962 in 1981. Another notable feature is that the child sex ratio has fallen below the sex ratio at birth according to the Census of India 2001. Prior to 2001, the child sex ratio was close to sex ratio at birth. The magnitude of the decline can be seen from the fact that 31 States / union territories have registered a decline in Child Sex Ratio according to Census 2001 as compared to Census 1991. This reflects a grim picture of the status of the girl child in the country and further points towards investigating the existence and causes of gender bias during infancy and early childhood among surviving children. That said, evidence on the existence of gender bias in nutritional status in India is contradictory empirically (Ryan et al., 1984); (Basu, 1989); (Basu, 1993); (Mishra et al., 1999). However under abnormal circumstances such as income shocks, the story might change. Thus, it would be worthwhile to explore if female children bear the excess burden in the face of shocks when households are unable to smooth consumption. This is the question I seek to address.

A large number of studies have found an excess mortality of girls relative to boys in South Asia (Sen, 1981); (Sen, 1988); (Dreze and Sen, 1991). An influential account has been provided by (Das Gupta, 1987) who argues that in Punjab, gender bias in mortality is more severe for daughters who are born into families with other surviving female children. This is more pronounced in the case of families with mothers who are younger and, even more, if they are educated. (Rose, 1999) also examines the connection between gender bias in mortality and shocks. She uses rainfall shock data for Indian districts and links to the mortality among girls, checking for consumption smoothing at the time of shock: a favourable rainfall shock increases the likelihood-relative to that of a boy- that a girl survives until school age.

While gender bias in mortality is shown to exist, it is less obvious when we compare the anthropometric outcomes of surviving girls and boys. On the one hand, (Sen and Sengupta, 1983) provide a descriptive account of malnutrition among children less than 5 years of age in two villages of the Birbhum district of West Bengal in India. The sex bias is reflected both in (i) the greater prevalence of undernourishment of various degrees among girls than among boys (ii) in the lower growth dynamics of girls vis-a-vis boys. They also found that the village with the better over-all nutritional record has much sharper sex discrimination. On the other hand, (Ryan et al., 1984) found no significant variation in anthropometric indices using data on six ICRISAT villages of Maharashtra and Andhra Pradesh in India.

Thinking about high mortality and poor anthropometric outcomes among girls in infancy and early childhood, the key suspects would seem to be less food or nutrient intake and/ or less medical care. In some earlier studies, authors found gender bias against girls in nutrition intake like (Ryan et al., 1984) for south- west India. Similarly, (Das Gupta, 1987) found that for children aged 0-2 years, boys receive food that is superior nutritionally and more valued socially in India. Considerably more is spent on clothing for boys than girls, reflecting more general differences in caring for boys and girls. A novel approach was developed by (Subramanian and Deaton, 1990) who used data on Maharashtra and estimated the expenditure elasticity of different food groups on the household budget. They were not able to find any gender differential in the intra-household allocation of food consumption. (Subramanian, 1995) repeated this exercise for three other Indian states with skewed sex ratios (Rajasthan, Punjab and Haryana) and found no evidence of gender bias in food consumption. (Deolalikar and Rose, 1998) use ICRISAT data and find increases in consumption of medicines, edible oils and fats after the birth of a male child (relative to female child) which are consistent with the substitution effect/preference explanation: "boys consume higher quality foods and are more likely to receive health care than girls, resulting in better health and increased survival probabilities for boys relative to girls than would exist if allocations were identical".

Results on healthcare and medical care also diverge. (Subramanian and Deaton, 1990) found no gender bias for medical expenses in Maharashtra, India. On the other hand, (Deolalikar and Rose, 1998) found higher expenditure on medicines and healthcare for male Indian children. (Das Gupta, 1987) also found much wider sex differentials among children in medical care than in food allocation. The expenditure on medical care for sons was found to be 2.34 times higher than that for daughters in Punjab, India.

In summary, the literature on gender bias in South Asia has explored several questions in the past. There exists a plethora of descriptive evidence on skewed sex ratios and excess female mortality in this region. However among the girls who manage to survive, results on food allocation, anthropometric outcomes and medical care seem to diverge. A part of the divergent results could be attributed to the specificities of the data used and the particular regions in which these studies are conducted. For example, it is well documented that gender bias in India is a more acute problem in the northern states as compared to the south.

## 1.2 Effect of income shocks on child health

The first channel through which rainfall affects child health is income. An important characteristic of developing countries is the exposure of its people to various kinds of risks and volatilities in incomes both within a given year and from year to year. One of the important sources of income volatility stems from poor rainfall, due to the dependence of a large proportion of population on agriculture and related activities. There do exist some local market and non-market mechanisms to smooth the impact of shocks across time and states of nature. But shocks are still hard to insure because of the commonality of shocks to all in a given region. The literature points that households can partially, but not completely smooth consumption. (Besley, 1995)

Some studies explore the links between shocks that affect child health at time period t and health states measured subsequently at period t+1. Some of these studies do find that the burden of shocks is borne disproportionately by women in South Asia. For example, using ICRISAT data in India, (Behrman, 1988) found that during the lean season, parents weigh a given health-related outcome for boys almost 5 percent more heavily than the identical health-related outcome for girls. This result suggests that when faced with lean season, parents exhibit male preference.

One can also draw from other similar studies in Africa, with largely no evidence of gender bias. For example, (Jensen, 2000) uses data from the Cote d'Ivoire and examines whether children living in areas which experience adverse climatic shocks, had lower investments in education and health. He compares the differences in height for weight Z score, children enrolled in school and the use of medical services in regions which had an adverse shock as compared to regions which experienced normal rainfall. He found an increase in the percentage of boys and girls who were malnourished and a decline in enrolment for children in shock regions. No girl-boy differences were found. (Hoddinott and Kinsey, 2001) examine the impact of drought (in 1995) on the growth in the heights of very young children; those aged 12 to 24 months. They use a panel data set in Zimbabwe and are thus able to measure the growth of children over time as opposed to estimating a level equation. They found that the 'drought cohort' or children aged 12 -24 months in 1995 grew, on an average, about 2 cm more slowly than other children, when measured 12 months later.

It is important to examine the effect of shocks in infancy as the consequences of underinvestment in female children during drought/ rainfall shock are likely to be high if such faltering has permanent effects. Indeed (Maccini and Yang, 2009) find that higher deviation (of this early-life rainfall from the mean rainfall in one's district) has positive effects on the adult outcomes of women, but not of men in Indonesia.

### *1.3 Effect of time spent in childcare on child health*

The second channel which I seek to explore is the time spent in childcare by parents in response to good rainfall. It is conceivable that good rainfall is accompanied by an increase in labour demand thereby increasing the parent's opportunity cost of time spent in childcare and vice versa. This may alter parental behaviour and finally child health outcomes. Recent evidence from India shows that good rainfall is accompanied by an increase in labour demand on women (Shah and Steinberg, 2012). On the other hand, the income effect of working on the farm might make health care more affordable.

One of the most important parental investment in childcare that could respond to changes in rainfall is breastfeeding. Not only is it time demanding but it also has a direct impact on child's health. Literature capturing the impact of mother's labor demand on time spent by her in breastfeeding is largely limited for developing countries. However, some studies in developed countries point that the most prominent reasons for breast milk weaning seem to be mother's return to work (Roe et al., 1999); (Baker and Milligan, 2008).

The World Health Organization (2003, pp. 7-8) recommends that infants should be exclusively breastfed throughout the first six months of their life. It also recommends mothers should continue to breastfeed children after 6 months upto two years or more even while other foods are being introduced into their diet. There are many health benefits associated with breastfeeding as recognized by previous studies including improved cognitive development (Kramer et al., 2008) and reduced risk of obesity (Kramer, 2010). In addition, (Jayachandran and Kuziemko, 2011) finds that not only are girls breastfed less than boys in India, but the gender of older siblings also affects how long a child is breastfed.

Another parental investment that could respond to rainfall shocks is taking children to a health clinic for vaccinations. This would be especially important in the case of India where parents might have to spend a considerable amount of time to reach the health clinic. (Jayachandran and Kuziemko, 2011) finds that sons are more advantaged in receiving vaccinations as compared to girls in India. It would be worthwhile to check whether rainfall shocks affect parent's behaviour with respect to getting their children vaccinated.

The paper is organized as follows. Section 2 briefly discusses the context of India and the data I use. In Section 3, I describe the econometric specification. Estimation results are reported in Section 4 and Section 5 concludes.

# 2 BACKGROUND AND DATA

## *2.1 Rainfall and Agriculture in India*

The monsoon plays a critical role in Indian agriculture and in determining whether the harvest will be bountiful, average, or poor in any given year. The agricultural season in India is divided into two prominent seasons- Kharif and Rabi (henceforth wet and dry respectively). During the wet season, crops are sown at the beginning of the south-west monsoon from May- July and harvested at the end of the south-west monsoon, that is, September- October. During the dry season, crops need relatively cool climate during the period of growth but warm climate during the germination of their seed and maturation. The sowing thus is between October and December and the harvesting season is from February to April. In India, not only the wet crops have higher production in million tonnes but they also occupy more land in India.

## *2.2 Rainfall Data*

In the absence of publicly available station rainfall data for India, I use a gridded rainfall dataset called 'Terrestrial Precipitation: 1900-2008 Gridded Monthly Time Series (Version 2.01)' interpolated and documented by Kenji Matsuura and Cort J. Willmott (with support from IGES and NASA).[1] This published dataset consists of interpolated (on a 0.5 degree latitude-longitude grid) global monthly rainfall data, from 1901 to 2008.

Using the latitude and longitude information, I used Mapinfo software to assign rainfall from 1122 weather stations to each of the 411 districts in DHS data (for the DHS subsample that I use for my analysis- more details in the next section). The idea was to assign to each district, weather stations in the 50 mile radius from the centroid of the district. Thereafter, I used the Inverse Distance Weighting to interpolate monthly rainfall values for 411 districts.

For the regression analysis, I consider rainfall data corresponding to children in the age group of 13- 36 months at the time of the survey. I identify the months from May- October as the wet season and consequently November- April as the dry season as these should be most closely related to agricultural cycles. So if a child is born in August 1994, the first wet season for the child would be May to October 1994 and the first dry season would be November 1994 to April 1995. The principal measure of rainfall that I use is defined below (I use other measure too for robustness checks and find results to be robust).

The measure of rainfall that I use based is on percentiles and has been used previously for India. [2] The variable equals 1 if rainfall in wet season around birth (and in utero, second year after birth, third year after birth) is above the 20th percentile (positive shock) for the district, and 0 if it is below the 20th percentile (negative shock). I use rainfall in the wet seasons between 1971 and 2004 (44 years) to calculate percentiles.

### *2.3 Health Data*

The data for the analysis of health outcomes among children is sourced from the second round of Demographic and Health Surveys conducted in 1998-99. [3] DHS is a nationally representative household survey with large sample sizes. These surveys provide data for a wide range of indicators in the areas of population, health, and nutrition. The survey was administered nationwide to ever married females aged 15-49 years. The rural sample in each state, which we use in the study, was selected by selecting primary sampling units (PSUs) with a probability proportional to the population. Thereafter the households were randomly selected within each PSU.

[1] The dataset is provided by Center for Climatic Research, Department of Geography, University of Delaware. Terrestrial Precipitation: 1900-2008 Gridded Monthly Time Series - Version 2.01, interpolated and documented by Kenji Matsuura and Cort J. Willmott (with support from IGES and NASA). For further information about this dataset, please refer to (Legates and Willmott, 1990) as the source for rainfall data.

[2] See (Jayachandran, 2006)

[3] I do not use the first round of DHS because there are a lot of missing observations for height and weight.

I observe the height and weight for children in the age group of 0-36 months at the time of the interview, born to mothers in the age group of 15-49 years. However I restrict my analysis to children aged 13-36 months as the impact of rainfall in the years around birth is likely to show up on children aged 1 and older. Another reason is the concern raised about the accuracy of measuring height and weight for children less than 1 year of age.

The outcomes that I am interested in are height for age Z scores (HAZ) and weight for age Z scores (WAZ). HAZ and WAZ are expressed as standard deviations from US National Center for Health Statistics (NCHS) standard of mean, used by the World Health Organisation (WHO), standardized by gender and age. While weight is a measure of short-term health status, height on the other hand is a stock variable and can be considered to be a long term predictor of nutrition. All eligible children had their height and weight measured, with some exceptions. Out of the total 27250 children, anthropometric data was measured for 24855 children out of which 18044 live in rural areas. After accounting for missing observations and restricting my sample to children only above 12 months of age, my final sample comprises of 5104 girls and 5556 boys.

For the set of outcomes on vaccinations, we have data on vaccinations for polio, BCG, DPT and measles. I referred to the schedule of vaccinations that the children are supposed to receive in the first year of birth in India– children are required to get all three polio vaccinations, both DPT vaccinations, BCG vaccination and measles vaccination in the first year of birth. I check for the impact of rainfall in the first year wet season on the probability to receive each of the vaccinations mentioned.

For the set of breastfeeding outcomes, we have information on the number of months the child has been breastfed and whether he/ she is still being breastfed. The best possible outcome is the duration of breastfeeding to understand whether rainfall shocks induce mothers to stop breastfeeding their children.

## 2.4 Conceptual framework

Following (Grossman, 1972), health status at time t is a function of genetic endowments ($K_0$), demographic variables such as gender and age (X), the availability of infrastructure in the village/ community ($C_0, C_1$..), the disease environment ($D_0, D_1$..) up until time t, and inputs to health ($N_0, N_1$..) at each time before t.

$$H_t = h(K_0, N_0, N_1, ..., N_t, X, C_0, C_1, ..., C_t, D_0, D_1, ..., D_t)$$

In examining the impact of birth year rainfall on HAZ and WAZ of children, I control directly for height and weight for the mother of the children thus accounting for genetic endowment. It is likely that taller and thinner mothers would have taller and thinner children respectively, all else being same. For example, (Hoddinott and Kinsey, 2001) find a well defined relationship between child growth and maternal height.

As far as the demographic variables are concerned, I use various maternal, household and individual level characteristics. Household characteristics include wealth index, sex and age of household head and dummies for caste and religion. I also include the number of sisters and brothers under 13 years of age, born to the mother and to other adult women in the household. Individual characteristics comprise the birth order of the child, season of birth and dummies for year of birth. I also include month of birth fixed effects in a separate specification to account for fertility decisions.

Parental characteristics include variables such as, the age and number of years of completed schooling of the mother and father and dummies for the occupation of father. Finally, I have included the age and the square of age of mother as explanatory variables. The age of the mother has an ambiguous effect on the child's health: older mothers might be expected to have more children thus putting a strain on the amount of time that is dedicated to the well being of each child. However, it might be that older mothers have extensive experience in childcare which might make them more knowledgeable about child health practices. For breastfeeding outcome, I include a binary variable of whether the mother works on the farm or not.

Further, I include various village infrastructure variables which include distance from the nearest all weather road, whether the village is electrified, population of the village, presence of a traditional attendant in the village, distance to all weather road, to health sub centre and to community health centre.

Table 1 provides descriptive statistics on anthropometric outcomes and explanatory variables for children, mothers and households along with the children's outcome variables. The anthropometric outcomes that I am interested in are height for age Z score (HAZ) and weight for age Z score (WAZ) for children in the ages of 13 to 36 months. The value of these variables lies between -6 and 6. The height for age Z score for children averages around -2.5 for girls and boys whereas the weight for age Z score averages around -1.9 for both groups. The children whose height (weight) for age Z score is between -2.0 and -2.99 standard deviations (SD) below the mean on the WHO international references standard are classified as moderately stunted (underweight). This sheds some light on the general status of the underperformance on anthropometric outcomes in the country. At the same time, in line with other studies, there does not seem to be any gender bias in anthropometric outcomes.

The birth order of the children in the sample averages around 2.87 and 2.91 for girls and boys. On an average, boys have 0.84 sisters and 0.68 brothers whereas the girls have 0.79 sisters and 0.74 brothers. Regarding household characteristics, the household head is a male in 94 percent of the households with an average age around 43.82 for girls and 43.46 for boys. The wealth score calculated using principal component analysis indicates that girls belong to less wealthier households than boys. Mother's height and weight averages around 151.65 cm and 44.7 kg respectively. The average age of the mother is 25.77 for girls and 25.89 for boys. The father and mother of boy households tend to be more educated that girl's parents. The fathers also tend to be more educated than the mothers. It is worthwhile to note that about 80 percent of boys and girls experienced positive rainfall in the first wet season around birth. There are no significant differences for girls and boys on an average on village and community characteristics.

Table 2 provides statistics on other outcome variables. The duration of breastfeeding (which includes children still being breastfed) is 19.3 months for boys and 18.57 months for girls, observed to be about 3/4 of a month higher for boys and significant. It seems that women continue to breastfeed children for a long time in India, more than that recommended by WHO. A smaller percentage of girls aged 13-36 months have vaccination as compared to boys of the same age. This is in line with evidence from (Jayachandran, 2006).

# 3 EMPIRICAL STRATEGY

## *3.1 Health outcome regressions*

In examining the relationship between early life rainfall and subsequent health outcomes for children, I use the child's height for age Z score and weight for age Z scores at the time of the interview. I restrict my sample to all eligible children in rural areas as the effect of the lack/ abundance of rainfall is likely to be highest here. I run all the regressions separately for boys and girls.

I estimate the relationship between rainfall shock and outcome for each gender as follows:

$$Y_{ihrt} = \beta_0 + \beta_1 * R_{rt} + \beta_2 * X_{ihrt} + \beta_3 * A_{hrt} + \beta_4 * C + \delta_r + \mu_{ihrt}$$

Where $Y_{ihrt}$ is the health outcome for child 'i' in household 'h' in district 'r' born in cohort 't'. $R_{rt}$ is an indicator of rainfall shock in district 'r' in cohort/year 't'. $X_{ihrt}$ is a vector of control variables at the level of the child. $A_{hrt}$ is vector of household level and maternal control variables which might have a direct bearing on child's health outcomes. C captures indicators at the village level. District fixed effects ($\delta_r$) capture time invariant features of districts, including determinants of quality of care that do not change over time and accounts for unobserved heterogeneity across districts. $\mu_{ihrt}$ is the individual specific standard error term. Standard errors are clustered at the district level. Clustering standard errors at the level of the DHS district allows for an arbitrary variance covariance structure within birth districts to account for possible correlation of errors within the same sampling cluster. For robustness checks, we also include rainfall variables for period 't-1' to check for the impact of in utero rainfall on children's health.

To be sure, I identify the impact using the exogenous change in rainfall in a district over time thus comparing children born in different years (and so experiencing different rainfall) but in the same district. Similarly for assessing the impact of rainfall on the probability to be vaccinated, I use the same regressions framework and use a Probit model to derive the estimates.

## 3.2 Regressions on breastfeeding outcomes

In order to check the impact of rainfall shocks on the stoppage of breastfeeding, I check if the positive rainfall shock in the first two years of birth leads to the stoppage of breastfeeding and whether this effect is different for girls and boys. In my data, I have children for whom breastfeeding has finished and for whom it is still ongoing. Since my data is censored, I use Cox's proportional hazard model as this technique adjusts for truncation bias by incorporating both complete and incomplete segments of histories in the analysis of breastfeeding-related data. For the question at hand, the hazard function measures the risk of stoppage of being breastfed at time t, given that the child has been breastfed until time t, given a set of characteristics X. Based on this hazard function, a log partial likelihood function is maximized to produce maximum partial likelihood estimates of the model parameters. In our case, the model we estimate gives the impact of rainfall shock on risk of termination of breastfeeding for children aged 13 to 36 months in rural India.

# 4 RESULTS

## 4.1 Anthropometric outcomes

The measure of rainfall that I use in Table 3 is a rainfall shock variable in percentiles explained in Section 3.1. Taking negative rainfall as the base (rainfall in the lowest 20 percentile), children born in areas which received positive rainfall in the first wet season after birth as well as in utero have better outcomes. The magnitudes are large and significant, although larger for girls as compared to boys. The rainfall shock in other years after birth do not seem to have an effect on children health (refer to Figures 3 and 4). In Table 4, I introduce month of birth fixed effects to the specification. Results for first year wet season rainfall remain the same. It is thus clear that positive rainfall shocks have a significant improving effect on HAZ and WAZ of both girls and boys.

For detailed results, refer to Table 13. The birth order is also an important determinant: the higher the birth order, the poorer are the outcomes. Further, the more the number of sisters, the lower is the HAZ of girls. This is in line with much of the literature on India which suggests that girls tend to have more siblings on an average as compared to boys, thus fewer resources allocated to every child. Children living in wealthier households and born to more educated mothers have better outcomes, irrespective of gender. Girls born to more educated fathers also tend to have better outcomes but the same is not observed for boys. As expected, mother's height and weight is significant for all outcomes and across both genders. Interestingly, girls born in households where the household head is male have better HAZ as well. Age of the mother is seen to have no effect on outcomes. Interestingly, it is found that girls have lower HAZ if they are from Muslim households and boys have better WAZ if they are from the General caste.

In Tables 3 and 4, I have run regressions separately for girls and boys. Thus, currently, I am comparing girls who experienced low rainfall around birth with girls who received good rainfall around birth, and similarly for boys. However, it would be interesting to see if negative rainfall deviation affects girls more than boys. To capture this effect, I introduce an interaction between gender and the rainfall variable and find (in table 5) the interaction variables to be not statistically significant. Thus, from my results, it is not clearly evident that girls bear a disproportionate burden from negative rainfall shocks.

## 4.2 Exploring the mechanisms

There are two potential channels through which rainfall could affect child health. Negative rainfall shocks have an effect on income (through its impact on agricultural output), and also on the relative price of parent's time. These two effects work in opposite directions and thus the overall effect of negative rainfall shocks on health outcomes could be ambiguous.

In order to check the impact of rainfall shocks on income, I regress the rainfall shock variable on the crop yield data (from the World Bank Agriculture and Climate Data). This dataset contains crop yields of all major Indian crops at the district level from 1951 to 1987. [4] We test the impact of rainfall shock in each year and in the wet season on the yield of wheat, rice, bajra, jowar and maize of that particular year. The results are provided in table 6. We see that rainfall in the lowest quintile is associated with reduced yields of 4 out of 5 major Indian crops.

In addition, more or less rainfall also has an impact on time spent by parents in childcare particularly breastfeeding by mothers and the time to take children to a health institution for getting a vaccination (as rainfall affects demand for parent's labour on the farm). As an initial check, I use time-use data for 15-60 year old women reported in the 1998-99 round of REDS survey conducted by National Council of Applied Economic Research, Delhi [5]. The questionnaire asked about time use for three seasons in the year 1998-99- October/ November is the key season for harvesting of wet season crops (majority of crops). Table 7 shows the results and provides suggestive evidence of slightly more time spent on agricultural activities in wet season, substituting it from leisure.

To dig further, I checked the impact of rainfall in the wet season of 1998 on time use of women in October/ November 1998. Table 8 provides regressions results on different categories. It is observed that higher rainfall induces women to spend more time on the field. Less time is spent

[4] We include only 1956 to 87 in our analysis as the data for 1951 to 55 contains a lot of missing data

[5] I use the 1998-1999 round of the REDS panel survey conducted by National Council of Applied Economic Research, Delhi in 1971, 1982 and 1999. The first round of REDS was conducted in 1971 and included complete village and household information from 4,527 households spread over 259 villages from 17 major states of India. The 1971 sample was designed to be representative of rural areas in India. The 1981-1982 round excluded Assam because of an insurgency at the time, but is claimed to be nationally representative of rural areas. It surveyed a total of 4,979 households across 250 villages. Finally, the 1998-99 survey covered all surviving 1982 households (except for those in Jammu and Kashmir due to unrest there) and added a small random sample of new households from the villages interviewed in previous rounds. Together with household division since 1982, this results in a sample of 7,474 households; a village-level survey also accompanied the household survey. Current representativeness of the survey data for rural India can be questioned and we can only make inferences for the baseline panel sample at subsequent dates.

doing household work, wage work, work in non-agricultural self employment and grinding and pounding of grains. Time spent in leisure also increases in the harvesting season in areas which experienced high wet season rainfall. Thus, there is evidence of some substitution of time away from household work in the wet season. Thus, we check whether good wet season rainfall also induces parents to not take their children for getting vaccinated or mothers to spend less time breastfeeding.

Tables 9 show the Probit estimates of the impact of rainfall shocks in the years around birth on the probability of getting polio vaccine. As is clear, there is no impact that I find here, with the exception of negative effect of positive rainfall shock on the first polio vaccinations for boys (no effect found on other vaccines either). I also checked the percentage of vaccinated girls and boys under age 5 separately for DHS rounds of 1992-93 and 1998-99. I find that even though the rate of vaccination is higher for boys than girls in both rounds, girls have had a higher percentage increase over time.

Table 11 shows the coefficients of the impact of rainfall shock on the hazard of stoppage of breast-feeding. Columns 1 and 2 show the coefficients for girls and boys separately. Exp(estimate), the exponentiated coefficient, gives the hazard ratio: effect of explanatory variables in the multi-plicative form of the model. A hazard ratio lower than 1 indicates decreased risk whereas a ratio higher than 1 indicates increased risk. For example, the hazard ratio for girls who faced positive rainfall in wet season around birth is exp(0.660)= 1.425, implying that the risk of stoppage of breastfeeding increases by a factor of 42.5 percent for girls who experienced average rainfall in the second year after birth. The impact is found to be highly significant for both girls and boys and is similar in magnitude.

## 4.3 Extensions

One must recognize the role of selective mortality in India. (Rose, 1999) examined the connection between gender bias in mortality and shocks for India. She uses rainfall shock data at the district level and links to the mortality among girls, checking for consumption smoothing at the time of shock: a favourable rainfall shock increases the likelihood relative to that of a boy that a girl survives until school age. In such a case, one can argue that the weaker girls have already died and we are left with a healthier sample of girls thus introducing selection. In addition, the child sex ratio figures for India have been continuously declining demonstrating that more girls are dying in the ages of 0 to 5 than boys. Thus, one of the reasons that we do not find differential impact of negative rainfall on girls and boys could be the fact that we are comparing a healthy sample of girls with an average healthy sample of boys. To employ a selection model, it would be imperative to justify the exclusion restriction of the instrument used. However, it is almost hardly possible to find a factor that affects the probability of a neonatal death without having an impact on height and weight. Thus, it would be worthwhile to mention that our impacts of rainfall on nutritional outcomes are lower bound estimates of the real causal estimates.

Further, we must consider that the impact of rainfall shock on heterogeneous groups. I look at the effect on shocks in the 7 richest and 6 poorest Indian states. It turns out that the point estimates are much higher in poorer states for girl's and boy's HAZ and WAZ. It is likely that poorer states rely more heavily on agriculture for their income and hence rainfall shocks affecting agriculture have a larger impact in poorer states. I also differentiated the impact for households which lie in the highest 40 percentile group and the lowest 60 percentile group in terms of wealth of the household. Analogous to the results on states, the estimates show that positive rainfall leads to better outcomes for both girls and boys in poorer households, while no effect is found for richer households. Finally, the results seem to point out that the impact of rainfall shock is more pronounced for girls born to uneducated mothers while no effect is found for boys. I check whether girls born to uneducated mothers are more likely to be discriminated against by looking at the estimates of the interaction of gender and rainfall shock variable. I do not find any evidence of gender discrimination.

# 5 CONCLUSION

While the finding that girls do not experience negative allocation of resources as compared to boys under normal circumstances is now well founded, evidence regarding the disproportionate allocation of resources under harder circumstances is still scarce. At the same time, it is found that the child sex ratio (0 to 6 years) has dropped below sex ratio at birth between Census of India 1981 and Census of India 2001, suggesting that more girls are dying in the ages of 0 to 6 years. However it could very well be argued that even girls which manage to survive are more undernourished as compared to boys. It is under this context that I check the impact of rainfall shocks around birth on health outcomes of children aged 13 to 36 months.

There are three potential channels through which rainfall affects the health of children. First, when households suffer a shock on their income, they may allocate resources among boys and girls differently leading to different anthropometric outcomes. Secondly, the amount of rainfall could determine the time spent by parents in childcare particularly breastfeeding and vaccinations and thus impact child's health. Lastly, enough/ excess rainfall could negatively affect health through the spread of water borne diseases such as malaria. In this paper, I explore the these channels.

Good rainfall implies higher income and availability of more/better resources for children, which in turn positively affects their HAZ and WAZ. It could also be that more income might allow the mother to spend more time in leisure including breastfeeding. Thus, the effect of positive rainfall on HAZ and WAZ is speculated to be positive. The results reveal that children who experience positive rainfall shocks in the wet season in utero and first year after birth have better height for age Z scores and weight for age Z scores as compared to children who experienced negative rainfall shock. The results are higher in magnitude for girls as compared to boys. Further, results point in the same direction irrespective of the measure of rainfall shock used. Controlling for rainfall shock in the wet season for upto 4 years after birth, the estimates of in utero and first year rainfall stay significant. However, I do not find any evidence of gender bias. Taking the interaction between rainfall deviation and gender, I do not find that girls bear a disproportionate burden (in terms of deteriorated health) from these shocks.

On the other hand, good rainfall could also provide economic incentives for the mother to work on the farm and hence spend less time breastfeeding, negatively impacting child's health. But at the same time more rainfall (and thus income) might allow the mother to spend more time in leisure including breastfeeding. Our results indicate that the former effect outweighs the latter, that is good rainfall is seen to increase the risk of termination of breastfeeding for both boys and girls and the estimates are similar in magnitude. No effect is found on the probability of getting vaccinated.

The impact of positive rainfall is improved child health– the positive income effect seems to dominate the negative substitution (of parental time) effect. These results have important policy implications. Over the past years, there has been an increased interest in weather based index insurance wherein farmers are insured against bad weather. This program has also been tested in some parts of India using experimentation. Our results suggest a negative impact of bad rainfall on the height and weight for children. Since these negative effects determine the long run attainment of good health, weather based insurance programs could help to improve outcomes by providing a way to smooth consumption. Another policy response could be providing support programmes during lean periods for drought stricken areas in India.

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**Table 1:** Characteristics by gender

| | Girl | Boy | t-test |
|---|---|---|---|
| HAZ | -2.50 | -2.52 | 0.02 |
| | (0.02) | (0.02) | (0.03) |
| WAZ | -1.92 | -1.90 | -0.02 |
| | (0.02) | (0.02) | (0.03) |
| Birth Order | 2.87 | 2.91 | -0.04 |
| | (0.03) | (0.03) | (0.04) |
| Number of brothers under 13 | 0.74 | 0.68 | 0.06*** |
| | (0.01) | (0.01) | (0.02) |
| Number of boys under 13 in HH | 2.51 | 2.47 | 0.04 |
| | (0.03) | (0.03) | (0.04) |
| Number of sisters under 13 | 0.79 | 0.84 | -0.05** |
| | (0.01) | (0.01) | (0.02) |
| Number of girls under 13 in HH | 2.40 | 2.48 | -0.08 |
| | (0.03) | (0.03) | (0.04) |
| Sex of HH Head | 0.94 | 0.94 | -0.00 |
| | (0.00) | (0.00) | (0.00) |
| Age of HH Head | 43.82 | 43.46 | 0.36 |
| | (0.22) | (0.20) | (0.30) |
| Wealth Score | -0.44 | -0.39 | -0.05*** |
| | (0.01) | (0.01) | (0.01) |
| Mother's height | 151.62 | 151.69 | -0.07 |
| | (0.08) | (0.07) | (0.11) |
| Mother's weight | 44.74 | 44.73 | 0.00 |
| | (0.09) | (0.09) | (0.13) |
| Age of mother | 25.77 | 25.89 | -0.12 |
| | (0.08) | (0.07) | (0.11) |
| Education of mother (in years) | 2.97 | 3.21 | -0.24** |
| | (0.06) | (0.06) | (0.08) |
| Education of father (in years) | 5.67 | 5.86 | -0.19* |
| | (0.07) | (0.07) | (0.09) |
| Positive rainfall in year 1 | 0.80 | 0.81 | -0.01 |
| | (0.01) | (0.01) | (0.01) |
| Traditional attendant in village | 1.42 | 1.43 | -0.01 |
| | (0.01) | (0.01) | (0.01) |
| Population of village | 10.50 | 10.41 | 0.08 |
| | (0.08) | (0.08) | (0.11) |
| Distance to all weather road | 14.45 | 14.34 | 0.11 |
| | (0.41) | (0.39) | (0.56) |
| Distance to health sub centre | 4.82 | 5.32 | -0.49 |
| | (0.18) | (0.18) | (0.25) |
| Distance to community health centre | 17.88 | 18.09 | -0.22 |
| | (0.30) | (0.28) | (0.41) |
| Obs | 5104 | 5556 | 10660 |

Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

**Table 2:** Characteristics by gender-vaccinations and breastfeeding

| | Girl | Boy | t-test |
|---|---|---|---|
| Duration of breastfeeding | 18.57 | 19.30 | -0.73*** |
| | (0.09) | (0.09) | (0.13) |
| First Polio | 0.13 | 0.13 | 0.00 |
| | (0.00) | (0.00) | (0.01) |
| Second Polio | 0.80 | 0.81 | -0.01 |
| | (0.01) | (0.00) | (0.01) |
| Third Polio | 0.75 | 0.76 | -0.02* |
| | (0.01) | (0.01) | (0.01) |
| BCG | 0.66 | 0.68 | -0.02** |
| | (0.01) | (0.01) | (0.01) |
| Measles | 0.47 | 0.50 | -0.03** |
| | (0.01) | (0.01) | (0.01) |
| First DPT | 0.65 | 0.68 | -0.03*** |
| | (0.01) | (0.01) | (0.01) |
| Second DPT | 0.59 | 0.62 | -0.03*** |
| | (0.01) | (0.01) | (0.01) |
| Observations | 6448 | 7091 | 13539 |

Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.
The number of observations differ depending on the outcome.

**Table 3:** Household and Village Characteristics by gender

| | Girl | Boy | t-test |
|---|---|---|---|
| Positive rainfall in year 1 | 0.80 | 0.81 | -0.01 |
| | (0.01) | (0.01) | (0.01) |
| Birth Order | 2.87 | 2.91 | -0.04 |
| | (0.03) | (0.03) | (0.04) |
| Number of brothers under 13 | 0.74 | 0.68 | 0.06*** |
| | (0.01) | (0.01) | (0.02) |
| Number of boys under 13 in HH | 2.51 | 2.47 | 0.04 |
| | (0.03) | (0.03) | (0.04) |
| Number of sisters under 13 | 0.79 | 0.84 | -0.05** |
| | (0.01) | (0.01) | (0.02) |
| Number of girls under 13 in HH | 2.40 | 2.48 | -0.08 |
| | (0.03) | (0.03) | (0.04) |
| Sex of HH Head | 0.94 | 0.94 | -0.00 |
| | (0.00) | (0.00) | (0.00) |
| Age of HH Head | 43.82 | 43.46 | 0.36 |
| | (0.22) | (0.20) | (0.30) |
| Wealth Score | -0.44 | -0.39 | -0.05*** |
| | (0.01) | (0.01) | (0.01) |
| Mother works on farm | 0.29 | 0.28 | 0.01 |
| | (0.01) | (0.01) | (0.01) |
| Age of mother | 25.77 | 25.89 | -0.12 |
| | (0.08) | (0.07) | (0.11) |
| Education of mother (in years) | 2.97 | 3.21 | -0.24** |
| | (0.06) | (0.06) | (0.08) |
| Education of father (in years) | 5.67 | 5.86 | -0.19* |
| | (0.07) | (0.07) | (0.09) |
| Traditional attendant in village | 1.42 | 1.43 | -0.01 |
| | (0.01) | (0.01) | (0.01) |
| Population of village | 10.50 | 10.41 | 0.08 |
| | (0.08) | (0.08) | (0.11) |
| Distance to all weather road | 14.45 | 14.34 | 0.11 |
| | (0.41) | (0.39) | (0.56) |
| Distance to health sub centre | 4.82 | 5.32 | -0.49 |
| | (0.18) | (0.18) | (0.25) |
| Distance to community health centre | 17.88 | 18.09 | -0.22 |
| | (0.30) | (0.28) | (0.41) |
| Obs | 5104 | 5556 | 10660 |

Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

**Table 4:** Household and Village Characteristics by gender

| | Girl | Boy | t-test |
|---|---|---|---|
| Religion | 1.43 | 1.46 | -0.02 |
| | (0.01) | (0.01) | (0.02) |
| Caste | 2.77 | 2.79 | -0.02 |
| | (0.02) | (0.01) | (0.02) |
| Partner's occupation | 5.78 | 5.63 | 0.14 |
| | (0.11) | (0.10) | (0.14) |
| Access to electricity in village | 2.18 | 2.19 | -0.01 |
| | (0.01) | (0.01) | (0.01) |
| Obs | 5104 | 5556 | 10660 |

Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

**Table 5:** Impact of Rainfall Shocks on health outcomes

| | (HAZ score) | | (WAZ score) | |
|---|---|---|---|---|
| | (Girl) | (Boy) | (Girl) | (Boy) |
| Positive rainfall in gestation | 0.233** | 0.196** | 0.122* | 0.077 |
| | (0.104) | (0.092) | (0.072) | (0.065) |
| Positive rainfall in year 1 | 0.362*** | 0.316*** | 0.265*** | 0.219*** |
| | (0.116) | (0.112) | (0.079) | (0.080) |
| Positive rainfall in year 2 | 0.158 | 0.126 | 0.071 | 0.069 |
| | (0.143) | (0.121) | (0.100) | (0.082) |
| Positive rainfall in year 3 | 0.070 | 0.129 | 0.019 | 0.045 |
| | (0.167) | (0.130) | (0.109) | (0.090) |
| Positive rainfall in year 4 | 0.167 | 0.212** | 0.161 | 0.131* |
| | (0.136) | (0.107) | (0.098) | (0.077) |
| Observations | 5104 | 5556 | 5104 | 5556 |
| $R^2$ | 0.244 | 0.225 | 0.289 | 0.285 |

Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.
The regressions include district fixed effects
Positive rainfall is wet season rainfall greater than 20th percentile.

**Table 6:** Impact of Rainfall Shocks on health outcomes- with MOB FE

| | (HAZ score) | | (WAZ score) | |
|---|---|---|---|---|
| | (Girl) | (Boy) | (Girl) | (Boy) |
| Positive rainfall in gestation | 0.165* | 0.132 | 0.083 | 0.041 |
| | (0.097) | (0.085) | (0.070) | (0.062) |
| Positive rainfall in year 1 | 0.287*** | 0.251** | 0.226*** | 0.181** |
| | (0.109) | (0.104) | (0.077) | (0.078) |
| Positive rainfall in year 2 | 0.140 | 0.119 | 0.062 | 0.062 |
| | (0.133) | (0.113) | (0.097) | (0.080) |
| Positive rainfall in year 3 | 0.041 | 0.102 | 0.006 | 0.025 |
| | (0.155) | (0.122) | (0.106) | (0.090) |
| Positive rainfall in year 4 | 0.113 | 0.171* | 0.133 | 0.103 |
| | (0.124) | (0.101) | (0.093) | (0.077) |
| Observations | 5104 | 5556 | 5104 | 5556 |
| $R^2$ | 0.256 | 0.241 | 0.296 | 0.293 |

Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.
The regressions include month of birth and district fixed effects
Positive rainfall is wet season rainfall greater than 20th percentile.

**Table 7:** Impact of Rainfall Shocks on gender bias in health outcomes

| | (HAZ) | (WAZ) | (HAZ) | (WAZ) |
|---|---|---|---|---|
| Positive rainfall in year 1 | 0.211** | 0.148** | 0.162** | 0.121** |
| | (0.082) | (0.059) | (0.077) | (0.057) |
| Positive rainfall in gestation | 0.143* | 0.095 | 0.073 | 0.055 |
| | (0.081) | (0.059) | (0.075) | (0.057) |
| Sex * positive rainfall in year 1 | 0.052 | 0.042 | 0.045 | 0.037 |
| | (0.081) | (0.060) | (0.079) | (0.060) |
| Sex * positive rainfall in year -1 | 0.072 | -0.013 | 0.080 | -0.009 |
| | (0.074) | (0.061) | (0.071) | (0.060) |
| Sex of child | -0.141 | -0.017 | -0.139 | -0.017 |
| | (0.093) | (0.070) | (0.090) | (0.069) |
| Observations | 10660 | 10660 | 10660 | 10660 |
| $R^2$ | 0.198 | 0.250 | 0.212 | 0.258 |
| MOB Fixed Effects | | | | |

Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.
The regressions include month of birth and district fixed effects
Positive rainfall is wet season rainfall greater than 20th percentile.

**Table 8:** Impact of Rainfall Shocks on crop yield

| | (Wheat) | (Rice) | (Rice) | (Rice) | (Rice) |
|---|---|---|---|---|---|
| Wet season rain | 0.004 | 0.059*** | 0.048*** | 0.041** | 0.030*** |
| | (0.016) | (0.013) | (0.009) | (0.019) | (0.008) |
| Observations | 7317 | 7317 | 7317 | 7317 | 7317 |
| $R^2$ | 0.726 | 0.706 | 0.516 | 0.442 | 0.308 |

Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.
The regressions include district fixed effects and controls for other agricultural inputs.
Positive rainfall is wet season rainfall greater than 20th percentile.

**Table 9:** Time use (in hours) of 15-60 year old women by season

| | Oct/Nov | Feb | Apr/May |
|---|---|---|---|
| Agriculture | 1.37 | 1.28 | 1.27 |
| | (0.02) | (0.02) | (0.02) |
| Livestock | 0.75 | 0.73 | 0.73 |
| | (0.01) | (0.01) | (0.01) |
| Wage work | 0.99 | 0.92 | 1.00 |
| | (0.02) | (0.02) | (0.02) |
| Salary work | 0.08 | 0.08 | 0.08 |
| | (0.01) | (0.01) | (0.01) |
| Non-agriculure emp work | 0.20 | 0.21 | 0.22 |
| | (0.01) | (0.02) | (0.01) |
| Studying | 0.65 | 0.65 | 0.63 |
| | (0.02) | (0.02) | (0.02) |
| Household work | 6.61 | 6.56 | 6.60 |
| | (0.03) | (0.03) | (0.03) |
| Grinding and pounding | 0.23 | 0.27 | 0.01 |
| | (0.01) | (0.01) | (0.01) |
| Fuel collection | 0.78 | 0.78 | 0.75 |
| | (0.01) | (0.01) | (0.01) |
| Water collection | 0.55 | 0.54 | 0.52 |
| | (0.01) | (0.02) | (0.01) |
| Leisure | 11.73 | 11.92 | 11.93 |
| | (0.02) | (0.02) | (0.02) |
| Total time | 12.27 | 12.27 | 12.28 |
| | (0.02) | (0.02) | (0.02) |
| Obs | 11176 | 11176 | 11176 |

Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

**Table 10:** Impact of rainfall on time use (October-November) of women 16-60 years old

| | (Agr.) | (Livestock) | (HH work) | (Wage) | (Salary) | (Non-ag self emp) | (Grinding) | (Leisure) |
|---|---|---|---|---|---|---|---|---|
| Categorical rainfall in year 1 (normal rain) | 0.367*** | -1.175*** | -0.322** | -0.368*** | 0.108** | -0.091** | -0.417*** | 3.087*** |
| | (0.112) | (0.059) | (0.145) | (0.103) | (0.050) | (0.043) | (0.033) | (0.094) |
| Categorical rainfall in year 1 (positive rain) | -0.812*** | -1.229*** | 1.395*** | -0.503*** | 0.053* | -0.098** | -0.430*** | 0.931*** |
| | (0.069) | (0.042) | (0.078) | (0.062) | (0.027) | (0.041) | (0.020) | (0.065) |
| Years of schooling of woman | -0.019*** | -0.021*** | 0.045*** | -0.016*** | 0.008*** | 0.003 | -0.003 | 0.030*** |
| | (0.006) | (0.006) | (0.011) | (0.006) | (0.003) | (0.002) | (0.003) | (0.010) |
| Years of schooling of husband | -0.004 | -0.000 | 0.014* | -0.008 | -0.000 | -0.001 | 0.001 | 0.006 |
| | (0.006) | (0.005) | (0.007) | (0.005) | (0.001) | (0.003) | (0.002) | (0.007) |
| Age of husband | 0.002 | 0.012*** | -0.017** | -0.001 | 0.001 | -0.005* | 0.003 | -0.002 |
| | (0.006) | (0.004) | (0.007) | (0.006) | (0.002) | (0.003) | (0.002) | (0.008) |
| Age of woman | 0.002 | 0.002 | -0.005 | 0.000 | 0.001 | 0.005* | -0.001 | -0.002 |
| | (0.007) | (0.004) | (0.009) | (0.006) | (0.002) | (0.003) | (0.002) | (0.008) |
| Age at marriage of woman | -0.004 | 0.001 | 0.011* | -0.002 | 0.000 | -0.001 | -0.001 | -0.002 |
| | (0.006) | (0.004) | (0.006) | (0.003) | (0.002) | (0.002) | (0.002) | (0.006) |
| Observations | 7920 | 7920 | 7982 | 7982 | 7920 | 7920 | 7920 | 7920 |
| $R^2$ | 0.447 | 0.229 | 0.408 | 0.648 | 0.571 | 0.278 | 0.149 | 0.236 |

Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.
The regressions include district fixed effects. It also includes variables for religion, caste group and occupation of husband and wife.

**Table 11:** Impact of Rainfall Shocks on the probability of receiving polio vaccinations

| | (First Polio) | | (Second Polio) | | (Third Polio) | |
|---|---|---|---|---|---|---|
| | (Girl) | (Boy) | (Girl) | (Boy) | (Girl) | (Boy) |
| Positive rainfall in year -1 | 0.038 | -0.241*** | -0.013 | 0.005 | -0.071 | -0.017 |
| | (0.097) | (0.091) | (0.087) | (0.079) | (0.081) | (0.070) |
| Positive rainfall in year 1 | -0.088 | -0.288** | -0.075 | 0.025 | -0.129 | -0.073 |
| | (0.121) | (0.115) | (0.109) | (0.104) | (0.093) | (0.082) |
| Positive rainfall in year 2 | 0.095 | -0.149 | -0.029 | 0.037 | -0.098 | -0.051 |
| | (0.146) | (0.128) | (0.122) | (0.109) | (0.124) | (0.097) |
| Positive rainfall in year 3 | 0.057 | -0.186 | -0.112 | -0.011 | -0.152 | -0.094 |
| | (0.150) | (0.135) | (0.148) | (0.118) | (0.131) | (0.107) |
| Positive rainfall in year 4 | 0.023 | -0.226* | -0.033 | -0.167 | -0.114 | -0.220** |
| | (0.121) | (0.120) | (0.120) | (0.102) | (0.101) | (0.091) |
| Observations | 4526 | 5070 | 4947 | 5662 | 5502 | 6088 |

Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.
All vaccinations should be received in the first year of birth
Normal rainfall corresponds to rainfall being between 20 and 80 percentile.
Positive rainfall is rainfall greater than 80th percentile.

**Table 12:** Impact of Rainfall Shocks on duration of breastfeeding

| | (Girl) | (Boy) |
|---|---|---|
| Positive rainfall in year 1 | 0.660*** | 0.507*** |
| | (0.127) | (0.112) |
| Positive rainfall in year 2 | 0.354** | 0.182 |
| | (0.160) | (0.154) |
| Observations | 6323 | 6929 |

Standard errors in parentheses. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.
The regressions include district fixed effects
Positive rainfall is wet season rainfall greater than 20th percentile.

**Table 13:** Impact of Rainfall Shocks on health outcomes

| | (HAZ score) | | (WAZ score) | |
|---|---|---|---|---|
| | (Girl) | (Boy) | (Girl) | (Boy) |
| Positive rainfall in gestation | 0.165* | 0.132 | 0.083 | 0.041 |
| | (0.097) | (0.085) | (0.070) | (0.062) |
| Positive rainfall in year 1 | 0.287*** | 0.251** | 0.226*** | 0.181** |
| | (0.109) | (0.104) | (0.077) | (0.078) |
| Positive rainfall in year 2 | 0.140 | 0.119 | 0.062 | 0.062 |
| | (0.133) | (0.113) | (0.097) | (0.080) |
| Positive rainfall in year 3 | 0.041 | 0.102 | 0.006 | 0.025 |
| | (0.155) | (0.122) | (0.106) | (0.090) |
| Positive rainfall in year 4 | 0.113 | 0.171* | 0.133 | 0.103 |
| | (0.124) | (0.101) | (0.093) | (0.077) |
| Birth Order | -0.014 | -0.029 | -0.043* | -0.055*** |
| | (0.028) | (0.027) | (0.024) | (0.019) |
| Number of sisters under 13 | -0.124*** | 0.034 | -0.054* | 0.035 |
| | (0.040) | (0.035) | (0.032) | (0.028) |
| Number of brothers under 13 | -0.059 | -0.006 | -0.008 | 0.022 |
| | (0.040) | (0.040) | (0.031) | (0.030) |
| Number of boys under 13 in HH | 0.014 | 0.006 | 0.010 | 0.007 |
| | (0.014) | (0.014) | (0.011) | (0.010) |
| Number of girls under 13 in HH | 0.003 | -0.005 | -0.007 | -0.008 |
| | (0.015) | (0.013) | (0.011) | (0.009) |
| Age of HH Head | -0.000 | -0.002 | -0.000 | 0.001 |
| | (0.002) | (0.002) | (0.001) | (0.001) |
| Sex of HH Head | 0.149* | -0.149 | 0.066 | -0.003 |
| | (0.084) | (0.099) | (0.069) | (0.072) |
| Wealth Score | 0.199*** | 0.179*** | 0.148*** | 0.170*** |
| | (0.047) | (0.049) | (0.041) | (0.039) |
| Age of mother | 0.022 | 0.045 | 0.007 | 0.043* |
| | (0.038) | (0.030) | (0.029) | (0.025) |
| Age of mother sq | -0.000 | -0.001 | -0.000 | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.000) |
| Education of mother (in years) | 0.020** | 0.038*** | 0.023*** | 0.031*** |
| | (0.008) | (0.008) | (0.007) | (0.006) |
| Mother's weight | 0.012*** | 0.015*** | 0.032*** | 0.030*** |
| | (0.004) | (0.004) | (0.003) | (0.003) |
| Mother's height | 0.043*** | 0.040*** | 0.019*** | 0.017*** |
| | (0.005) | (0.005) | (0.004) | (0.004) |
| Education of father (in years) | 0.018** | 0.005 | 0.014*** | 0.006 |
| | (0.007) | (0.007) | (0.005) | (0.005) |
| Access to electricity in village | -0.078 | 0.031 | 0.090 | 0.101 |
| | (0.112) | (0.117) | (0.092) | (0.069) |
| Access to electricity in village | -0.125 | 0.025 | 0.043 | 0.049 |
| | (0.129) | (0.114) | (0.107) | (0.073) |
| Traditional attendant in village | 0.064 | 0.042 | 0.034 | 0.051 |
| | (0.064) | (0.057) | (0.045) | (0.041) |
| Population of village | 0.003 | -0.004 | 0.003 | -0.005 |
| | (0.006) | (0.005) | (0.005) | (0.004) |
| Distance to all weather road | 0.001 | 0.001 | 0.001 | 0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Distance to health sub centre | -0.001 | -0.002 | 0.000 | -0.001 |
| | (0.003) | (0.002) | (0.002) | (0.001) |
| Distance to community health centre | -0.001 | -0.001 | -0.002 | -0.000 |
| | (0.002) | (0.001) | (0.001) | (0.001) |
| Observations | 5104 | 5556 | 5104 | 5556 |
| $R^2$ | 0.256 | 0.241 | 0.296 | 0.293 |

Standard errors in parentheses. * p<0.10, ** p<0.05, *** p<0.01.
The regressions include month of birth, religion, caste and district fixed effects. Also includes controls for occupation of father.
Positive rainfall is wet season rainfall greater than 20th percentile.