In-utero Exposure to Rainfall Variability and Early Childhood Health

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Abstract

Climate change has drastically altered precipitation patterns across the globe and has caused an increase in rainfall variability, including the incidence of extreme rainfall events such as droughts and floods. Exploiting the exogenous variation in rainfall to which children were exposed during the nine months in utero, we find that rainfall variability adversely affects the anthropometric status of children under five years of age in 55 low and middle-income countries. Moreover, the consequences of fetal exposure to rainfall variability are strongly apparent in the child's first year of life and linger to some extent at later ages. Our heterogeneity analyses further show that children of disadvantaged backgrounds, such as poor and uneducated households, are especially vulnerable to rainfall variability during gestation.

JEL codes: I15, J13, O15, Q54

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1 Introduction

Climate change has drastically altered precipitation patterns across the globe and has caused an increase in rainfall variability, including the incidence of extreme rainfall events such as droughts and floods (Alexander, 2016; Myhre et al., 2019). Prior studies document that precipitation variability and change may influence economic performance. Specifically, rainfall variability has been shown to adversely affect agricultural production (Levine and Yang, 2006, Vogel et al., 2019) and lower incomes (Hidalgo et al., 2010; Bruckner and Ciccone, 2011). The increased climate variability related to global warming also leads to social unrest by inducing more conflict and crime (Miguel et al., 2004; Sekhri and Storeygard, 2011). Furthermore, rainfall variability is reported to have adverse effects on educational and health outcomes. For example, exposure to rainfall variability can reduce primary school enrollment for female children (Bjorkman-Nyqvist, 2013) and worsen nutrition statuses for children under five years old (Skoufias and Vinha, 2012; Jacoby et al., 2014).

This paper investigates the extent to which exposure to rainfall variability and shocks, including droughts and heavy rainfall events, in utero affects early childhood health for 55 low and middle-income countries. Our study makes three contributions to the literature. First, drawing from the climate and epidemiologic literature, we quantify the impacts of fetal exposure to rainfall variability and shocks, measured as deviations in the level of rainfall received during the in-utero period from the location-specific norm, on early childhood health. Second, our paper presents evidence that the adverse effects of in-utero exposure to rainfall shocks are strongly apparent in the first year of life and still persist at later ages, which supports the theory on the latency of the in-utero event impacts. Finally, instead of studying one particular country, our sample consists of children from 55 low and middle-income countries across five continents over three decades. The wide spatial and temporal coverage lends external validity to our estimates.

In order to explore the relationship between rainfall variability and child health outcomes, we employ data from the Demographic and Health Surveys (DHS), including Global Positioning System (GPS) information, and the Climatic Research Unit Time Series (CRUTS). The

DHS provides rich information on child health status, including anthropometric measures for height-for-age, weight-for-height, and weight-for-age. The GPS information collected in recent DHS rounds helps identify the geographic location of the childs residential cluster. Each cluster refers to a residential area and can be identified with a pair of latitude and longitude coordinates. The CRUTS provides monthly rainfall data obtained from land-based stations. Utilizing the detailed spatial information as well as the child's birth date from these datasets, we construct our main explanatory variables based on the deviation of the nine-month in-utero rainfall from the long-run average of total rainfall during those nine months for the childs residential cluster.

Exploiting the exogenous variation in the rainfall deviation from the long-run local average to which the child was exposed in utero, our study reaches the following findings. First, fetal exposure to increased rainfall variability leads to adverse health outcomes in early childhood. Both anomalously wet and dry conditions are negatively associated with childrens anthropometric measures. In particular, excessive rainfall, measured as a one standard deviation increase in in-utero rainfall relative to the location-specific norm: (i) reduces child's height-for-age, weight-for-height, and weight-for-age z-scores by 0.03, 0.03, and 0.04 standard deviations respectively, and (ii) makes children 0.6, 0.6, and 1.1 percentage points more likely to be stunted, wasted, and underweight respectively. Similarly, deficient rainfall, which is measures as a one standard deviation decrease in in-utero rainfall relative to the location-specific norm: (i) decreases child's height-for-age, weight-for-height, and weight-for-age z-scores by 0.03, 0.04, and 0.04 standard deviations respectively, and (ii) raises the incidence of stunting, wasting, and underweight 0.5, 0.8, and 0.9 percentage points respectively. Second, by analyzing children of different age groups, we find that the above effects are strongly apparent in the first year of life and to some extent linger in later years. Finally, our heterogeneity analyses show that deficient rainfall tends to harm children from disadvantaged socioeconomic backgrounds (those from uneducated, poor, and agriculturally dependent households) while less pronounced differences among population groups are detected for excessive rainfall.

Since undernutrition in early childhood can exert long-lasting consequences over the life course (Glewwe and Miguel, 2008; Briend and Berkley, 2016) and children from low and middle-income countries are more vulnerable to the detrimental impacts than children from high-income nations (Currie and Vogl, 2013), our findings highlight the threat of increasing climate variability to the long-term well-being of people in the developing world. The paper calls for global efforts to be directed towards combating the threats posed by climate change, such as increased rainfall variability and the rising frequency of extreme rainfall events. In particular, it is important to have policy interventions that aim to protect pregnant women from the threats of adverse climatic events. Furthermore, government programs need to prioritize the populations that are most vulnerable to weather shocks, particularly those from disadvantaged socioeconomic backgrounds.

The paper proceeds as follows. Section 2 presents the conceptual framework and reviews related literature. Section 3 describes the data. Section 4 outlines the empirical strategy. Section 5 discusses our estimating results, heterogeneity analyses, and robustness checks. Section 6 concludes the paper.

2 Literature Review

Our empirical model to estimate the impacts of in-utero exposure to rainfall variability on child health is guided by the United Nations Children's Fund's conceptual framework where child undernutrition is caused by many interconnected factors which can be categorized into basic, underlying, and intermediate causes (UNICEF, 2014). First, the basic causes deal with the macro-level challenges that indicate the structural and political processes in society. For example, household limited access to services, inadequate financial and human resources, as well as sociocultural, economic, and political context are risk factors leading to child undernutrition. Second, the underlying causes focus on challenges at the household level. For instance, household food insecurity, inadequate care, and feeding practices, as well as an unhealthy environment, and inadequate health care are the underlying causes of child undernutrition. Finally, at the lowest level, the immediate causes are factors directly affecting child nutrition, such as diseases and insufficient nutrition, which can be resulted from the basic and underlying causes at a higher level.

Prior studies suggest that rainfall variability can affect all three causes mentioned above. First, at the basic level, rainfall variability might impair child health through factors in the sociocultural, economic, and political context. It is documented that rainfall variability could induce crimes against women, violence against civilians, and armed conflicts (Vanden Eynde, 2018; Sekhri and Storeygard, 2014). Such social instability could put a strain on pregnant women and impair the fetus (Le and Nguyen, 2020a). As unfavorable conditions during pregnancy can compromise child health, in-utero exposure to rainfall variability could harm child growth and development (Akombi et al., 2017).

Second, underlying factors at the household level can also be potential pathways to the impacts of in-utero rainfall variability. Specifically, unfavorable rainfall conditions could pose a threat to the fetuses through women's time use during pregnancy. Adverse conditions such as droughts might raise the labor demand for women. Doing physically demanding tasks during pregnancy is likely to adversely affect birth weight (Rao et al., 2003). Rainfall variability can further cause psychological distress among pregnant women, which stimulates the production of the corticotrophin-releasing hormone and therefore suppresses fetal development (Black et al., 2016). As unhealthy infants will develop into unhealthy children (Akombi et al., 2017), in-utero exposure to unfavorable rainfall conditions can be harmful to early childhood development.

Finally, rainfall variability during the in-utero period can affect child health via the immediate causes which include diseases and nutrition. Specifically, rainfall variability is documented to make diseases such as diarrhea and malaria more prevalent (Umbers et al., 2011; Levy et al., 2016). The affliction of such diseases during pregnancy is likely to interfere with fetal growth and generate unfavorable birth outcomes (Newman et al., 2019; Ngai et al., 2020). In terms of nutrition, adverse rainfall conditions depress crop production and household incomes, which in turns worsens food security (Levine and Yang, 2006). There is concrete evidence that nutrition deprivation in pregnancy will result in intrauterine growth restriction and low birth weight (Ramakrishnan, 2004; Englund-Ogge et al., 2019). Given that low birth weight infants are more likely to have unfavorable health outcomes (Akombi et al., 2017), in-utero exposure to rainfall variability can be damaging to early childhood health and development.

Empirically, our paper is related to two strands of studies. The first branch focuses on how in-utero shocks affect child health. For example, armed conflict is one source of negative shock that could deteriorate child health. The studies from Cote d'Ivoire and Afghanistan show that fetal exposure to armed conflict causes children to be thinner compared to their peers and substantially raises the incidence of underweight (Minoiu and Shemyakina, 2012; Oskorouchi, 2019). Food price inflation is another example of a negative shock which can affect early childhood health and development, as demonstrated for Ethiopian children who were more likely to be stunted and underweight childhood as a result of exposure to food price inflation in utero (Woldemichael et al., 2017). Also in the context of Ethiopia, Miller (2017) document that children exposed to seasonal food scarcity during the intrauterine period tend to have shorter stature in their childhood years.

The second branch of the literature to which our study is related explores the relationship between rainfall variability and shocks and the health outcomes of children. For instance, in the context of Mexico, Skoufias and Vinha (2012) uncover that rainfall shocks in prior seasons reduce child's height-for-age. Jacoby et al. (2014) find that current rainfall variation makes Nigerian children both shorter for their age and thinner for their height. More recently, Dimitrova and Muttarak (2020) show that excessive rainfall during the monsoon months increases the risk of stunting for Indian children. Closer to our paper are studies looking at the relationship between prenatal rainfall and child health. In particular, Cornwell and Inder (2015) show that prenatal exposure to rainfall variability lowers Indonesian children's height-for-age z-scores in early childhood. Dimitrova and Bora (2020) detect a clear nutrition effect on Indian children where those exposed to excessive rainfall during the intrauterine period are more likely to be stunted. Randell et al. (2020) find that higher prenatal rainfall raises the incidence of stunting among Ethiopian children.

3 Data

3.1 Child Health Data

Child health outcomes and socio-demographic characteristics are retrieved from the Demographic and Health Surveys (DHS). The DHS is a rich dataset focusing on the health outcomes of children under five years old (i.e. less than 60 months old) in developing countries. Child health in early childhood is measured by anthropometric z-scores including height-for-age, weight-for-height, and weight-for-age. In addition, we construct three other nutritional statuses from the z-scores. Stunting, Wasting, and Underweight respectively take the value of 1 if height-for-age, weight-for-height, and weight-for-age z-scores fall below -2 standard deviations of the World Health Organization (WHO) Child Growth Standards media, and zero otherwise. While stunting reflects long-term exposure to environmental stressors, wasting reflects lower food intake and the presence of diseases in the short term (WHO, 2008). These anthropometric measures have been shown to adequately reflect growth and nutrition statuses for children under five. In particular, a low height-for-age (stunting) can lead to poorer physical and cognitive development (Victora et al., 2008; UNICEF, WHO, and World Bank, 2020). A low weight-for-height (wasting) can structurally damage the brain and increase mortality risks (Guerrant et al., 2008). A low weight-for-age (underweight) can indicate both stunting and/or wasting (WHO, 2008).

To construct the estimation sample, we utilize the DHS surveys where child health measures, as mentioned above, are available. We also rely on the DHS surveys where the Global Positioning System components are present (DHS-GPS) since participating households are geo-referenced. With the DHS-GPS dataset, we can identify the exact geographic location of the household cluster a child belongs to. The cluster is the lowest geographic level in the DHS-GPS. Each cluster refers to a residential area and is identified by a pair of latitude and longitude coordinates. A household cluster is displaced by two kilometers for urban areas and five kilometers for rural areas. Randomly selected 1% of the rural clusters are further displaced from zero to ten kilometers (Burgert et al., 2013). The displacement is intended to reduce disclosure risk, especially for rural areas which tend to be more sparsely populated than urban areas. Given the spatial information, we can incorporate the rainfall data to each residential cluster.

3.2 Rainfall Data

Rainfall data are drawn from the latest version of the Climatic Research Unit Time Series (CRUTS, version 4.03). The dataset is produced by the United Kingdom's National Center for Atmospheric Science at the University of East Anglia's Climatic Research Unit. Monthly rainfall data are obtained from land-based stations. Each 0.5°×0.5° grid cell is assigned rainfall data according to its covering station. If a cell is covered by one station, rainfall data are taken from that station. If a cell is covered by two or more stations, rainfall data are calculated using the angular distance-weight average from those stations (Harris et al., 2020). If a cell is not covered by any stations, rainfall data are interpolated with the cell's average rainfall between 1961-1990. In constructing our rainfall measure, we only utilize grid cell supported by at least one station. Rainfall data from cells that are not covered by any stations are simply predicted means, thus, are not meaningful in our analysis.[1]

Since we know the location (latitude-longitude coordinates) of residential clusters in DHS-GPS, we can extract the entire record of rainfall information of the cluster from CRUTS dataset. It is worth noting that rainfall data of a cluster in a given month are only incorporated in our measure if the cluster locates in a cell that is covered by at least one station for the month. Our rainfall measures are the rainfall variability in the interval between conception and childbirth. From the monthly CRUTS dataset, we can calculate the total rainfall during the nine months in the womb for each child based on the reported month-year of birth and the geographic location of the residential cluster. We require that rainfall data for each month be supported by at least one underlying station in order to be incorporated in our measure. For example, if the in-utero duration is from January to September, then rainfall data from stations must be available for all nine months from January to September.

In examining the impacts of rainfall during utero on child health outcomes, we focus on the deviation of the nine-month in-utero rainfall from the long-run average of total rainfall during those nine months for the child's residential cluster. First, we measure in-utero rainfall deviation as the differences between total rainfall in the childs cluster during the nine months of pregnancy and the cluster's long-run average, then divided by the long-run standard

[1] By restricting to data points supported by at least one station, we obtain meaningful measures of rainfall at the expense of the loss of observations. If the station locations were to be correlated with rainfall variability and child health at the same time, then our estimates would be affected. However, prior studies argue that shocks to local norms are random event (Skoufias and Vinha, 2012; Bjorkman-Nyqvist, 2013; Cornwell and Inder, 2015; Dimitrova and Muttarak, 2020), so it is unlikely that our estimates would be driven by this issue.

deviation of rainfall in that cluster. The nine month long-run mean rainfall is calculated from 1981 to 2018 for each cluster. For example, for a child in utero between October 2005 and June 2006, in-utero rainfall deviation ($IUR_{Oct-Jun}$) is given by,

$$IUR_{Oct-Jun} = \frac{TR_{Oct-Jun} - LRAR_{Oct-Jun}}{LRSD_{Oct-Jun}} \tag{1}$$

where the total rainfall in these nine months in the child's cluster ($TR_{Oct-Jun}$) is calculated by summing the monthly total rainfall from October 2005 to June 2006. The nine-month long-run average rainfall ($LRAR_{Oct-Jun}$) and the nine-month long-run standard deviation of rainfall ($LRSD_{Oct-Jun}$) are the 1981-2018 mean and standard deviation of total rainfall for October through June in the child's cluster, respectively.

Since we are interested in both positive (wet) and negative (dry) shocks of rainfall, we construct our two main explanatory variables capturing the deviations above (In-Utero Excess of Rainfall) and below (In-Utero Lack of Rainfall) the long-run local average. Specifically, In-Utero Excess of Rainfall is the rainfall deviation during the in-utero period as described above if the rainfall deviation is positive, zero otherwise. In-Utero Lack of Rainfall is the absolute value of in-utero rainfall deviation as described above if the rainfall deviation is negative, zero otherwise. Back to our example in the previous paragraph, for a child in utero between October 2005 and June 2006, In-Utero Excess of Rainfall and In-Utero Lack of Rainfall are calculated as follows,

$$IUER_{Oct-Jun} = \begin{cases} IUR_{Oct-Jun} \quad if \quad IUR_{Oct-Jun} > 0 \\ 0 \quad otherwise \end{cases} \tag{2}$$

$$IULR_{Oct-Jun} = \begin{cases} -IUR_{Oct-Jun} \quad if \quad IUR_{Oct-Jun} < 0 \\ 0 \quad otherwise \end{cases} \tag{3}$$

where $IUER_{Oct-Jun}$ and $IULR_{Oct-Jun}$ are in-utero excess of rainfall and in-utero lack of rainfall measures for the child in utero between October 2005 and June 2006, respectively.

Thus, an increase by one unit of $IUER_{Oct-Jun}$ can be interpreted as one standard deviation increase in in-utero rainfall relative to the long-run local average (i.e. one standard deviation increase in positive rainfall anomalies during the utero period relative to the location-specific norm), and an increase by one unit of $IULR_{Oct-Jun}$ can be seen as one standard deviation decrease in in-utero rainfall relative to the long-run local average (i.e. one standard deviation increase in negative rainfall anomalies during the in-utero period relative to the location-specific norm).

Table 1: Summary Statistics

	Mean	SD	Observations
	(1)	(2)	(3)
Panel A: Dependent Variables			
Height-for-age Z-score	-1.258	1.566	593,717
Weight-for-height Z-score	-0.534	1.269	593,717
Weight-for-age Z-score	-1.206	1.292	593,717
Stunting	0.303	0.460	593,717
Wasting	0.107	0.309	593,717
Underweight	0.274	0.446	593,717
Panel B: Independent Variables			
In-Utero Excess of Rainfall	0.477	0.664	593,717
In-Utero Lack of Rainfall	0.318	0.500	593,717
Mother's Age at Birth	26.46	6.158	593,717
Mother's Education	5.312	5.050	593,717
Household Head's Gender	0.854	0.353	593,717
Wealth Index	2.814	1.395	487,074
Rural Area	0.696	0.460	593,717
Child's Age	29.47	17.01	593,717
Child's Birth Order	3.052	2.168	593,717
Male Child	0.510	0.500	593,717

3.3 Estimation Sample

Our sample consists of almost 600,000 children under five years old (i.e. less than 60 months old) in 55 low and middle-income countries from 1990 to 2018. Table A1 in the Appendix provides the list of countries and the survey waves. Table 1 presents the descriptive statistics of our dependent and control variables. As indicated in Panel A, on average, children in our sample have height-for-age, weight-for-height, and weight-for-age z-scores of roughly

-1.26, -0.53, and -1.21 standard deviations, respectively. These anthropometric measures are expressed as the number of standard deviations below or above the median value of an international reference population. The average values of these measures are all negative (below the reference median of zero) because our sample consists of only children from low and middle-income countries. Approximately 30%, 11%, and 27% of the children are categorized as stunted, wasted, and underweight, respectively.

The summary statistics of our control variables are provided in Panel B of Table 1. Our main explanatory variables, In-Utero Excess of Rainfall and In-Utero Lack of Rainfall, take the mean values of 0.47 and 0.32, respectively. Other characteristics are also presented in Panel B. On average, mothers were 26 years old when they gave birth (regardless of birth order) and completed 5 years of education. Around 85% of household heads are male and 70% of households live in rural areas. Child's average age is approximately 29.5 months, i.e. around 2.5 years of age.

4 Empirical Methodology

To examine the impacts of in-utero exposure to rainfall variability on child health outcomes, we employ the following regression model,

$$Y_{imtr} = \beta_0 + \beta_1 IUER_{imtr} + \beta_2 IULR_{imtr} + \delta_m + \gamma_t + \lambda_r + X'_{imtr}\Omega + \epsilon_{imtr} \quad (4)$$

where the subscripts i, m, t, and r denote child, birth month, birth year, and residential cluster, respectively. The outcome variable Y_{imtr} represents three anthropometric z-scores (height-for-age, weight-for-height, weight-for-age) and three nutrition indicators derived from the z-scores (stunting, wasting, underweight).

We also denote by δ_m, γ_t, and λ_r birth month, birth year, and residential cluster fixed effects, respectively. A residential cluster is a place of residence located within a district of a country where the child resides. X'_{imtr} is a vector of individual, maternal, and household characteristics that affect child health, including mothers age at birth, mothers age at birth squared, mothers years of education, household head gender, household wealth index, whether the household resides in a rural area, childs age in months, childs age in months squared, childs birth order, and male child indicator. Finally, ϵ_{imtr} stands for the error term. Standard errors throughout the paper are clustered at the residential cluster level.

Our main explanatory variables are $IUER_{imtr}$ (In-Utero Excess of Rainfall) and $IULR_{imtr}$ (In-Utero Lack of Rainfall). $IUER_{imtr}$ captures the excess of rainfall, and the corresponding coefficient β_1 is the impacts of one standard deviation above the long-run local average of rainfall on child health outcomes. $IULR_{imtr}$ reflects the deficiency of rainfall, and the corresponding coefficient β_2 is the impacts of one standard deviation below the long-run local average of rainfall on child health outcomes. In this framework, we exploit the plausibly exogenous variation in rainfall the child experienced during the in-utero period relative to the location-specific norm of rainfall for the same period of the year to identify the impacts of in-utero rainfall variability on child health outcomes. The underlying assumption is that the deviations of rainfall from the long-term local average are random events across and within residential clusters. As a result, the rainfall deviations to which the child was exposed in utero are also random. Similar to ours, prior studies also rely on rainfall volatility as the source of exogenous variation to identify the effects on health and educational outcomes such as the works of Skoufias and Vinha (2012), Bjorkman-Nyqvist (2013), Cornwell and Inder (2015), and Dimitrova and Muttarak (2020).

5 Results

5.1 Main Results

The estimated impacts of rainfall variability during the in-utero period on child health outcomes are reported in Table 2. Here, each column presents the coefficients of a separate regression. The column headings indicate dependent variables. HAZ, WHZ, and WAZ stand for height-for-age, weight-for-height, and weight-for-age z-scores, respectively. In general, the results show that in-utero exposure to both excessive and deficient rainfall relative to the long-run local average negatively affects child health.

Specifically, Columns 1 through 3 show that a one standard deviation increase in positive rainfall anomalies during the in-utero period is associated with reductions in child's HAZ, WHZ, and WAZ scores by 0.03, 0.03, and 0.04 standard deviations, respectively. A one standard deviation increase in negative rainfall anomalies during the in-utero period is likewise associated with 0.03, 0.04, and 0.04 standard deviations lower HAZ, WHZ and WAZ scores, respectively.

As shown in Columns 4 through 6, a one standard deviation increase in positive rainfall anomalies during the in-utero period raises the incidences of stunting, wasting, and underweight by 0.6, 0.6, and 1.1 percentage points, respectively. Children are also 0.5, 0.8, and 0.9 percentage points more likely to be stunted, wasted, and underweight in response to a one standard deviation increase in negative rainfall anomalies.[2] Taken together, both excessive and deficient rainfall are harmful to early childhood health proxied by anthropometric measures.

Table 2: In-Utero Rainfall and Child Health - Main Results

	HAZ (1)	WHZ (2)	WAZ (3)	Stunting (4)	Wasting (5)	Underweight (6)
In-Utero Excess of Rainfall	-0.029***	-0.027***	-0.037***	0.006***	0.006***	0.011***
	(0.004)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
In-Utero Lack of Rainfall	-0.027***	-0.041***	-0.043***	0.005***	0.008***	0.009***
	(0.005)	(0.004)	(0.004)	(0.002)	(0.001)	(0.001)
Observations	593,717	593,717	593,717	593,717	593,717	593,717
All Controls	✓	✓	✓	✓	✓	✓
Fixed Effects	✓	✓	✓	✓	✓	✓

Note: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Each column represents the coefficients in a separate regression. The column headings indicate dependent variables. HAZ, WHZ, and WAZ stand for height-for-age, weight-for-height, and weight-for-age z-scores, respectively. Stunting, Wasting, and Underweight are defined as height-for-age, weight-for-height, and weight-for-age z-scores less than -2, respectively. All Controls include mother's age at birth, mother's age at birth squared, mother's years of education, household head gender, household wealth indicator, whether the household resides in a rural area, child's age in months, child's age in months squared, child's birth order, and male child indicator. Fixed Effects include birth month, birth year, and residential cluster fixed effects. Robust standard errors are clustered at the residential cluster level.

We also map the countries in our sample where vulnerabilities to rainfall shocks are the highest. To do so, we estimate the effects of fetal exposure to excessive and deficient rainfall (relative

[2] Since stunting, wasting, and underweight are indicator variables, we also utilize the logistic regression models in Panel A of Table A4. A one standard deviation increase in positive rainfall anomalies during the intrauterine period is associated with the 0.029, 0.053, and 0.056 increases in the log-odds of being stunted, wasted, and underweight, respectively. A one standard deviation increase in negative rainfall anomalies during the intrauterine period is linked to the 0.035, 0.085, and 0.061 increases in the log-odds of being stunted, wasted, and underweight, respectively. Please see Appendix A for more details.

to the historical norms) on child's anthropometric z-scores, for each country separately. The estimated impacts of excessive rainfall and deficient rainfall are illustrated in Figures A1 and A2 in the appendix where the results for HAZ, WHZ, and WAZ scores are displayed in Panels a, b, and c, respectively. All shaded areas are countries covered in our sample. The darkest shade represents countries where the estimates are negative and statistically significant. The second darkest shade represents countries where the estimates are negative but fall short of statistical significance. Overall, the figures suggest that East Africa, West Africa, South Asia, and the western part of South America are the most vulnerable to excessive and deficient rainfall.

5.2 Do the Impacts of In-utero Rainfall Variability Stay Latent?

According to the fetal origin hypothesis, the nine months in utero are regarded as one of the most crucial stages in a person's development and intrauterine conditions can shape later life outcomes (Barker, 1990; Almond and Currier, 2011). While the fetal origin hypothesis has been widely accepted, there remains much debate on the exact stage when the effects of in-utero events begin to materialize. One strand of the epidemiological literature argues that fetal exposure to environmental shocks can result in adverse outcomes apparent right after birth (Jones et al., 1973). Another branch of the literature promotes the idea of latent health effects whereby the effects of adverse in-utero conditions stay latent for several years after birth (Kermack et al., 1934; Schulz, 2010). In other words, adverse in-utero conditions could potentially compromise the health and development of children in later years even though the infants appear healthy right after birth.

We contribute to the above-mentioned debate by investigating whether the impacts of prenatal exposure to weather shocks are apparent right after birth or stay latent until later years of life. To do so, we estimate the impacts of intrauterine exposure to excessive and deficient rainfall for children of different age groups. The results are reported in Table 3. In each panel, each column represents the coefficients of a separate regression. The panel names indicate various groups of children with different age ranges. The column headings indicate dependent variables.

Table 3: In-Utero Rainfall and Child Health for Different Age Groups

	HAZ (1)	WHZ (2)	WAZ (3)	Stunting (4)	Wasting (5)	Underweight (6)
Panel A: Children Aged Zero						
In-Utero Excess of Rainfall	-0.070***	-0.026*	-0.038***	0.018***	0.003	0.004
	(0.015)	(0.013)	(0.012)	(0.004)	(0.003)	(0.004)
In-Utero Lack of Rainfall	-0.086***	-0.073***	-0.108***	0.019***	0.008*	0.008*
	(0.019)	(0.017)	(0.016)	(0.005)	(0.004)	(0.005)
Observations	115,702	115,702	115,702	115,702	115,702	115,702
Panel B: One-year Old Children						
In-Utero Excess of Rainfall	-0.009	-0.002	-0.017	-0.002	0.001	0.008*
	(0.015)	(0.012)	(0.012)	(0.005)	(0.004)	(0.005)
In-Utero Lack of Rainfall	-0.036*	-0.021	-0.033**	0.009	0.006	0.011*
	(0.019)	(0.016)	(0.015)	(0.007)	(0.005)	(0.006)
Observations	110,539	110,539	110,539	110,539	110,539	110,539
Panel C: Two-year Old Children						
In-Utero Excess of Rainfall	0.013	-0.011	-0.003	-0.006	0.006*	-0.000
	(0.015)	(0.010)	(0.012)	(0.005)	(0.003)	(0.005)
In-Utero Lack of Rainfall	-0.033*	-0.022*	-0.034**	0.003	-0.000	0.014**
	(0.018)	(0.012)	(0.014)	(0.006)	(0.004)	(0.006)
Observations	121,003	121,003	121,003	121,003	121,003	121,003
Panel D: Three-year Old Children						
In-Utero Excess of Rainfall	-0.034**	0.001	-0.017*	0.009*	0.001	0.001
	(0.014)	(0.010)	(0.010)	(0.005)	(0.003)	(0.004)
In-Utero Lack of Rainfall	-0.040**	0.002	-0.004	0.008	0.002	-0.004
	(0.018)	(0.013)	(0.014)	(0.006)	(0.004)	(0.006)
Observations	110,625	110,625	110,625	110,625	110,625	110,625
Panel E: Four-year Old Children						
In-Utero Excess of Rainfall	-0.028**	0.006	-0.011	0.005	0.001	0.006
	(0.012)	(0.009)	(0.009)	(0.004)	(0.002)	(0.004)
In-Utero Lack of Rainfall	-0.034**	-0.011	-0.027**	0.009	0.004	0.007
	(0.015)	(0.012)	(0.012)	(0.006)	(0.003)	(0.005)
Observations	115,125	115,125	115,125	115,125	115,125	115,125
All Controls	✓	✓	✓	✓	✓	✓
Fixed Effects	✓	✓	✓	✓	✓	✓

Note: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. In each panel, each column represents the coefficients in a separate regression. The panel names indicate various groups of children with different age ranges. The column headings indicate dependent variables. Robust standard errors are clustered at the residential cluster level. See the note under Table 2 for more details.

Evident from Panel A, intrauterine exposure to excessive and deficient rainfall has detrimental effects on child health during the first year of life (children who are less than one year old).

Specifically, both higher and lower rainfall relative to the location-specific norm lowers all three anthropometric z-scores among these children. The effects are statistically significant and large in magnitude. Children aged zero are also more likely to be stunted, wasted, and underweight due to exposure to both positive and negative rainfall shocks during the intrauterine period. In Panels B, C, D, and E, we provide the estimated impacts of in-utero exposure to rainfall variability on children who are one, two, three, and four years old, respectively. Overall, in-utero exposure to rainfall variability is negatively associated with the health of these children although some of the estimates are not statistically significant at the conventional levels. In terms of magnitude, the estimates tend to be smaller than those in Panel A. Therefore, the results presented in Table 3 suggest that fetal exposure to rainfall shocks is associated with adverse health outcomes during the first year of life and the effects are still visible to some extent at later ages.

It would be interesting to note here that the effects of in-utero exposure to rainfall shocks on HAZ scores are still visible and statistically significant up to age five. In contrast, the effects on WHZ scores are not visible beyond the first year of life. This can be explained by the fact that HAZ scores reflect long-term development (childrens height), which is influenced by conditions in the womb. In contrast, WHZ reflects acute weight loss which is affected by events in the more recent past. Collectively, Table 3 presents some evidence supporting the latent health effect argument for HAZ and not so for WHZ and WAZ.

5.3 Heterogeneity Analyses

In this section, we explore the heterogeneous impacts of in-utero exposure to rainfall variability on child health by mothers level of education, households wealth position, households place of residence (i.e. rural or urban), and the countrys level of dependence on agriculture. The results are presented in Tables 4 and 5.

First, we investigate whether the effects of in-utero rainfall variability differ between children born to uneducated mothers and those born to educated mothers. Uneducated mothers are those who have not completed primary school. Educated mothers refer to at least primary school graduates. Evident from Panels A and B of Table 4, in-utero exposure to both excessive and deficient rainfall has adverse health effects for children regardless of their mothers level of education but the impacts are larger in the uneducated group. These findings suggest that higher mother's education can buffer the detrimental impacts of adverse environmental conditions in utero on the health outcomes of children, consistent with prior studies showing maternal education as a key determinant of child health (Keats, 2018; Le and Nguyen, 2020b).

Table 4: In-Utero Rainfall and Child Health - Heterogeneity Analysis 1

	HAZ (1)	WHZ (2)	WAZ (3)	Stunting (4)	Wasting (5)	Underweight (6)
Panel A: Low-education Mothers						
In-Utero Excess of Rainfall	-0.031***	-0.029***	-0.044***	0.004***	0.006***	0.013***
	(0.006)	(0.004)	(0.004)	(0.002)	(0.001)	(0.002)
In-Utero Lack of Rainfall	-0.048***	-0.051***	-0.064***	0.008***	0.010***	0.016***
	(0.007)	(0.006)	(0.006)	(0.002)	(0.002)	(0.002)
Observations	304,301	304,301	304,301	304,301	304,301	304,301
Panel B: High-education Mothers						
In-Utero Excess of Rainfall	-0.031***	-0.025***	-0.031***	0.008***	0.006***	0.010***
	(0.005)	(0.004)	(0.004)	(0.002)	(0.001)	(0.002)
In-Utero Lack of Rainfall	-0.018**	-0.032***	-0.028***	0.007***	0.006***	0.004*
	(0.007)	(0.006)	(0.006)	(0.002)	(0.002)	(0.002)
Observations	285,238	285,238	285,238	285,238	285,238	285,238
Panel C: Relatively Poor Households						
In-Utero Excess of Rainfall	-0.023***	-0.018***	-0.023***	0.007***	0.005***	0.008***
	(0.006)	(0.005)	(0.005)	(0.002)	(0.001)	(0.002)
In-Utero Lack of Rainfall	-0.032***	-0.044***	-0.042***	0.007***	0.008***	0.009***
	(0.009)	(0.006)	(0.006)	(0.003)	(0.002)	(0.003)
Observations	221,149	221,149	221,149	221,149	221,149	221,149
Panel D: Relatively Non-poor Households						
In-Utero Excess of Rainfall	-0.021***	-0.013***	-0.019***	0.003*	0.004***	0.006***
	(0.006)	(0.004)	(0.004)	(0.002)	(0.001)	(0.002)
In-Utero Lack of Rainfall	-0.016**	-0.030***	-0.026***	0.004	0.008***	0.003
	(0.008)	(0.006)	(0.006)	(0.002)	(0.002)	(0.002)
Observations	265,925	265,925	265,925	265,925	265,925	265,925
All Controls	✓	✓	✓	✓	✓	✓
Fixed Effects	✓	✓	✓	✓	✓	✓

Note: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. In each panel, each column represents the coefficients in a separate regression. The panel names indicate the dimensions of heterogeneity. The column headings indicate dependent variables. Robust standard errors are clustered at the residential cluster level. See the note under Table 2 for more details.

Next, we examine whether children from households with different wealth positions are affected differentially by rainfall variability. Households whose wealth indices lie in the bottom and the next bottom quintiles of the within-country distribution are categorized as relatively poor households (relative to others in the same country). Likewise, those with wealth indices in the middle, upper middle, and top quintiles of the within-country distribution are considered relatively non-poor. Estimated effects for relatively poor households and relatively non-poor households are reported in Panels C and D, respectively. It is evident from Table 4 that children from relatively poor households are more vulnerable to rainfall variability than those from relatively non-poor households. Particularly, for children from relatively poor households, fetal exposure to excessive and deficient rainfall has adverse effects on their health outcomes evidenced by lower anthropometric z-scores and higher incidence of undernutrition. Regarding children from relatively non-poor households, the impacts are substantially weaker in magnitude. These results suggest that a better socio-economic background can counteract the adverse consequences of weather shocks on child health.

We additionally explore the heterogeneity in the impacts of in-utero rainfall shocks by household's place of residence. Estimates for children in rural and urban households are provided in Panels A and B of Table 5, respectively. The results suggest that children in rural areas are more severely impacted by in-utero exposure to deficient rainfall (relative to the historical norms) than those in urban areas. Nevertheless, the impacts of excessive rainfall do not seem to significantly differ between these two groups.

We further explore whether the impacts of in-utero exposure to rainfall variability differ by the countrys level of dependence on agriculture. Countries with high dependence on agriculture are defined as those in the upper two quartiles (i.e. upper half) of the GDP share of agriculture. Countries with low dependence on agriculture are defined as those in the lower two quartiles (i.e. lower half) of the GDP share of agriculture. We obtain the GDP share of agriculture for each country during 1990 and 2018 from the World Bank national account data. Then we get the 1990-2018 averages of the share of agriculture in total GDP for each country. The average value is utilized to classify into quartiles indicating levels of dependence on agriculture. According to the results reported in the lower half of Table 5, almost all of the estimates on both rainfall variability measures are larger in Panel C than those in Panel

D. In other words, the in-utero exposure to rainfall variability tend to be more devastating for children in countries with high dependence level on agriculture.

Table 5: In-Utero Rainfall and Child Health - Heterogeneity Analysis 2

	HAZ (1)	WHZ (2)	WAZ (3)	Stunting (4)	Wasting (5)	Underweight (6)
Panel A: Rural Households						
In-Utero Excess of Rainfall	-0.027***	-0.027***	-0.036***	0.006***	0.006***	0.012***
	(0.004)	(0.004)	(0.003)	(0.001)	(0.001)	(0.001)
In-Utero Lack of Rainfall	-0.037***	-0.045***	-0.051***	0.008***	0.009***	0.010***
	(0.006)	(0.005)	(0.004)	(0.002)	(0.001)	(0.002)
Observations	413,236	413,236	413,236	413,236	413,236	413,236
Panel B: Urban Households						
In-Utero Excess of Rainfall	-0.040***	-0.025***	-0.040***	0.007***	0.005***	0.010***
	(0.007)	(0.005)	(0.005)	(0.002)	(0.001)	(0.002)
In-Utero Lack of Rainfall	-0.008	-0.034***	-0.025***	-0.000	0.007***	0.007***
	(0.009)	(0.007)	(0.007)	(0.003)	(0.002)	(0.002)
Observations	180,481	180,481	180,481	180,481	180,481	180,481
Panel C: High Dependence on Agriculture						
In-Utero Excess of Rainfall	-0.024***	-0.040***	-0.049***	0.003*	0.006***	0.014***
	(0.006)	(0.005)	(0.005)	(0.002)	(0.001)	(0.002)
In-Utero Lack of Rainfall	-0.054***	-0.067***	-0.085***	0.007***	0.013***	0.019***
	(0.007)	(0.006)	(0.006)	(0.002)	(0.001)	(0.002)
Observations	290,372	290,372	290,372	290,372	290,372	290,372
Panel D: Low Dependence on Agriculture						
In-Utero Excess of Rainfall	-0.039***	-0.012***	-0.027***	0.010***	0.005***	0.009***
	(0.005)	(0.004)	(0.004)	(0.002)	(0.001)	(0.001)
In-Utero Lack of Rainfall	-0.015**	-0.013**	-0.005	0.007***	0.003*	-0.000
	(0.007)	(0.006)	(0.005)	(0.002)	(0.002)	(0.002)
Observations	303,345	303,345	303,345	303,345	303,345	303,345
All Controls	✓	✓	✓	✓	✓	✓
Fixed Effects	✓	✓	✓	✓	✓	✓

Note: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. In each panel, each column represents the coefficients in a separate regression. The panel names indicate the dimensions of heterogeneity. The column headings indicate dependent variables. Robust standard errors are clustered at the residential cluster level. See the note under Table 2 for more details.

Our heterogeneity analyses show that children born to uneducated mothers, and in relatively poor households, and rural areas, as well as children in countries heavily dependent on agriculture, are particularly vulnerable to rainfall variability. The results presented in Table 4 suggest that when it comes to deficient rainfall, both mothers education and wealth seem to play a protective role since the impacts are substantially smaller in magnitude for the educated and relatively non-poor groups compared to the uneducated and relatively poor ones. However, when it comes to excessive rainfall, there are less obvious differences between education and wealth groups. According to Table 5, deficient rainfall is particularly bad for agriculturally dependent countries and for rural households. Nevertheless, when it comes to excessive rainfall, the disparities are not so large. Our findings are consistent with the works of Muttarak et al. (2015) and Dimitrova and Muttarak (2020) who point out that socio-demographic factors play an important role in determining the degree of vulnerability of populations to climatic shocks.

5.4 Other Specifications and Measures

In this section, we conduct a series of alternative specifications and measures to confirm the main findings of our paper. First, we explore the potential differences in the impacts of rainfall shocks during different trimesters. The results in Table A2 in the Appendix show that impacts are not significantly prevalent in any particular trimester relative to others. Second, we examine the potential nonlinear impacts of rainfall anomalies by adding the quadratic terms for both the excessive and deficient rainfall measures. Evident from Table A3, rainfall variability influences child health in a way that reinforces the main effects of positive rainfall anomalies but moderates the effects of negative rainfall anomalies. Third, we utilize logistic regressions for indicator outcomes (stunting, wasting, and underweight) instead of the linear probability regressions. Our conclusions remain unchanged (Table A4, Panel A). Fourth, controlling for rainfall variability before conception and after birth does not substantially change our results (Table A4, Panels B and C). Fifth, we restrict our sample to households that have stayed in the same location since the conception of the child. Our estimated impacts of rainfall variability remain negative and statistically significant (Table A4, Panel D). Finally, using different measures of rainfall shocks and various levels of station coverage leaves our results virtually intact (Table A5).

5.5 Discussion

We have provided evidence that in-utero exposure to rainfall variability leads to poorer health outcomes in early childhood. Specifically, a one standard deviation increase in positive rainfall anomalies is associated with the reductions in childs HAZ, WHZ, and WAZ scores by 0.03, 0.03, and 0.04 standard deviations, respectively. Children are also 0.6, 0.6, and 1.1 percentage points more likely to be stunted, wasted, and underweight. Not only excessive rainfall but deficient rainfall is also harmful to child health. A one standard deviation increase in negative rainfall anomalies makes children 0.03, 0.04, and 0.04 standard deviations shorter for their age, thinner for their height, and thinner for their age, respectively. Children are 0.5, 0.8, and 0.9 percentage points more likely to be stunted, wasted, and underweight in response to a one standard deviation increase in negative rainfall anomalies.

By estimating the impacts for children of different age ranges, we find that in-utero exposure to rainfall variability leaves detrimental consequences apparent in the first year of life and the effects still linger at later ages. Particularly, the impacts of in-utero exposure to rainfall shocks on HAZ scores are still visible and statistically significant up to age five. In contrast, the effects on WHZ scores are not visible beyond the first year of life. This is because HAZ scores reflect long-term development (childrens height), which is influenced by conditions in the womb. Nevertheless, WHZ reflects acute weight loss which is affected by events in the more recent past. Collectively, we find some evidence supporting the latent health effect argument for HAZ scores and less so for WHZ and WAZ scores.

In exploring the heterogeneity in the impacts of in-utero exposure to rainfall variability, we find that children born to uneducated mothers, those from relatively poor households, those residing in rural areas, and those in countries with high dependence on agriculture are particularly vulnerable. The unequal distribution of the impacts of weather shocks is consistent with the demographic differential vulnerability findings in previous studies such as the works of Muttarak et al. (2015) and Dimitrova and Muttarak (2020). Furthermore, our heterogeneity analyses also reveal that deficient and excessive rainfall have different effects across different groups of the population. Deficient rainfall tends to harm uneducated, poor, rural, and agriculturally dependent groups of the population. It could be the case that deficient rainfall harms agricultural production, which lowers household income. Poor, rural, and uneducated households are less likely to be able to smooth consumption and also more likely to depend on agricultural income in the first place. As for excessive rainfall, we detect less pronounced differences among population groups. This could be explained that excessive rainfall leads to higher prevalence of diseases, water contamination, etc, which is likely to affect all groups equally.

Our estimated results are in accordance with previous studies on the importance of in-utero conditions to early human health. Particularly, fetal exposure to armed conflict leads to poorer health and growth statuses in early childhood (Minoiu and Shemyakina, 2012; Oskorouchi, 2019). Nutritional deprivation induced by food price inflation and food scarcity during the intrauterine period has been shown to be detrimental to the child's initial stock of health (Miller, 2017; Woldemichael et al., 2017). In a different vein, our findings are consonant with preceding works on the relationship between climatic events and health outcomes of children (Cornwell and Inder, 2015; Cooper et al., 2019; Dimitrova and Bora, 2020; Randell et al., 2020). These studies also highlight the inimical repercussions of rainfall variability during the in-utero period on child's anthropometric z-scores.

Given the projected increase in the global intensity and frequency of extreme precipitation events (Alexander, 2016; Myhre et al., 2019), our paper highlights the cost of climate volatility to early human health. Because poor health during early childhood could leave long-lasting effects on educational attainment, cognitive ability, health, and employment in adulthood (Case et al., 2005; Glewwe and Miguel, 2008; Doyle et al., 2009; Briend and Berkley, 2016), in-utero exposure to rainfall variability could also be damaging to long-term human development. Therefore, the paper calls for global efforts being directed to combat the potential consequences of climate change such as rainfall variability. In particular, it is important to have policy interventions that aim to protect pregnant women from the threats of adverse climatic events. Since excessive rainfall and deficient rainfall could potentially affect child health through different channels, policies targeting these two conditions could be different. Specifically, as excessive rainfall is likely to worsen child health through diseases, health interventions are important to protect pregnant women from such risks in areas prone to excessive rainfall. As deficient rainfall tends to harm child health through agricultural production, weather monitoring system and adaptive strategies should be developed in areas which usually suffer from abnormally dry conditions. Furthermore, government programs need to prioritize the population who are especially vulnerable to unusual weather shocks, especially those from disadvantaged socioeconomic backgrounds.

5.6 Limitations

We acknowledge the limitations of our empirical method as our research design cannot account for selectivity due to mortality, fertility, differential sex ratio, and migration. First, regarding selective mortality, the variability of rainfall could have been extreme enough to raise the rate of miscarriage and the infant mortality rate, making these children drop out of the sample. Our research design cannot account for such a possibility. The exclusion of the (unborn) unhealthy children would narrow the health gaps between children severely affected by rainfall variability and those barely affected during the intrauterine period. In other words, selective mortality could exert downward pressure on our estimates.

Second, regarding fertility-related issues, rainfall variability can restrict fertility by inducing food insecurity as the lack of food might make it difficult for women to conceive. If the (unborn) children had been conceived during times of food scarcity, they would grow up to have poor health because of the lack of nutrition in this critical period. Therefore, the omission of these (unborn) children can result in smaller impacts of in-utero exposure to rainfall variability, which biases our estimates toward zero.

Another potential issue with fertility is the possibility of advanced response by women. Specifically, there could be a probability that women may delay childbirth in anticipation of adverse rainfall variability. Although there is no direct way to test for the possibility of women's advanced response, we attempt to provide suggestive evidence against that possibility by controlling for positive and negative rainfall anomalies within 12 months prior to conception. The insensitivity of our results to the inclusion of rainfall variability before conception suggests that mothers' advanced response is unlikely to drive our results. Even if mothers could predict the variability of rainfall and delay childbirth, the omission of the (unborn) unhealthy children, who would have been exposed to rainfall variability, from the estimation sample would exert downward pressure on our estimates.

The third limitation lies in our inability to address the differential survival probability across sexes. In particular, rainfall variability can potentially lead to a difference in sex ratios among exposed women since boy fetuses would be more likely to die as they are weaker (Kraemer, 2000). Similar to the previous cases, the selection of less healthy children out of the sample would bias our estimated impacts of in-utero exposure to rainfall variability toward zero, making our estimated impacts smaller than the actual ones.

Finally, our research design does not address selective migration. Specifically, households might have migrated in response to adverse weather events. Unfortunately, we cannot assess the degree to which selective migration affects our estimates since migration information is unavailable in the data. It is possible that pregnant women might have moved to different locations due to adverse rainfall variability. Their children could have been exposed to adverse conditions in the intrauterine period prior to migration and they are not observed in the sample. The exclusion of such children could narrow the health gaps between children severely affected by rainfall variability and those barely affected during gestation. To put it differently, selective migration can make our estimates the lower bounds of the true impacts of rainfall variability in gestation.

Overall, our study can be subject to several selection bias issues that omit less healthy children caused by rainfall variability from the estimation sample. The data limitation makes it impossible to overcome such issues. Thus, our estimates can only be viewed as the lower bounds of the true impacts of in-utero exposure to rainfall variability on child health.

6 Conclusion

This paper contributes to the literature by quantifying the impacts of fetal exposure to rainfall variability on child health for 55 low and middle-income countries. The data are drawn from the Demographic and Health Surveys with the Global Positioning System and the Climatic Research Unit Time Series. Our rainfall measures are the deviations of the nine-month in-utero rainfall above and below the long-run average of total rainfall during those nine months for the child's residential cluster. In terms of identification, we exploit the exogenous variation in the rainfall deviations from the long-run local average to estimate how experiencing rainfall variability during the intrauterine period affects the health outcomes of children under five years old.

Our findings indicate that fetal exposure to rainfall variability deteriorates the health outcomes of children in their early years of life. Both positive and negative rainfall anomalies during the in-utero period harm children's HAZ, WHZ, and WAZ scores and raise the incidences of stunting, wasting, and underweight. By estimating the impacts on children of different age ranges, we find some evidence supporting the latent health effect argument for HAZ scores and less so for WHZ and WAZ scores. Our heterogeneity analyses show that deficient rainfall tends to harm uneducated, poor, and agriculturally dependent groups of the population while less pronounced differences among population groups are detected for excessive rainfall.

The paper underlines the tremendous costs of rainfall variability. Given that poor health in early life exerts long-lasting consequences over the life cycle such as impaired cognitive development, poorer adult health, and declining productivity (Case et al., 2005; Glewwe and Miguel, 2008; Doyle et al., 2009; Briend and Berkley, 2016), the detrimental impacts of in-utero rainfall variability detected in this paper highlight the potential threat of climate change to long-term human development, especially in low and middle-income countries. Policy interventions are needed to combat the potential consequences of climate change such as rainfall variability. As abnormally wet weather in the utero period can deteriorate child health by making water-borne diseases more prevalent, it is important to implement health interventions such as oral rehydration therapy to protect pregnant women from such risks in areas prone to excessive rainfall. Since abnormally dry weather can affect in-utero nutrition via agriculture production and food availability, weather monitoring system and adaptive strategies should be developed in rural areas which tend to suffer from deficient rainfall. Nutrition interventions for pregnant women could also counteract the adverse consequences of rainfall variability. Since rainfall shortage can worsen child health by making pregnant women engage in physically demanding work (Randell et al., 2020), it is also important to raise awareness among pregnant women in rainfall deficient regions of the risks associated with such activities. Furthermore, extra attention needs to be drawn to the disadvantaged groups, including, uneducated, poor, rural women, and women from countries with high dependence on agriculture, who have been shown to be the most vulnerable.

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Appendix A

Impacts by Pregnancy Trimesters – So far, we have considered the effects of rainfall variability exposure throughout the whole nine months in utero. Here, we further explore the potential differences in the impacts during different trimesters. To do so, we re-calculate our rainfall measures to indicate the excess of rainfall (1st Trimester Excess of Rainfall, 2nd Trimester Excess of Rainfall, 3rd Trimester Excess of Rainfall) and the lack of rainfall (1st Trimester Lack of Rainfall, 2nd Trimester Lack of Rainfall, 3rd Trimester Lack of Rainfall) during each of the three trimesters relative to the historical norms. The results provided in Table A2 suggest that rainfall variability in all three trimesters is detrimental to early childhood health. Both excessive and deficient rainfall in all trimesters worsen child's anthropometric z-scores. The impacts are not significantly prevalent in any particular trimester relative to others.

Non-linearity – The employed model in main analyses assumes that the impacts of rainfall variability are linear (equation (4)). One may be interested in the potential non-linearity in the negative impacts of in-utero exposure to rainfall variability on child health. In other words, one may want to know whether the impacts of rainfall variability are stronger when rainfall deviates further from the norm. Thus, we add the quadratic terms for both the excess of rainfall and the lack of rainfall (relative to the historical norms) measures to equation (4). With this setup, a positive and statistically significant coefficient on the quadratic term suggests a diminishing effect while a negative and statistically significant coefficient implies an increasing effect. The results are reported in Table A3. We find that rainfall variability influences child health in a way that reinforces the main effects of positive rainfall anomalies (increasing effects of excessive rainfall) but moderates the effects of negative rainfall anomalies (diminishing effects of deficient rainfall).

Logistic Regressions – Recall that our three measures of nutritional statuses, Stunting, Wasting, and Underweight are zero-one indicators taking the value of one if height-for-age, weight-for-height, and weight-for-age z-scores are less than -2, respectively, and zero otherwise. Employing the linear probability specification as in equation (4), we find that in-utero exposure to higher rainfall and lower rainfall relative to the historical norms raises the incidences of stunting, wasting, and underweight. As the outcome variables are indicators, one may also be interested in the odd-ratio interpretation derived from the logistic regression instead of the probability interpretation derived from the linear probability regression. Therefore, we re-estimate the impacts of in-utero rainfall variability on the three nutritional indicators using logistic regressions. The results are reported in Panel A of Table A4. A one standard deviation increase in positive rainfall anomalies during the intrauterine period is associated with the 0.029, 0.053, and 0.056 increases in the log-odds of being stunted, wasted, and underweight, respectively. A one standard deviation increase in negative rainfall anomalies during the intrauterine period is linked to the 0.035, 0.085, and 0.061 increases in the log-odds of being stunted, wasted, and underweight, respectively.

Rainfall Variability before Conception – One potential concern to our empirical strategy is the possibility of advanced response by women. Specifically, there could be a probability that women may delay childbirth in anticipation of adverse rainfall variability. This possibility is unlikely because of the following reasons. Our rainfall measures are the deviations of rainfall above and below the long-run local averages of rainfall. Our identification hinges upon the plausibly exogenous variation in rainfall the child experienced during utero relative to normal local rainfall to isolate the impacts of in-utero rainfall variability. The underlying assumption of our empirical strategy, which is the deviations of rainfall from the historical norms to which the child was exposed during the in-utero period are random, is validated in prior studies (Skoufias and Vinha, 2012; Bjorkman-Nyqvist, 2013; Cornwell and Inder, 2015; Dimitrova and Muttarak, 2020). Since the deviations of rainfall from the historical norms are random, it is difficult for mothers to anticipate the adverse rainfall variability to delay childbirth. Besides, we further control for location, month, and year fixed effects in our empirical model, which captures rainfall patterns across residential clusters and time. Thus, systematic correlation across time is not likely to drive the results.

However, if women could somehow predict climatic shocks and delay childbirth, the exclusion of the (unborn) unhealthy children, who would have been exposed to rainfall variability, from the estimation sample would make our estimates the lower bounds of the true impacts of in-utero exposure to rainfall variability on child health. To provide additional evidence against the possibility of this advanced response by mothers, we control for the deviation of rainfall within 12 months prior to conception both above and below the historical norms in our main specifications. As shown in Panel B of Table A4, our results are insensitive to the inclusion of rainfall variability before conception as the estimates remain significant in both economic and statistical senses. The results provide some suggestive evidence that selective fertility or mothers' advanced response is unlikely to drive our results, further supporting the integrity of our empirical model.

Rainfall Variability after Birth – Another concern is that in-utero rainfall variability might be correlated with after-birth rainfall variability and rainfall variability happening after birth might also influence child health. However, the correlation between in-utero rainfall and after-birth rainfall is unlikely because the deviations of rainfall from the historical norms to which the child was exposed during the intrauterine period are exogenous as argued in prior studies (Skoufias and Vinha, 2012; Bjorkman-Nyqvist, 2013; Cornwell and Inder, 2015; Dimitrova and Muttarak, 2020). Furthermore, the inclusion of residential cluster, month, and year fixed effects in our empirical model makes it unlikely for our results to be driven by systematic correlation across time as rainfall patterns across location and time are accounted for.

In any case, we control for positive rainfall anomalies relative to the location-specific norm (After-Birth Excess of Rainfall) and negative rainfall anomalies relative to the location-specific norm (After-Birth Lack of Rainfall) for the period that lasts from the birth of the child to the survey date. It is worth noting that the inclusion of after-birth rainfall will make it difficult to interpret the results as the effects of after-birth rainfall also depend on child' age at the time (the older the child gets, the more he/she will be exposed to rainfall variability). In other words, the reference period after birth is not fixed.

The results of this exercise are provided in Panel C of Table A4, showing that our estimates are slightly larger after controlling for rainfall variability after birth. While not reported, the impacts of rainfall variability (both excess and lack of rainfall) after birth are also negative and statistically significant. Nevertheless, as noted above, controlling for after-birth rainfall could be problematic because the reference period after birth is not fixed and the impacts of after-birth rainfall depend on the child's age at the time.

Migration – Since households might have moved to different places in response to adverse weather events, we attempt to provide some suggestive evidence whether such selective migration issue could potentially affect our estimates. Therefore, we restrict our sample to households that remained in the same place since the conception of the child. The results are presented in Panel D of Table A4. We continue to find negative and statistically significant impacts of excessive and deficient rainfall on child health, suggesting that selective migration might not influence our results. However, this is only suggestive evidence and there is no formal test for selective migration.

Different Measures of Rainfall Variability – Recall that our main rainfall variability measures are In-Utero Excess of Rainfall and In-Utero Lack of Rainfall. When observed rainfall is higher than the long-run mean rainfall, the variable In-Utero Lack of Rainfall equals zero and the variable In-Utero Excess of Rainfall is calculated as the differences between total rainfall in the child's cluster during the nine months of pregnancy and the cluster's long-run average, then divided by the long-run standard deviation of rainfall in that cluster. When observed rainfall is lower than the long-run mean rainfall, the variable In-Utero Excess of Rainfall equals zero and the variable In-Utero Lack of Rainfall is calculated as the absolute value of the differences between total rainfall in the child's cluster during the nine months of pregnancy and the cluster's long-run average, then divided by the long-run standard deviation of rainfall in that cluster. Here, we use alternative measures of rainfall variability to test whether our results are driven by how we construct the main explanatory variables.

First, we replace In-Utero Excess of Rainfall and In-Utero Lack of Rainfall with two other measures, In-Utero Excess of Rainfall-Indicator and In-Utero Lack of Rainfall-Indicator. In-Utero Excess of Rainfall-Indicator takes the value of one if total rainfall in the child's cluster during the nine months of pregnancy is at least one standard deviation above the cluster's long-run average, zero otherwise. In-Utero Lack of Rainfall-Indicator takes the value of one if total rainfall in the child's cluster during the nine months of pregnancy is at least one standard deviation below the cluster's long-run average, zero otherwise. Evident from Panel A of Table A5, estimates are highly significant in both statistical and economic senses. Abnormally wet and dry weather still exert detrimental consequences on child's anthropometric z-scores and nutritional statuses.

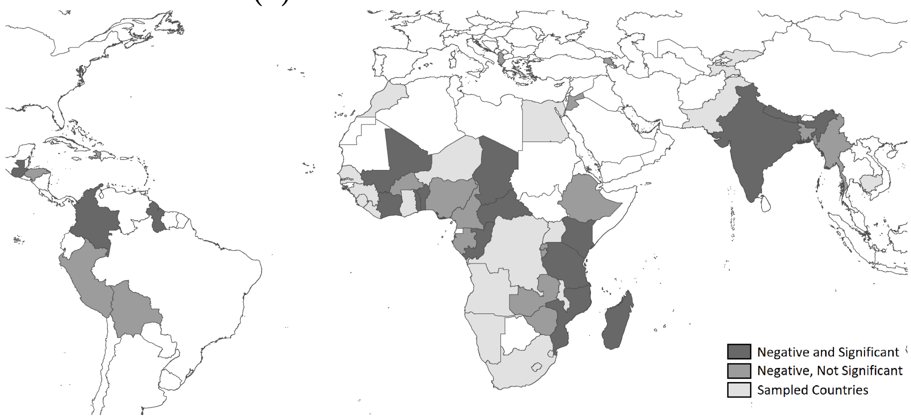
Second, we replace In-Utero Excess of Rainfall and In-Utero Lack of Rainfall with two other two measures, In-Utero Excess of Rainfall-Percentage and In-Utero Lack of Rainfall-Percentage. When observed rainfall is higher than the long-run mean rainfall, the variable In-Utero Lack of Rainfall-Percentage equals zero and the variable In-Utero Excess of Rainfall-Percentage is the differences between total rainfall in the child's cluster during the nine months of pregnancy and the cluster's long-run average, then divided by the long-run average (instead of long-run standard deviation). The computation is analogous when rainfall is lower than the historical norm. Employing these measures as explanatory variables does not change the conclusion of our analysis (Panel B, Table A5). Collectively, our results are robust to some other measures of rainfall variability.

Station Coverage – Recall that in constructing the rainfall measure from the CRUTS, we require the rainfall data for each month be supported by at least one underlying station. One might concern that our results could possibly be driven by: (i) recording errors from stations, and (ii) measurement errors for residential clusters located further away from the stations. Therefore, in this section, we restrict our samples from clusters supported by at least one station to clusters supported by at least two or four stations. By imposing these restrictions, we lose geographic coverage but gain more precision in the rainfall measure.

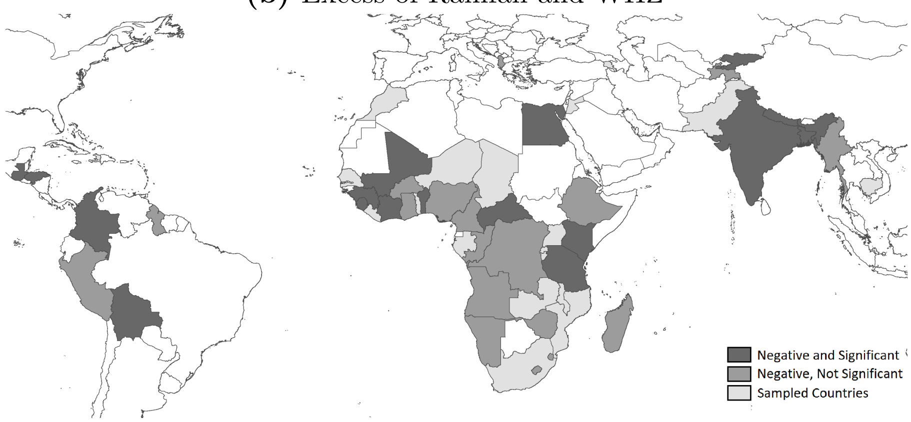
Panels C and D report the results where rainfall measure is constructed for the clusters supported by at least two and four underlying stations for each month of the nine months, respectively. With these restrictions, the sample sizes are now smaller than those in Section 5.1. The estimated impacts of in-utero rainfall on child health slightly vary compared to the ones in Table 2. The coefficients on all anthropometric z-scores and nutrition statuses are all statistically distinct from zero and have expected signs. Estimates in both Panels C and D suggest both excessive and deficient rainfall are detrimental to health outcomes of children in early childhood. The results suggest that measurement errors are not likely to be an issue since the results vary little when we restrict our sample to clusters covered by two or four stations.

Figure A1: In-Utero Excess of Rainfall and Child Health across Regions

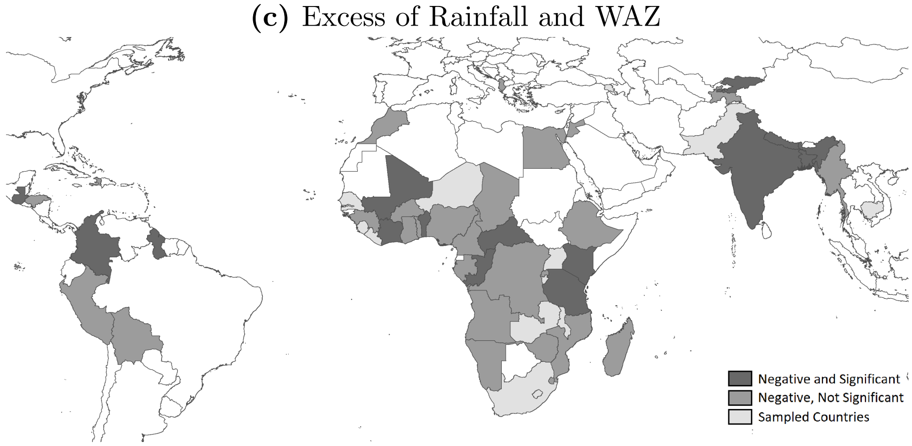
(a) Excess of Rainfall and HAZ



(b) Excess of Rainfall and WHZ



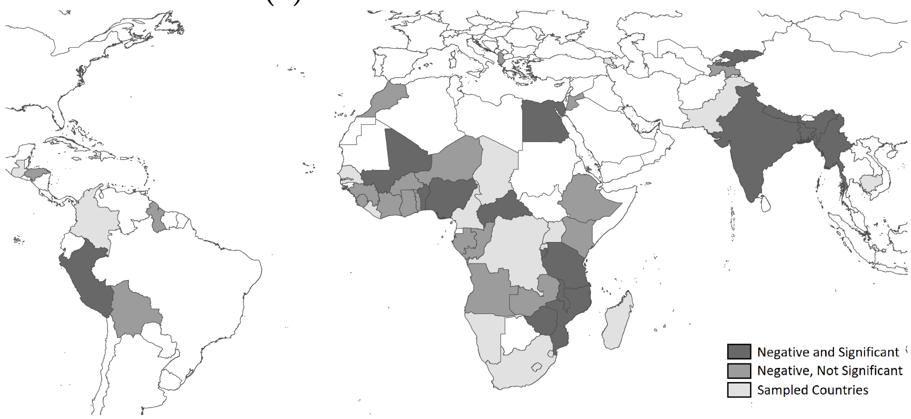
(c) Excess of Rainfall and WAZ



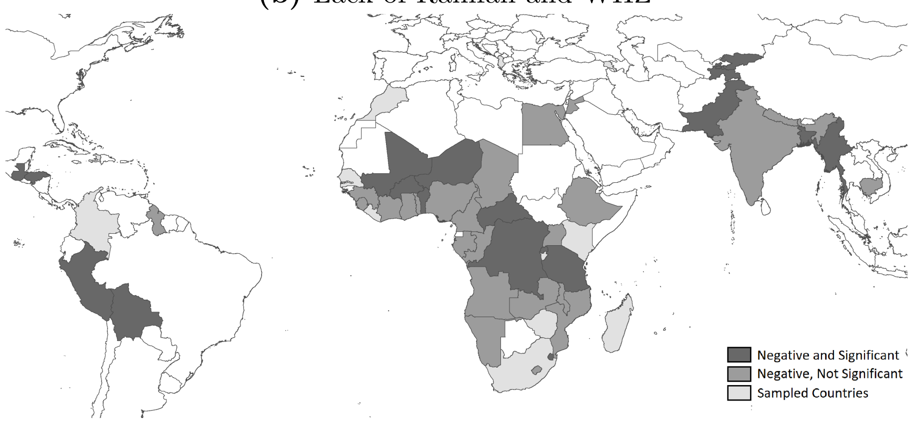
Note: The estimated impacts of in-utero exposure to excessive rainfall on height-for-age, weight-for-height, and weight-for-age z-scores are illustrated in Panels a, b, and c, respectively. All shaded areas are countries covered in our sample. The darkest shade represents countries where the estimates are negative and statistically significant. The second darkest shade represents countries where the estimates are negative but fall short of statistical significance.

Figure A2: In-Utero Lack of Rainfall and Child Health across Regions

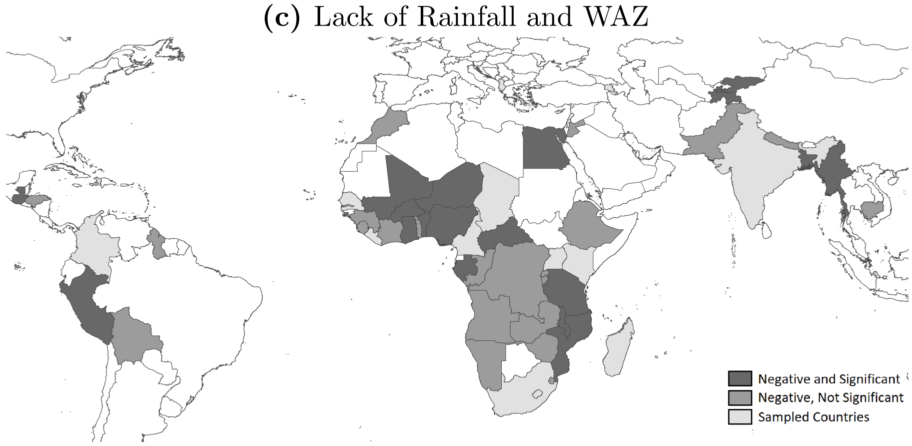
(a) Lack of Rainfall and HAZ



(b) Lack of Rainfall and WHZ



(c) Lack of Rainfall and WAZ



Note: The estimated impacts of in-utero exposure to the lack of rainfall on height-for-age, weight-for-height, and weight-for-age z-scores are illustrated in Panels a, b, and c, respectively. All shaded areas are countries covered in our sample. The darkest shade represents countries where the estimates are negative and statistically significant. The second darkest shade represents countries where the estimates are negative but fall short of statistical significance.

Table A1: The List of Countries

Code (1)	Name (2)	Wave (3)	Excess (4)	Lack (5)	HAZ (6)	WHZ (7)	WAZ (8)	Obs. (9)
AL	Albania	5, 7	0.598	0.145	-0.297	0.567	0.209	3,711
AM	Armenia	7	0.099	0.373	1.062	1.357	1.719	216
AO	Angola	7	0.209	0.464	-1.318	-0.494	-1.218	895
BD	Bangladesh	3, 4, 5, 6	0.307	0.365	-1.583	-1.003	-1.747	25,535
BF	Burkina Faso	2, 3, 4, 6	0.405	0.327	-1.332	-0.793	-1.424	15,123
BJ	Benin	3, 4, 6, 7	0.501	0.233	-1.284	-0.315	-1.066	15,244
BO	Bolivia	5	0.206	0.329	-1.091	0.350	-0.424	5,798
BU	Burundi	6, 7	0.529	0.325	-1.997	-0.440	-1.562	4,627
CD	Congo Dem. Rep.	5, 6	0.384	0.409	-1.548	-0.431	-1.284	4,694
CF	Central African Rep.	3	0.140	0.577	-1.435	-0.424	-1.218	1,367
CI	Cote d'Ivoire	3, 6	0.397	0.420	-1.208	-0.475	-1.130	3,734
CM	Cameroon	4, 6	0.521	0.132	-0.814	0.185	-0.375	2,208
CO	Colombia	5	0.660	0.167	-0.671	0.086	-0.396	10,717
DR	Dominican Rep.	5, 6	0.290	0.138	-0.360	0.094	-0.212	7,182
EG	Egypt	2, 3, 4, 5, 6	0.376	0.382	-0.685	0.262	-0.264	18,390
ET	Ethiopia	4, 6, 7	0.383	0.283	-1.625	-0.762	-1.576	14,630
GA	Gabon	6	0.638	0.088	-0.907	-0.028	-0.615	2,888
GH	Ghana	2, 3, 4, 5, 6	0.387	0.386	-1.128	-0.531	-1.117	8,457
GN	Guinea	3, 4, 6, 7	0.550	0.181	-0.998	-0.415	-0.946	8,022
GU	Guatemala	6	0.881	0.234	-1.743	0.076	-1.045	9,534
GY	Guyana	5	0.805	0.080	-0.823	-0.100	-0.629	1,471
HN	Honduras	6	0.329	0.314	-1.167	0.031	-0.723	5,793
HT	Haiti	4, 5, 6, 7	0.405	0.450	-0.935	-0.298	-0.835	10,210
IA	India	6	0.591	0.301	-1.273	-1.017	-1.592	176,264
JO	Jordan	4, 5, 6	0.194	0.495	-0.440	-0.007	-0.323	12,170
KE	Kenya	4, 5, 6	0.406	0.392	-1.041	-0.213	-0.830	17,415
KH	Cambodia	4, 5, 6	0.393	0.321	-1.573	-0.809	-1.596	12,357
KY	Kyrgyz Rep.	6	0.356	0.369	-0.701	0.220	-0.290	3,983
LB	Liberia	6	1.815	0.000	-1.225	0.086	-0.737	116
LS	Lesotho	4, 5, 6	0.601	0.139	-1.544	-0.221	-1.125	123
MA	Morocco	4	0.228	0.496	-0.751	-0.086	-0.582	2,560
MD	Madagascar	3	0.317	0.414	-1.916	-0.595	-1.676	832
ML	Mali	3, 4, 5, 6, 7	0.486	0.297	-1.326	-0.720	-1.380	26,875
MM	Myanmar	7	0.500	0.505	-1.256	-0.605	-1.253	3,108
MW	Malawi	4, 5, 7	0.423	0.283	-1.763	0.024	-1.074	20,416
MZ	Mozambique	6	0.193	0.320	-1.502	-0.134	-1.047	5,160
NG	Nigeria	2, 4, 5, 6	0.400	0.292	-1.359	-0.471	-1.221	18,879
NI	Niger	2, 3	0.268	0.493	-1.486	-0.947	-1.646	4,488
NM	Namibia	4, 5, 6	0.575	0.462	-0.935	-0.428	-0.934	2,304
NP	Nepal	4, 5, 6, 7	0.428	0.382	-1.767	-0.878	-1.754	14,441
PE	Peru	4, 5, 6	0.397	0.440	-1.330	0.349	-0.572	16,148
PK	Pakistan	7	0.454	0.280	-1.478	-0.508	-1.310	2,735

Note: Columns 1 and 2 display country code and name. Column 3 shows the survey wave. Columns 4 and 5 provide the average values of In-Utero Excess of Rainfall and In-Utero Lack of Rainfall. Columns 6 through 8 further provides the means for height-for-age, weight-for-height, and weight-for-age z-scores, respectively. Column 9 gives the number of observations.

(Table A1 continued)

Code (1)	Name (2)	Wave (3)	Excess (4)	Lack (5)	HAZ (6)	WHZ (7)	WAZ (8)	Obs. (9)
RW	Rwanda	4, 6	0.694	0.241	-1.613	0.085	-0.937	8,008
SL	Sierra Leone	5, 6	0.306	0.064	-1.103	-0.283	-0.916	424
SN	Senegal	2, 4, 6	0.606	0.323	-0.975	-0.627	-1.107	12,283
SZ	Swaziland	5	0.064	0.286	-0.982	0.378	-0.329	991
TD	Chad	6	0.379	0.272	-0.791	-0.393	-0.773	641
TG	Togo	3, 6	0.556	0.156	-1.099	-0.646	-1.191	5,944
TJ	Tajikistan	6, 7	0.451	0.276	-0.837	-0.325	-0.801	7,881
TL	Timor-Leste	5, 7	0.059	0.265	-1.689	-1.172	-1.933	418
TZ	Tanzania	3, 5, 7	0.325	0.508	-1.487	-0.314	-1.169	13,054
UG	Uganda	4, 5, 6, 7	0.568	0.255	-1.099	-0.101	-0.781	5,071
ZA	South Africa	7	0.146	0.405	-1.033	0.437	-0.354	377
ZM	Zambia	5, 6	0.459	0.212	-1.515	-0.161	-1.068	9,362
ZW	Zimbabwe	4, 5, 6, 7	0.384	0.275	-1.158	-0.017	-0.754	8,443

Note: Columns 1 and 2 display country code and name. Column 3 shows the survey wave. Columns 4 and 5 provide the average values of In-Utero Excess of Rainfall and In-Utero Lack of Rainfall. Columns 6 through 8 further provides the means for height-for-age, weight-for-height, and weight-for-age z-scores, respectively. Column 9 gives the number of observations.

Table A2: In-Utero Rainfall and Child Health - Trimester Measures

	HAZ (1)	WHZ (2)	WAZ (3)	Stunting (4)	Wasting (5)	Underweight (6)
1st Trimester Excess of Rainfall	-0.014***	-0.009***	-0.019***	0.003***	0.002***	0.006***
	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
1st Trimester Lack of Rainfall	-0.000	-0.009**	-0.006	0.002	0.003***	0.001
	(0.005)	(0.004)	(0.004)	(0.002)	(0.001)	(0.001)
2nd Trimester Excess of Rainfall	-0.014***	-0.007**	-0.016***	0.003***	0.003***	0.004***
	(0.004)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
2nd Trimester Lack of Rainfall	-0.014***	-0.008**	-0.013***	0.002	0.001	0.000
	(0.005)	(0.004)	(0.004)	(0.002)	(0.001)	(0.001)
3rd Trimester Excess of Rainfall	-0.009**	-0.010***	-0.010***	0.003***	0.002**	0.002*
	(0.004)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
3rd Trimester Lack of Rainfall	-0.016***	-0.006	-0.013***	0.003**	-0.000	0.000
	(0.005)	(0.004)	(0.004)	(0.002)	(0.001)	(0.001)
Observations	593,717	593,717	593,717	593,717	593,717	593,717
All Controls	✓	✓	✓	✓	✓	✓
Fixed Effects	✓	✓	✓	✓	✓	✓

Note: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Each column represents the coefficients in a separate regression and the column headings indicate dependent variables. Robust standard errors are clustered at the residential cluster level. See the note under Table 2 for more details.

Table A3: In-Utero Rainfall and Child Health - Non-Linearity

	HAZ (1)	WHZ (2)	WAZ (3)	Stunting (4)	Wasting (5)	Underweight (6)
In-Utero Excess of Rainfall	0.002	-0.010	-0.013*	-0.001	-0.002	0.008***
	(0.010)	(0.008)	(0.008)	(0.003)	(0.002)	(0.003)
In-Utero Excess of Rainfall Squared	-0.016***	-0.009***	-0.013***	0.003***	0.004***	0.002
	(0.004)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
In-Utero Lack of Rainfall	-0.045***	-0.072***	-0.084***	0.006	0.009***	0.017***
	(0.013)	(0.010)	(0.010)	(0.004)	(0.003)	(0.004)
In-Utero Lack of Rainfall Squared	0.015**	0.021***	0.028***	-0.001	-0.001	-0.005***
	(0.007)	(0.005)	(0.005)	(0.002)	(0.001)	(0.002)
Observations	593,717	593,717	593,717	593,717	593,717	593,717
All Controls	✓	✓	✓	✓	✓	✓
Fixed Effects	✓	✓	✓	✓	✓	✓

Note: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. Each column represents the coefficients in a separate regression and the column headings indicate dependent variables. Robust standard errors are clustered at the residential cluster level. See the note under Table 2 for more details.

Table A4: In-Utero Rainfall and Child Health - Other Specifications

	HAZ (1)	WHZ (2)	WAZ (3)	Stunting (4)	Wasting (5)	Underweight (6)
Panel A: Logistic Regression						
In-Utero Excess of Rainfall				0.029***	0.053***	0.056***
				(0.006)	(0.009)	(0.006)
In-Utero Lack of Rainfall				0.035***	0.085***	0.061***
				(0.008)	(0.011)	(0.008)
Observations				593,717	593,717	593,717
Panel B: Before Conception Controls						
In-Utero Excess of Rainfall	-0.029***	-0.027***	-0.037***	0.006***	0.006***	0.011***
	(0.004)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
In-Utero Lack of Rainfall	-0.027***	-0.041***	-0.043***	0.005***	0.008***	0.009***
	(0.005)	(0.004)	(0.004)	(0.002)	(0.001)	(0.001)
Observations	593,717	593,717	593,717	593,717	593,717	593,717
Panel C: After Birth Controls						
In-Utero Excess of Rainfall	-0.051***	-0.035***	-0.048***	0.012***	0.007***	0.016***
	(0.004)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
In-Utero Lack of Rainfall	-0.045***	-0.052***	-0.058***	0.009***	0.010***	0.013***
	(0.005)	(0.004)	(0.004)	(0.002)	(0.001)	(0.001)
Observations	593,717	593,717	593,717	593,717	593,717	593,717
Panel D: Migration Issue						
In-Utero Excess of Rainfall	-0.044***	-0.035***	-0.048***	0.010***	0.008***	0.016***
	(0.005)	(0.004)	(0.004)	(0.001)	(0.001)	(0.001)
In-Utero Lack of Rainfall	-0.026***	-0.031***	-0.034***	0.005***	0.007***	0.007***
	(0.006)	(0.005)	(0.005)	(0.002)	(0.001)	(0.002)
Observations	399,299	399,299	399,299	399,299	399,299	399,299
All Controls	✓	✓	✓	✓	✓	✓
Fixed Effects	✓	✓	✓	✓	✓	✓

Note: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. In each panel, each column represents the coefficients in a separate regression. The panel names indicate different specifications. The column headings indicate dependent variables. Robust standard errors are clustered at the residential cluster level. See the note under Table 2 for more details.

Table A5: In-Utero Rainfall and Child Health - Other Measures

	HAZ (1)	WHZ (2)	WAZ (3)	Stunting (4)	Wasting (5)	Underweight (6)
Panel A: Indicator						
In-Utero Excess	-0.034***	-0.027***	-0.041***	0.007***	0.005***	0.014***
of Rainfall - Indicator	(0.006)	(0.004)	(0.004)	(0.002)	(0.001)	(0.002)
In-Utero Lack	-0.024***	-0.044***	-0.042***	0.006***	0.008***	0.009***
of Rainfall - Indicator	(0.007)	(0.005)	(0.005)	(0.002)	(0.001)	(0.002)
Observations	593,717	593,717	593,717	593,717	593,717	593,717
Panel B: Percentage						
In-Utero Excess	-0.112***	-0.117***	-0.153***	0.024***	0.028***	0.051***
of Rainfall - Percentage	(0.017)	(0.013)	(0.013)	(0.005)	(0.004)	(0.005)
In-Utero Lack	-0.073***	-0.144***	-0.136***	0.019***	0.030***	0.025***
of Rainfall - Percentage	(0.022)	(0.018)	(0.017)	(0.007)	(0.005)	(0.006)
Observations	593,717	593,717	593,717	593,717	593,717	593,717
Panel C: 2 Stations						
In-Utero Excess	-0.032***	-0.029***	-0.040***	0.007***	0.006***	0.012***
of Rainfall - 2 Stations	(0.004)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)
In-Utero Lack	-0.032***	-0.045***	-0.050***	0.005***	0.008***	0.010***
of Rainfall - 2 Stations	(0.005)	(0.004)	(0.004)	(0.002)	(0.001)	(0.002)
Observations	509,427	509,427	509,427	509,427	509,427	509,427
Panel D: 4 Stations						
In-Utero Excess	-0.029***	-0.041***	-0.048***	0.005***	0.007***	0.013***
of Rainfall - 4 Stations	(0.005)	(0.004)	(0.004)	(0.002)	(0.001)	(0.001)
In-Utero Lack	-0.037***	-0.051***	-0.062***	0.005**	0.010***	0.013***
of Rainfall - 4 Stations	(0.007)	(0.005)	(0.005)	(0.002)	(0.001)	(0.002)
Observations	353,018	353,018	353,018	353,018	353,018	353,018
All Controls	✓	✓	✓	✓	✓	✓
Fixed Effects	✓	✓	✓	✓	✓	✓

Note: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. In each panel, each column represents the coefficients in a separate regression. The panel names indicate different measures of rainfall and station coverage. The column headings indicate dependent variables. Robust standard errors are clustered at the residential cluster level. See the note under Table 2 for more details.