Early-life climate exposures and adult fertility: Evidence from the global tropics

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Abstract

There is increasing of evidence of the significant social and economic costs of global climate change. The lifelong consequences of many early-life shocks for individuals' health and socioeconomic attainment have been well documented, but few studies consider the influence of early-life climate exposures and (or) the effects of early-life conditions on completed fertility despite strong conceptual bases for expecting such impacts. We address this gap by examining the effects of early-life temperature and precipitation exposures on the number of children ever born to women ages 40-49 years, with a focus on countries in the global tropics where climate vulnerability is high. We measure the global effects of climatic anomalies from the prenatal year to age 4 on women's parity across 26 countries. We also evaluate whether this relationship varies by world region, countries' position in the demographic transition, and by the historical temperature and rainfall of the birthplace. Finally, we compare the effects of early-life exposures, measured from ages –1 to 4, to those of exposures during a longer period that includes later years of childhood, as a means of exploring the mechanisms that may drive effects. Overall, we find a negative and significant association of temperature anomalies on lifetime fertility. This effect is also observed in countries with relatively low fertility rates, while the region stratification models reflect strong negative effects of rainfall anomalies in Latin America. We find consistent evidence of substantive differences in temperature and precipitation effects when measured over a longer exposure period, and by historic temperature and rainfall.

Introduction and Background

Global climate change is increasing many populations' exposure to adverse, and in some cases extreme, environmental conditions (Tuholske et al., 2021). An extensive and expanding literature in demography and other social sciences has documented large, and often-negative effects of environmental exposures on demographic, health, and socioeconomic outcomes around the world. These impacts include changes in migration patterns, increased malnutrition, and elevated mortality risks (Kaczan & Orgill-Meyer, 2020; Thiede & Strube, 2020; Vicedo-Cabrera et al., 2021). Most of these prior studies have measured the contemporaneous or near-contemporaneous effects of temperature and precipitation anomalies (e.g., how a shock in year t affects an outcome in t+1), which impose the most immediate costs and needs for intervention. However, environmental exposures can also have much more persistent, long-term impacts (Maccini & Yang, 2009; Randell & Gray, 2019; Thiede et al., 2022). The life-long consequences of several types of early-life health and economic shocks for individuals' health and socioeconomic attainment have been well documented (Almond et al., 2018; Currie & Vogl, 2013), but relatively few studies have examined the long-term effects of climate exposures or considered fertility as an outcome variable. These are important issues to consider given increasing climate risks and the multi-dimensional implications of fertility changes for health, wellbeing, and population dynamics (Canning & Schultz, 2012).

We aim to address these gaps in the current study by examining the effects of early-life temperature and precipitation exposures for the number of children ever born to women ages 40-49 years in the global tropics. This outcome merits attention as it has significant implications for women's health and socioeconomic attainment, as well as populations' demographic and economic trajectories We do so by drawing on data from 56 censuses conducted across 26 countries in the global tropics, which provide information on birthplace, fertility, and sociodemographic characteristics for 7,435,468 women, and combining these data with historical climate records to measure early-life temperature and precipitation exposures. We first measure the overall effects of exposure to temperature and precipitation anomalies during the prenatal year to age 4. We then evaluate whether this relationship varies by comparing effects by world region and countries' position in the demographic transition, as well the historical temperature and rainfall of the province of birth. Last, we compare the effects of early-life exposures, measured from ages –1 to 4, to those of exposures in later childhood (ages 5 to 9) and in adolescence (ages 10-14), as exploratory means of assessing the hypothesized developmental and socioeconomic mechanisms that we expect may drive early-life climate effects on lifetime fertility.

Early-life Environment and Reproductive Outcomes

There are strong conceptual reasons to expect early-life climate exposures to influence the number of children born to women in later adulthood. In utero and childhood stressors are implicated in developmental disruptions that often manifest in poor health and lower socioeconomic attainment into adulthood (Almond et al., 2018; Currie & Vogl, 2013). They can also lead to other social and physiological disruptions and changes that alter individuals' life course trajectories. Collectively, these changes have several potentially important implications for fertility.

First, childhood climate exposures can have direct, physiological effects on fertility. Early-life exposures to climatic changes may affect childhood nutrition by reducing caloric intake, diet quality, and health (McMahon & Gray, 2021; Randell et al., 2020), which can in turn potentially have effects on fecundity and fertility in later life. Sufficient and appropriate caloric intake is necessary for gynecological development, which can have later life consequences on fertility (Harville et al., 2021). Negative effects on menarche and disruption in gynecological development can negatively affect fecundity (Bridge-Comer et al., 2019; Mishra et al., 2009). Prior research on exposure to low crop yields in early life in preindustrial societies has shown to reduce fertility (Hayward et al., 2013). Other instances of reduced caloric intake, such as during the Dutch Winter Hunger, are known to be associated with reduced fertility or, as in the case of the Great Leap Forward Famine in China, an increased risk of fetal loss (Lumey & Stein, 1997; Song, 2013). Furthermore, increased prevalence of diseases—including rickets (leading to pelvic deformities), eating disorders, and micronutrient deficiencies—are all associated with reduced fertility (Micali et al., 2007; Thoms, 1927; Thornburg, 2011).

Climate exposures may also influence lifetime fertility through socioeconomic and behavioral pathways. Early-life climate exposures can lead to lower levels of educational attainment and adult income. Prior evidence from the global tropics shows that exposures to higher-than-average temperatures during the prenatal stage and early childhood reduces educational attainment by ages 12-16 years (Randell & Gray, 2019). Negative rainfall shocks in utero and during early childhood have also been associated with lower school enrollment and poorer cognitive ability (Alderman et al., 2006; Thai & Falaris, 2011). Lower levels of human capital have several important implications related to fertility, including changing the economic costs and benefits of childbearing and shaping the knowledge of reproduction (Peet et al., 2015). While the economic determinants of fertility are complex and contested, an inverse correlation between income and the number of children born to women is observed across many contexts. This pattern may reflect socioeconomic differences in the demand for children and in access to and knowledge about contraceptives, leading to an increase in fertility with lower income and educational attainment (Gakidou & Vayena, 2007; Jones, 2015). Changes in education and income have also been implicated in changing migration and marriage patterns, which are correlated with fertility in many contexts (Castro Torres, 2023; Corno et al., 2020; Thiede et al., 2022).

In addition to these physiological and socioeconomic mechanisms, it is possible that early-life climate exposures may influence later-life fertility via changes in risk perceptions and tolerance. Prior research suggests that an individual's level of risk tolerance is established early in life and does not vary with age. Weather shocks in early childhood may therefore make individuals more adverse to climate (and other) risks, either directly or through the influence of parental responses to those shocks. Doss et al., (2008) and Brown et al., (2018) find empirical evidence for an increase in risk perception after exposure to community-level shocks and natural disasters in more vulnerable populations. Importantly, there are plausible reasons to expect such risk tolerance to influence fertility behavior. Bellani & Arpino (2022) find the likelihood of a first and second birth increases as risk tolerance decreases, and this effect is more salient for low-income individuals in the case of a first birth. Trinitapoli & Yeatman (2018) argue that desired fertility amongst women is tied to perceived uncertainty and stratified by socioeconomic status and perceptions of survival.

Each of these pathways suggests a plausible link between early-life climate exposures and later-life fertility. Yet these mechanisms may not always operate in the same direction, and there is no strong basis to expect one mechanism to dominate the others. We therefore treat the direction of early-life climate effects as an empirical question.

Research Objectives

Our overall goal is to measure the effects of early-life climate exposures on the number of children ever born to women ages 40-49 years across the global tropics, where development, environmental, and health challenges are significant (Pörtner et al., 2022). Toward this overall goal, we address four specific objectives. First, we measure the overall effects of temperature and precipitation anomalies during the prenatal year to age 4 on women's parity across the entire sample. Second, we evaluate whether this relationship varies by world region and countries' position in the demographic transition, which we respectively expect to capture broad differences in social and environmental contexts and reproductive decision-making across our sample. Third, we compare the effects of early-life exposures, measured from ages –1 to 4, to those of exposures during a longer period of time that includes later years of childhood (ages 5 to 9, 10 to 14). Finally, we evaluate whether the relationship varies by the historical temperature and rainfall of the birthplace. We use these extensions to produce exploratory evidence about the hypothesized mechanisms.

Data and Methods

Data

We extract and analyze census microdata from the Integrated Public Use Microdata Series-International (IPUMS-I) database, (Minnesota Population Center, 2020).The data in our sample come from 26 countries across the global tropics, with selection criteria as follows: (1) at least 50 percent of the land area is located within the global tropics (between approximately 23.5° N and 23.5° S latitude), (2) at least two censuses of data are available since 1990, and (3) geographic identifiers that can be standardized over time are available for place of birth and current residence at the time of the census. The final sample includes data from 56 censuses conducted between 1990 and 2012 in 26 countries across tropical East and Southern Africa (6 countries), West Africa (3 countries), Central America and the Caribbean (7 countries), South America (7 countries), and Southeast Asia (3 countries).

We use these data to create an individual-level dataset (summarized in Table 1) that includes measures of age, sex, educational attainment, and province and year of birth. We restrict the analytic sample to women aged 40 to 49 years at enumeration. Some women may have been observed in the few consecutive censuses that took place within ten years of each other. For example, censuses in Ecuador were conducted in 2001 and 2010. A woman born in 1961 would have been age 40 in the 2001 census, age 49 in the 2010 census, and therefore observed twice in our dataset in the absence of mortality and international migration. We drop any such second occurrence of such a birth cohort as to avoid repeated observations in the data. We also drop observations which had random missing values for our dependent variable (children ever born), and our controls (education, age, and marital status). After these restrictions, the total sample size is 7,435,468.

Temperature and precipitation data for the study come from the Climatic Research Unit Time Series (CRU TS) (Harris et al., 2020). CRU TS provides monthly gridded estimates of mean temperature and total precipitation from 1900 to present at 0.5° resolution. The dataset is created by interpolating weather station data from over 4,000 locations throughout the world. We extract time-varying rainfall and temperature data for the period 1949 to 2012 as province-level spatial means using time-stable geographic boundaries created by IPUMS-I. We use these data to construct measures of childhood climate exposures as described below.

Empirical Strategy

The analyses center on a series of linear regression models, in which the number of children ever born to woman *i* at the time of the census is a function of temperature and precipitation anomalies over three five-year periods from age –1 to 4 5 to 9, and 10 to 14 years, net of controls, province fixed-effects, and a linear time trend (operationalized as a numerical birth year variable). Anomalies, which can be interpreted as z-scores, capture the extent to which temperature and precipitation deviated from the local (province-level) historical mean during the exposure period. This value is standardized over the standard deviation of all similar 5-year periods in the local climate history, providing a locally meaningful measure of climate extremes (or lack thereof). We create categories of the temperature and precipitation anomalies, respectively, for the ease of interpretation wherein each category reflects whether the anomaly is close to the mean, below the mean (colder/drier), or above the mean (hotter/wetter). Models also control for women's age, educational attainment, and marital status, as well as the total fertility rate (TFR) of each woman's country at age 14. Province fixed effects capture all time-invariant differences across provinces and the linear time trend captures all changes that were common across the sample (e.g., common warming, declining fertility) so long as they occurred monotonically over time. All models apply sampling weights and adjust standard errors for clustering at the province level, where the focal exposure terms are measured.

Results

Overall Estimates

In Model 1, we measure the effects of temperature and precipitation variability on the completed fertility of women aged 40-49 years, with exposures measured from the prenatal period to 4 years after birth, ages 5-9, and ages 10-14. According to point estimates from this full model, exposure to below mean temperature, during ages prenatal to 4 years old, is associated with a 0.029-child decrease in the number of children ever born compared to exposures close to the mean, (Table 3). Above mean exposure of temperature is also negatively associated, though with a larger effect size, with a 0.067 decrease in the number of children ever born. While these effect sizes are modest, they represent a sample of over 7.4 million women. Thus, a 0.029 decrease in children ever born translates into nearly 220,000 children. These negative effects are even stronger with temperature exposures between the ages of 5 to 9 years (below the mean: -0.032, above the mean: -0.083), though the strength and direction of association is varied for the oldest age of exposure in our analysis (ages 10 to 14), with above the mean exposure to temperature anomalies leading to a positive effect (0.065).

Early-life precipitation is also significantly & negatively associated with later-life fertility, with point estimates suggesting a 0.013 reduction in number of children ever born with exposures of rainfall below the mean, and -0.011 with exposures above the mean. Effects at older ages remain negative and small when compared to the effects of temperature exposures.

Stratified Models

Next, we stratify our results by place in the demographic transition for each of the countries in our sample. We create three categories of the TFR distribution for the year the women in the sample were at age 14 in each country and census year: TFR <=25th percentile, TFR >25th & <=75th percentile, and finally, TFR>75th percentile. Table 2 provides a snapshot of the breakdown of regions and TFRs, and as expected, the lowest TFRs are concentrated in Latin America and Southeast Asia, and highest TFRs are concentrated in Sub-Saharan Africa. In the birthplaces with lowest TFRs, we find overall consistency in our regression results with the main model, with a negative association of temperature and rainfall exposures on number of children ever born (Table 4). However, as observed in the main model (Table 3), above mean temperature exposures are positively associated with number of children ever born at later ages (0.069; 0.045). In contrast to the main model, early life exposures of below mean rainfall were positively associated with the number of children ever born, though effect sizes are small (0.015; 0.011), while the effects of above mean rainfall exposure during prenatal to 4 years are substantively strong and negative, with a point estimate of -0.101.

When compared with the countries with lowest TFRs in the sample, effects of rainfall exposures in the highest TFR countries are comparatively stronger. The results show a positive association of above mean rainfall exposures in early life with lifetime fertility in these countries (0.043), and this association is also reflected in the exposure age group 5 to 9 years (0.101). Below mean rainfall exposures have non-significant effects in early life, but are very strong and significant in later life, with a 0.184 reduction in the number of children ever born when exposed at ages 5-9 years.

Temperature exposures in high TFR countries are less strong, though when compared to mid TFR countries, below the mean temperature exposures are similar in strength and direction with a positive association with lifetime fertility. The strongest effects observed in the mid-TFR countries is for above the mean exposure of temperature in later life (ages 10-14), with a positive point estimate of 0.197. We also observe negative effects of rainfall exposures in early life in mid-TFR countries, and positive association in the older ages of exposure.

Next, we run regression models stratified by region: Sub-Saharan Africa, Latin America, and Southeast Asia. As expected, the region models roughly corroborate with the TFR models (Table 5). We observe strong effects of below mean rainfall exposures (-0.146) in age group 5-9 years and for above mean rainfall exposures (0.077), suggesting drought conditions to be negatively associated with lifetime fertility, while higher rainfall than the mean in these countries where rainfall is typically low, to be positively associated with lifetime fertility. In contrast, results from Latin America suggest that higher than mean rainfall in the early age groups is strongly associated with negative effects on the number of children ever born (-0.169; -0.106), while below mean rainfall is associated with a positive effect for the same age groups (0.055; 0.066). Effects of temperature exposures above the mean are also negative and are strong and consistent in early life to ages 5-9 (-0.101; -0.107), though below the mean exposures are positively associated with number of children ever born during the prenatal to 4 years age group (0.057). In Southeast Asia, observed effects are significant and negative for early life exposures to below the mean heat and rainfall (-0.013, -0.15) and in ages 5-9 years (-0.046; -0.053).

The remaining two sets of models stratify birthplaces by historical temperature and historical rainfall. With these models, we aim to explore whether the effects of exposures differ if a birthplace is historically warm or rainy. For both sets of these models, we create categories based on the distribution of historical temperature and of rainfall of the birthplaces in the sample: <=25th percentile; >25th to <= 75th percentile, and finally, >75th percentile.

In the first set of these models, we observe the effects of exposures of anomalous temperature and rain in birthplaces stratified by historical temperature. In places with the lowest & highest historical temperature, we find strong positive effects of below the mean temperature exposures in the prenatal to 4 years age group. This effect is weaker for older age groups in historically low temperature birthplaces. In contrast to effects of temperature, below mean exposures of rainfall are associated with negative effects on lifetime fertility in birthplaces with the lowest and highest historical temperatures, across all age groups. Effects of above mean exposures are, in contrast, positive for historically low temperature places, and negative for mid- and high temperature places.

In the final set of models, we stratify birthplaces by historical rainfall. In birthplaces with lowest levels of historical rainfall (Table 7), we observe strong and positive effects on lifetime fertility of above mean exposures of temperature, across all ages (0.183; 0.153; 0.273). However, in birthplaces with the highest rainfall, above mean temperature exposures are associated with negative effects on the number of children ever born (-0.051; -0.129). While below mean exposures to heat are not substantively meaningful in birthplaces with low rainfall, the effects remain negative and significant in high rainfall birthplaces, suggesting that anomalous temperatures in high rainfall areas are associated with a negative effect on lifetime fertility.

In this set of models, the results for rainfall exposures follow a similar trend as temperature exposures. In birthplaces with low rainfall, rainfall exposures below the mean during prenatal to 4 years are associated with a 0.065 increase in number of children ever born, and this positive association is observed across all age groups. Similar to temperature exposures in birthplaces with high rainfall, we find that the effects of exposures to rainfall anomalies on the number of children ever born is negative, and is consistent across all age groups, suggesting rainfall anomalies in high rainfall places are negatively associated with lifetime fertility.

Discussion and Conclusion

This study examined the relationship between exposures to early-life temperature and precipitation anomalies and lifetime fertility among women ages 40-49 years across the global tropics. Overall, we find statistically significant, negative effects of temperatures during the prenatal year to age 4 on lifetime fertility. Precipitation exposures in early life are also negatively associated with lifetime fertility, although with limited strength in effect size. Importantly, our subsequent analyses also demonstrate meaningful variation in climate effects across world regions and by the reproductive context in which women grew up (as measured by the TFR of their country at age 14). For example, temperature effects were relatively strong and negative in Latin America, and less substantively meaningful in Southeast Asia.

These findings provide additional evidence that early-life environmental conditions can influence demographic and socioeconomic outcomes later in life (Randell & Gray, 2019; Thiede et al., 2022), and also contribute to the growing literature on climate change and reproductive outcomes (Grace, 2017; Thiede et al., 2022; Wilde et al., 2017). However, this study and its limitations also point to several important opportunities for future research. First and perhaps foremost, our use of census data provides exceptional spatial and temporal scope, which enhances generalizability and provides considerable spatial and temporal variation in environmental conditions to identify climate effects. However, these data are cross-sectional and provide only limited information about individuals' socioeconomic characteristics, which precludes the analysis of causal mechanisms, constrains our ability to measure climate vulnerability in a detailed manner, and keeps open the risk of omitted variable bias. We hope that future research will build on this study by using richer datasets, which are typically collected in a context-specific manner within individual countries or regions.

Second, our data provide information on birthplace and characteristics at the time of the census, but lack data on conditions and outcomes in the intervening years (including many critical parts of the life course). It is possible that such exposures—and their influence on lifetime fertility—is correlated and (or) conditioned by the early-life exposures that we focus on here. Understanding such cumulative effects over the lifecourse is an important topic for future research to address with longitudinal data.

Third and finally, we measure climate exposures at the province level as temperature and precipitation anomalies. These represent the most appropriate measures of exposure given the level at which birthplace is measured and since anomalies provide indicators of locally-meaningful departure from norms that are comparable across our large and ecologically diverse dataset. However, province sizes vary across our dataset, and in some cases are quite large, which can introduce measurement error. Anomalies may likewise not fully capture the effects of important absolute thresholds (e.g., when temperatures exceed 90º F). This limitation highlights the value of complementing this "big data" approach with context-specific studies that are better able to account for such location specific dynamics.

Despite these limitations, this analysis provides a useful empirical snapshot of the association between early-life environmental stressors and later-life fertility. Given the demographic and socioeconomic importance of fertility, we hope that additional research on this area will build on our findings.

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Tables

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Children Ever Born	3.624	2.636	0	20
Temperature Range (z)				
-1 to 4				
Close to the mean	.649	.477	0	1
Below the mean	.339	.473	0	1
Above the mean	.013	.113	0	1
5 to 9 years				
Close to the mean	.543	.498	0	1
Below the mean	.446	.497	0	1
Above the mean	.011	.106	0	1
10 to 14 years				
Close to the mean	.582	.493	0	1
Below the mean	.41	.492	0	1
Above the mean	.008	.087	0	1
Rain Range (z)				
-1 to 4				
Close to the mean	.587	.492	0	1
Below the mean	.256	.436	0	1
Above the mean	.157	.364	0	1
5 to 9 years				
Close to the mean	.657	.475	0	1
Below the mean	.19	.392	0	1
Above the mean	.153	.36	0	1
10 to 14 years				
Close to the mean	.676	.468	0	1
Below the mean	.161	.368	0	1
Above the mean	.162	.369	0	1
Historical Temperature	24.08	3.348	4.592	29.899
Historical Rain	1730.086	743.361	28.385	5263.57
Historical Temperature Range				
Low (=<21.57° C)	.147	.354	0	
Mid (>21.57° C & <=27.12 ° C)	.796	.403	0	1
High (° C >27.12)	.058	.233	0	1
Historical Rain Range				
Low (=<799.12 mm)	.086	.281	0	1
Mid (>799.12 mm & <=1649.007 mm)	.475	.499	0	1
High (>1649.007 mm)	.439	.496	0	1
Total Fertility Rate (TFR)	5.126	1.03	2.716	8.056
TFR Range (percentiles)				
Low (<=5.44)	.666	.472	0	1
Mid (5.44> & <=6.71)	.218	.413	0	1
High TFR (>6.71)	.116	.321	0	1

Region				
Sub-Saharan Africa	.151	.358	0	1
Latin America & Caribbean	.49	.5	0	1
Southeast Asia	.36	.48	0	1
Age	43.843	2.882	40	49
Education				
Less than primary	.425	.494	0	1
Primary	.356	.479	0	1
Secondary plus	.219	.414	0	1
Marital Status				
Single/never married	.059	.236	0	1
Married/in union	.785	.411	0	1
Separated/divorced/absent	.097	.296	0	1
Widowed	.059	.236	0	1

Table 2: Share of sample by TFR and by region

	Low TFR ≤ 5.44	Mid 5.44< TFR ≤ 6.71	High TFR>6.71
Sub-Saharan Africa	0.02%	18.15%	95.43%
Latin America	58.49%	43.48%	4.57%
Southeast Asia	41.49%	38.37%	-

Table 3: Regression Model

	(1) Main Model	
	β	SE
Temperature Exposures (z) by Age		
-1 to 4 years		
Below the mean	-0.029***	0.003
Above the mean	-0.067***	0.012
5 to 9 years	0.000	
Below the mean	-0.032***	0.002
Above the mean	-0.083***	0.010
10 to 14 years	0.000	
Below the mean	-0.023***	0.002
Above the mean	0.065***	0.012
Rainfall Exposures (z) by Age		
Prenatal to 4 years		
Below the mean	-0.013***	0.003
Above the mean	-0.011**	0.004
5 to 9 years	0.000	
Below the mean	0.005	0.003
Above the mean	-0.014**	0.004
10 to 14 years	0.000	
Below the mean	-0.022***	0.003
Above the mean	-0.007*	0.003
TFR	-0.055***	0.004
Individual Controls	Yes	
Province Fixed Effects	Yes	
R-squared	0.316	
Sample Size	7,435,468	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Regression models stratified by stage of demographic transition

	(1)		(2)		(3)	
	TFR<=5.44		5.44 >TFR <=6.71		TFR>=6.71	
	β	SE	β	SE	β	SE
Temperature Exposures (z) By Age						
-1 to 4 Years						
Below mean	-0.019***	0.003	0.015	0.008	-0.029**	0.009
Above mean	-0.076***	0.012	-0.092**	0.033	-	
5 to 9 Years						
Below the mean	-0.026***	0.002	0.050***	0.008	0.047***	0.011
Above the mean	0.069**	0.026	0.182***	0.018	-0.099	0.858
10-14 Years						
Below the mean	-0.024***	0.002	0.025*	0.010	-0.012	0.010
Above the mean	0.045**	0.015	0.197***	0.022	-0.010	0.099
Rainfall Exposures (z) By Age						
-1 to 4 Years						
Below the mean	0.015***	0.002	-0.056**	0.021	0.036	0.028
Above the mean	-0.101***	0.005	-0.025*	0.011	0.043***	0.009
5 to 9 Years			0.000		0.000	
Below the mean	0.011***	0.003	0.024**	0.009	-0.184***	0.017
Above the mean	-0.076***	0.004	0.007	0.014	0.101***	0.010
10-14 Years						
Below the mean	-0.042***	0.003	0.050***	0.009	-0.071***	0.018
Above the mean	-0.014***	0.003	0.049***	0.012	-0.010	0.011
Country TFR (at age 14)	0.036**	0.012	-0.160***	0.016	-0.148***	0.028
Individual Controls			Yes			
Province Fixed Effects			Yes			
R^2	0.217		0.225		0.142	
Sample Size	4,952,104		1,617,887		865,477	

Table 5: Regression models stratified by world region

	(1)		(2)		(3)	
	Sub-Saharan Africa		Latin America		Southeast Asia	
	β	SE	β	SE	β	SE
Temperature Exposures (z) By Age						
-1 to 4 Years						
Below mean	-0.031***	0.008	0.057***	0.003	-0.013**	0.005
Above mean			-0.101***	0.011	-0.079	0.072
5 to 9 Years						
Below the mean	0.001	0.007	-0.037***	0.003	-0.046***	0.005
Above the mean	0.028	0.555	-0.107***	0.011		
10 to 14 Years					0.000	
Below the mean	-0.031***	0.008	-0.068***	0.003	-0.006	0.007
Above the mean			0.052***	0.012		
Rainfall Exposures (z) By Age						
-1 to 4 Years						
Below the mean	0.020	0.019	0.055***	0.003	-0.015**	0.005
Above the mean	0.001	0.007	-0.169***	0.005	0.001	0.007
5 to 9 Years			0.000			
Below the mean	-0.146***	0.014	0.066***	0.003	-0.053***	0.005
Above the mean	0.077***	0.008	-0.160***	0.004	-0.003	0.009
10 to 14 Years						
Below the mean	-0.038**	0.012	-0.048***	0.003	-0.014	0.007
Above the mean	-0.001	0.009	-0.039***	0.004	0.013*	0.006
Country TFR (at age 14)	0.222***	0.018	0.090***	0.010	-0.054***	0.007
Individual Controls			Yes			
Province Fixed Effects			Yes			
R^2	0.144		0.287		0.196	
Sample Size	1,120,501		3,639,760		2,675,207	

Table 6: Regression models stratified by historical temperature

	(1) Low Historical Temperature		(2) Mid Historical Temperature		(3) High Historical Temperature	
	β	SE	β	SE	β	SE
Temperature Exposures (z) by Age						
-1 to 4 Years						
Below mean	0.100***	0.006	-0.061***	0.003	0.060***	0.012
Above mean	-0.025	0.018	-0.087***	0.016		
5 to 9 Years						
Below the mean	0.051***	0.006	-0.060***	0.003	0.002	0.012
Above the mean	0.084***	0.016	-0.104***	0.015		
10-14 Years						
Below the mean	-0.012	0.006	-0.038***	0.003	0.061***	0.010
Above the mean	0.165***	0.019	-0.013	0.016		
Rainfall Exposures (z) by Age						
-1 to 4 Years						
Below the mean	-0.006	0.006	0.006*	0.003	-0.152***	0.018
Above the mean	0.041***	0.010	-0.044***	0.005	0.001	0.013
5 to 9 Years						
Below the mean	-0.061***	0.007	0.030***	0.003	-0.075***	0.017
Above the mean	0.080***	0.009	-0.040***	0.005	-0.077***	0.012
10-14 Years						
Below the mean	-0.071***	0.007	-0.004	0.004	-0.005	0.016
Above the mean	0.028**	0.009	-0.009**	0.003	-0.064***	0.013
Birth Year	-0.053***	0.002	-0.070***	0.001	-0.080***	0.002
Country TFR (at age 14)	-0.047**	0.015	-0.085***	0.008	0.018**	0.007
Individual Controls			Yes			
Province Fixed Effects			Yes			
R-squared	0.409		0.289		0.367	
Sample Size	1,090,376		5,915,975		429,117	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Regression models stratified by historical rain

	(1) Low Historical Rainfall		(2) Mid Historical Rainfall		(3) High Historical Rainfall	
	β	SE	B	SE	β	SE
Temperature Exposures (z) By Age						
-1 to 4 Years						
Below mean	0.008	0.010	0.010**	0.004	-0.025***	0.004
Above mean	0.183***	0.033	-0.103***	0.018	-0.051**	0.017
5 to 9 Years						
Below the mean	0.003	0.009	-0.019***	0.003	-0.019***	0.004
Above the mean	0.153***	0.026	-0.037*	0.017	-0.129***	0.016
10 to 14 Years						
Below the mean	-0.002	0.009	-0.037***	0.003	-0.016***	0.005
Above the mean	0.273***	0.026	0.017	0.014	-0.007	0.043
Rainfall Exposures (z) By Age						
-1 to 4 Years						
Below the mean	0.065***	0.012	0.033***	0.004	-0.028***	0.004
Above the mean	0.024*	0.012	-0.030***	0.005	-0.015*	0.007
5 to 9 Years						
Below the mean	0.027*	0.012	0.029***	0.004	-0.042***	0.005
Above the mean	0.012	0.010	-0.029***	0.005	-0.018*	0.009
10 to 14 Years						
Below the mean	0.025*	0.012	-0.057***	0.004	-0.005	0.006
Above the mean	-0.021*	0.011	0.007	0.004	-0.023***	0.005
Country TFR (at age 14)	0.128***	0.016	-0.072***	0.006	-0.086***	0.009
Individual Controls			Yes			
Province Fixed Effects			Yes			
R-squared	0.340		0.373		0.191	
Sample Size	640,495		3,532,224		3,262,749	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix

Table A1: Share of sample by region and country

Sub-Saharan Africa	14.9%	Latin America	48%	Southeast Asia	36.3%
Botswana	0.2	Bolivia	0.6	Cambodia	1.6
Burkina Faso	1.1	Brazil	34.3	Indonesia	34.1
Ghana	2.5	Colombia	3.9	Thailand	0.6
Kenya	2.4	Costa Rica	0.6		
Mali	1.0	Dominican Republic	1.1		
Mozambique	1.5	Ecuador	1.9		
Tanzania	4.2	El Salvador	0.5		
Uganda	1.1	Jamaica	0.2		
Zambia	0.9	Nicaragua	0.5		
		Panama	0.4		
		Paraguay	0.4		
		Peru	2.6		
		Trinidad and Tobago	0.1		
		Venezuela	0.9		