The Impact of In-Utero Flood Shocks on Education Achievement: Evidence From El Niño in Peru*

Muchin Bazan†

Virginia Tech

For latest version, click here

Abstract

This paper investigates the long-term effects of in-utero exposure to floods. Using data from the Peruvian National Household Survey (ENAHO) over the period 2001-2017, I examine the completion of primary and secondary education for individuals born between 1975 and 1983 following the exposure to floods during the 1982-1983 El Niño in Peru. The findings indicate that the probability of completing primary education during adulthood decreases by 1.5 percentage points after in-utero exposure to the 1982-1983 floods. The effects are statistically significant only for individuals in urban dwellings and they are robust to the inclusion of covariates. Individuals, who experienced prenatal exposure to floods, are more likely to suffer a chronic disease later in life. In contrast, the estimates on income variables are statistically insignificant. In addition, this study demonstrates that boy fetuses are disadvantaged when affected in-utero compared to girls fetuses, and that family characteristics such as parental education play an important role in the education achievement of daughters and sons. In a context where the occurrence of El Niño events is more frequent due to climate change, most vulnerable groups need the help of the government to better prepare for extreme weather conditions.

Keywords: Rainfall Shocks, Health, Education Completion, Development Countries.

JEL classification codes: I10, I15, I21, I25, O10.

*I would like to thank seminar participants at Virginia Tech and SEA 91th Annual Meeting. I also thank Sudipta Sarangi, Jorge Agüero, Suqin Ge, Marcos Agurto, Wei Zhang and Subha Mani for their support and valuable comments to improve this paper.

†Corresponding author. The Department of Economics, Virginia Tech. 3016 Pamplin Hall, 880 West Campus Drive, Blacksburg, VA 24061, United States. Email: muchin90@vt.edu. Phone number: (+1)-540-988-3779.

1 Introduction

As individuals are exposed to weather shocks they are subject to risks and negative consequences on individuals' well-being. In addition to contemporaneous effects, the effects of certain types of shocks may still be present many years or even decades later. Previous studies have examined the effect of early-life exposure to extreme weather conditions on individuals' long-term educational and health outcomes. However, certain types of weather phenomena may be predictable or recurrent and to the best of my knowledge, no studies have examined the predictability of the shocks and how this can impact individuals' outcomes differently. I expect that if the shock is anticipated then it is possible to prepare for it and to take further mitigating steps.

In the particular context of "El Niño"[1], which is a climate pattern that describes the unusual warming of surface waters in the eastern tropical Pacific Ocean, its impact on education and health outcomes has been examined before. However, there are no studies that compare "El Niño" shocks that happen in different periods of time and how their predictability has affected the consequences. Not all the shocks are the same in terms of anticipation and intensity, and the capability to predict the occurrence of climate events due to the development of new technology and daily climatology reports mitigates the adverse consequences of early-life exposure and in-utero exposure to shocks. This paper contributes to the literature as it investigates the persistent effects of an in-utero exposure to severe floods during the 1982-1983 El Niño event in Peru on human capital formation, and it contrasts the effects of the 1982-1983 El Niño event with the effects of similar El Niño shocks that happened in Peru with different anticipation and intensity. I exploit two sources of variation: i) cohort variation, ii) geographic variation in the exposure to severe floods that occurred in Peru during 1982-1983. This setting introduces an exogenous exposure to a negative environment while in-utero to measure its causal effects on long-term outcomes.

In recent decades, scientists have come to appreciate how significantly El Niño Southern Oscillation (ENSO) impacts can vary from event to event and this variation across events makes it difficult to understand how climate change will influence future ENSO events. According to NOAA, "Extreme El Niño and La Niña events may increase in frequency from about one every 20 years to one every 10 years by the end of the 21st century under aggressive greenhouse gas emission scenarios, and the strongest events may also become even stronger than they are today."[2] Given the increase in the frequency of occurrence of El Niño due to climate change, the development of tools to forecast El Niño can help mitigate its adverse effects.

The effects of in-utero exposure to events on short-term and long-term outcomes have been

[1] El Niño means "The Little Boy" and it refers to the period of the warming of the sea's surface temperature during the summer months in the southern hemisphere. Source: https://oceanservice.noaa.gov/facts/ninonina.html.

[2] For details please see: https://research.noaa.gov/article/ArtMID/587/ArticleID/2685/New-research-volume-explores-future-of-ENSO-under-influence-of-climate-change

documented in several studies.[3] Most of these studies support the "fetal origins" hypothesis. According to the "fetal origins" hypothesis, and its proponent, David Barker, the nine months in utero is one of the most critical periods in a person's life because cognitive abilities and health paths at adulthood strongly depend on the intrauterine environment [Barker (1995), Almond & Currie (2011)]. Adverse shocks that affect a fetus' health may lead to worse health in the future, worse education outcomes such as less cognitive achievement, education attainment, human capital accumulation, and lower productivity.[4] For instance, Almond et al. (2007) study the negative effects of in-utero exposure to the 1959-1961 China Famine on human capital formation. Almond (2006) collects data from the 1918 Influenza Pandemic in the U.S. and analyzes outcomes later in life. In Almond's study cohorts affected by the pandemic while in-utero had on average less education, lower earnings, and more physical disabilities than adjacent cohorts unaffected by the pandemic. Scholte et al. (2015) find a significant adverse effect of exposure during the first trimester of gestation to the 1944-1945 Dutch Hunger Winter on employment outcomes using administrative data from the Dutch population. Similarly, Banerjee et al. (2010) use regional variation in the timing of exposure to the phylloxera event (1863-1890) to explore long-term impacts on health, life expectation, and adult height. More recently, Oliveira et al. (2021) study the impacts of in-utero exposure to Hurricane Catarina on infant health outcomes, birth weight, and post-neonatal mortality. Even if all the studies mentioned above show that shocks experienced while in-utero affect individuals' outcomes, these studies have not investigated heterogeneous effects by the predictability of the shocks.

Another branch of literature explores the relationship between changes in weather conditions (i.e. temperature, precipitation) that affect the development of humans while in-utero and their long-term outcomes.[5] For example, Leight et al. (2015) assess the impact of rainfall shocks observed in-utero and during the first two years of life using longitudinal data from rural China. The results show that shocks in-utero and during the first year of life are important and have negative consequences on cognitive skills without any impact on the formation of non-cognitive skills.[6] Maccini & Yang (2009) investigate the effect of early life shocks, in particular weather shocks on the well-being of individuals, adult health, education attainment, and socio-economic outcomes. The authors found no effect of exposure to extreme rainfall prior to the date of birth, but they found that exposure to shocks during the early infancy (first year of life) has the most important influence on future outcomes

[3] See for instance Almond (2006), Black et al. (2007), Elaine (2009), Almond & Currie (2011), Almond et al. (2015), Hoynes et al. (2016) Rosales-Rueda (2018).

[4] A growing body of literature supports the negative short-run and long-run impact of shocks experienced early in life or in-utero. See for instance Galdo (2013), Koppensteiner & Manacorda (2016), Persson & Rossin-Slater (2018), Quintana-Domeque & Ródenas-Serrano (2017), Rosales-Rueda & Triyana (2019), Torche & Villarreal (2014), Valente (2015), Torche (2011), Lee (2014), Bongkyun et al. (2017), Karbownik & Wray (2019), Currie & Rossin-Slater (2013), Carrillo et al. (2020), Carlson (2018), Carlson (2015), Camacho (2008).

[5] See for instance Agüero (2014), Andalón et al. (2016), Brando & Santos (2015), Groppo & Kraehnert (2016), Rabassa et al. (2014), Rocha & Soares (2015).

[6] A more recent study, Kumar et al. (2016) find evidence that in-utero exposure to drought is associated with lower weight-for-age z scores and the probability of malnutrition in rural India. Chang et al. (2022) using longitudinal data from Young Lives in India find negative effects of in-utero exposure to rainfall shocks on cognitive and non-cognitive skills.

for women but not for men. Women exposed to weather shocks during childhood attain greater height, were more likely to complete grades of schooling, and they live in wealthy households measured by the asset index. In contrast, men were not affected by early life shocks. The authors suggest that rainfall exposure determines nutrition in infancy variation through intermediate channels such as crop production, household income, and food availability. Another study, Shah & Steinberg (2017), finds that positive rainfall shocks increase the opportunity cost of child labor, and lead to a switch out of school into productive work. Overall, the effects of exposure to extreme weather conditions on education and health outcomes vary across events and depend on the context.

Among the studies looking specifically at "El Niño", Aguilar & Vicarelli (2018) investigate the exogenous exposure to weather variations due to the 1997-1998 "El Niño Southern Oscillation (ENSO)" during early childhood on children's physical condition, children's behavior, and cognitive skills in Mexico. On average, children who were affected by the shock have lower weight and height, and a decrease in cognitive skills (i.e. language development, working memory, visual-spatial thinking) compared to their peers who were not exposed to the shocks. The authors attributed the effects to a decline in household income and a substitution of food intake. Another recent study that uses data from Ecuador and exposure to the 1997-1998 "El Niño" is Rosales-Rueda (2018), which finds that the event had negative and significant impacts on individuals' middle-term outcomes like vocabulary test scores and height. My study adds to the previous literature by contrasting different El Niño events (1982-1983 and 1997-1998) based on predictability and exploring the effect of in-utero and early in life exposure to these events on individuals' long-term outcomes.

Climate change has affected regions located along the coasts of northern Peru and Ecuador by increasing the frequency of extreme El Niño events, leading to intensifying floods. There have been three extreme "El Niños"- 1982, 1997, and 2015, when temperatures have surpassed historical records and intense rainfall shocks were observed. During "El Niños" of 1982 and 1997, the Peruvian territory was affected by intense floods and high temperatures along the coast. The events lead to a deterioration of the infrastructure, disruption of access to public services, negative effects on agriculture, and industrial production [Bayer et al. (2014)].[7] Despite the similarities between 1982 and 1997 "El Niño", Fedorov et al. (2003), Glantz (2001*b*), and Glantz (2001*a*) have shown that the 1982 "El Niño" was less predictable than the 1997 "El Niño" and it brought higher deaths and economic losses.[8]

I examine the impact of in-utero exposure to a less predictable and more intense the 1982-1983 "El Niño" on educational achievement 17 years later. In Peru, returns to education are high, and individuals with more years of education earn more on average. The return to tertiary education is approximately three times the return to secondary education, which

[7]See: https://www.focus-economics.com/blog/posts/peru-el-nino-still-on-economic-radar, https://blogs.worldbank.org/transport/what-el-ni-o-has-taught-us-about-infrastructure-resilience.

[8]See for instance CAF (2000), Rocha (2007).

is a clear sign of a severe problem in income distribution.[9] In addition, even though the proportion of individuals between 12-13 years old who have completed primary education has increased by 21% between 2001 and 2015, still the average years of education in Peru is ten years [Florian (2019)], which is equivalent to 10th Grade in the US, and less than high school completion.[10] Among the reasons why individuals do not complete school is the lack of cognitive skills and non-cognitive skills.

I combine the rainfall data from the University of Delaware's Terrestrial Precipitation project with Peruvian household survey datasets.[11] I exploit the timing of birth variation and the geographic variation in exposure to floods to identify causal effects on education outcomes. I restrict the sample to individuals born between 1975 and 1983 to alleviate the concern of time-varying unobservable confounders. In the empirical design, I compare the probability of completing primary (secondary) education for individuals exposed and not exposed to floods during the 1982-1983 El Niño event in a district (municipality). The availability of data also permits the analysis of different specifications controlling for socio-demographic characteristics, survey year, cohort of birth, and district fixed effects in the regressions.

The results show that individuals who are 16 years old or older at the time of the survey, and who were exposed to the floods during the 1982-1983 El Niño event are less likely to have completed primary education by 1.5 percentage points (significant at the 5%), exclusively for those individuals living in urban areas. To test the validity of my identification strategy, I control for several fixed effects and I perform falsification tests to rule out the presence of confounding factors.[12] On the other hand, my results suggest that in-utero exposure to the more predictable El Niño event of 1997-1998 did not affect education outcomes later in life. The cross-comparison between El Niño shocks demonstrates that people can prepare for anticipated shocks and thus mitigate their impacts. Overall, this study highlights the importance to increase the predictability of events such as El Niño, which might be happening more frequently due to climate change. National authorities should devote efforts to the development of sophisticated methods to improve weather forecasts.

The remainder of the paper is organized as follows. Section 2 outlines the empirical setting. Section 3 describes the data, and in section 4 the empirical strategy is introduced. In section 5 main results are presented. Section 6 discusses robustness checks and heterogeneous effects. Finally, section 7 concludes.

[9] The job opportunities of university graduates vary based on the region of residence of the graduates, the characteristics of the universities/colleges they graduated from, the economic sectors in which they work and the career they studied. College graduates, who are 21-35 years old and compared with young people of the same age group with technical studies only or without higher education completion, face low unemployment rates, low informal employment, and they receive better remuneration. College graduates are 31.4% less likely to be underemployed, 58.3% more likely to find a formal job, and earn 73.7% more than their peers without higher education. Source: SUNEDU (2020), https://cdn.www.gob.pe/uploads/document/file/1230044/Informe%20Bienal.pdf

[10] The calculations use the sample of individuals who are 25 years or older.

[11] The datasets used in this study are public available and can be downloaded from the Peruvian National Institute of Statistics (INEI) website. The main dataset is the Peruvian National Household Survey (ENAHO).

[12] Through a balance test, I show that socio-demographic characteristics of family members and individual characteristics do not drive the results.

2 Empirical Setting

2.1 El Niño Phenomenon

Understanding the long-term effects of weather shocks on human capital accumulation, and the mechanisms that drive them is key in the context of climate change. My study evaluates the effect of El Niño shocks on primary education completion as the main outcome in Peru. During an El Niño event, the surface waters in the Pacific Ocean become significantly warmer than usual. That change is tied to the atmosphere and to the winds blowing over the Pacific. Easterly trade winds blowing from the Americas to Asia falter and turn around westerlies (in the opposite direction). Because of that, a great quantity of warm water comes to the Americas. Moreover, it produces reversing ocean currents along the equator and along the west coast of South and Central America.

El Niño events occur roughly every two to seven years and it alternates with its sibling La Niña. La Niña is a cooling pattern in the eastern Pacific. In order to determine when we have El Niño, sea surface temperatures are measured from time to time from space by satellite radiometers, which can detect the electromagnetic energy, light and heat emitted by objects and surfaces on Earth. The National Oceanic and Atmospheric Administration (NOAA) records of the sea temperature are used by the climatologists at NOAA to examine the occurrence of El Niño. An El Niño is declared when the average temperature in the east-central tropical Pacific stays more than 0.5 degrees Celsius above the long-term average for five consecutive months. In addition, the Southern Oscillation Index can be used to detect El Niño events by observing the atmospheric pressure pattern. According to this index, which computes the difference of monthly pressure release between Tahiti (French Polynesia) and Darwin (Australia), El Niño event happens when the actual Southern Oscillation Index value differs greatly from its average historical value.

El Niño has both positive and negative consequences. Among the negative impacts of El Niño, the Peruvian Ministry of Environment mentions the loss of agricultural land, destruction of infrastructure (i.e. machines, bridges, roads, schools, hospitals), telecommunication networks, deaths or migration of flora and fauna (animals and plants), and the increase of diseases such as the Cholera and Malaria [MINAM & SENHAMI (2014)].[13] On the other hand, El Niño also has positive effects such as better conditions for rice cultivation on the Coast, regeneration of dry forest due to high intake of rainfall, an increase of green areas, the appearance of temporary grasslands in the Northern Coast of Peru which benefits farming, and it also regulates low-temperatures in the highlands by increasing them [Corcuera-García (2016)].

The 1982-1983 El Niño was very intense and it produced losses of approximately one billion

[13] Near 2600 kilometers of roads were destroyed during the flood disaster of 1982-1983. Also, 47 bridges collapsed, this affected public and private transportation of people as well as the transportation of food for internal consumption. 8500 people died in accidents or for diseases and 260 health centers had difficulties in daily operations or service provision. See: http://www.indeci.gob.pe/compend_estad/1997/6.2_fenom.pdf.

dollars (USD).[14] In Northern Peru, it rained from December 1982 to June 1983. As a consequence, the volume of water in the main rivers of the Coast increased leading to floods and the formation of numerous streams. The climate change due to the 1982-1983 El Niño also produced droughts in the south and in the Peruvian highlands, affecting severely all socio-economic activities in Peru. The affected population was 6 million, which represents about a third of the national population in 1983. The economic impact of this disaster was reflected in the significant decrease in the country's Gross Domestic Product, which decreased by 12%. In addition, 15 regions were affected: Tumbes, Piura, Lambayeque, La Libertad, Lima, Cajamarca, Junin, Ayacucho, Huancavelica, Apurimac, Cusco, Arequipa, Puno, Moquegua, and Tacna.

The 1997-1998 El Niño episode (November 1997- May 1998) marked the first time that Peruvian scientists predicted the severe El Niño episode six months before heavy rains began [Bayer et al. (2014), Glantz (2001*b*)]. The Peruvian government implemented a prevention plan that centered on the preservation of infrastructure (i.e. schools, churches, hospitals) by the provision of proper drainage for the excess rainwater [Glantz (2001*b*)]. The Peruvian National Meteorology and Hydrology Office (SENHAMI) detected an increase in the sea temperature on the Coast in 1996, and these levels turned out to be sufficiently high enough by May 1997, the moment that a contingency plan was implemented by the Peruvian government.

At the end of November 1997, an extreme El Niño took place. The National Institute of Civil Defense reported that the first damages occurred on the 6th of December in Tumbes and Piura region, in Northern Peru; after that El Niño continued to spread to the other regions of the country. The highest impact of the 1997-1998 El Niño was in the agricultural sector. For example, high temperatures affected crop production and led to the appearance of insect pests. In addition, the mortality rates of the animals rose, which are the main resource in the diet of families in rural areas.[15] The high intake of rainfall between November 1997 and April 1998 affected households. Houses near the rivers were destroyed by the floods. In rural areas, many houses made with precarious materials (i.e adobe and concrete) collapsed. The houses in the southern areas, although were not affected by torrential rains, suffered extensive damage due to avalanches of mud. Because of its predictability, the 1997-1998 El Niño's effect on individuals' outcomes might be mitigated and very different from the 1982-1983 El Niño. The Development Bank of Latin America (CAF) and CEPAL have estimated that the total losses of the 1997-1998 El Niño are USD 3.5 billion and the regions more affected were Piura, La Libertad, Lambayeque, Tumbes, Ica, and Loreto.[16]

[14] Source: INDECI, Compendio Estadístico: https://portal.indeci.gob.pe/wp-content/uploads/2019/01/6.2_fenom.pdf.

[15] During the 1997-1998 El Niño, the health system collapsed because of the proliferation of acute diseases such as diarrhea and respiratory infections.

[16] The total losses of the 1997-1998 El Niño in 1983 dollars are USD 2.1 billion.

2.2 The Education System in Peru

In Peru, education is compulsory from the age of 5 to the age of 16, with the school year running from March to December, as Peru is located in the Southern Hemisphere. The school system consists of six years of primary education and five years of secondary education. According to INEI (2018), the matriculation rates in primary school are high, and in both rural and urban areas almost all boys and girls aged 6 to 11 years old are enrolled in primary education (92.1% in 2017 versus 93.9% in 2007), with no observed differences by gender in school attainment.[17] Despite high attendance rates, the level of education achieved by individuals is very low.[18] For instance, in Peru the average years of education for a person who is 25 years old or older are 10 years (equivalent to Grade 10 in the U.S.). The average years of education in rural and urban zones are 6.9 and 10.6, respectively, with a gap of 3.7. Moreover, gender differences in years of education completed are notable in the Peruvian context. While a woman of 25 years old or older has studied on average 9.7 years, a man of the same age has completed 10.2 years of education. Another determinant of education completion in Peru is race. Individuals who have Spanish as a mother tongue have 2.9 more years of education than individuals whose native language is not Spanish. Socio-economic inequality and poverty prevent individuals to complete more years of education. Individuals in the top 20 percentile of the income distribution study 12.4 years on average. In contrast, individuals in the bottom 20 percentile have on average only 6.8 years of education.

The maximum level of education completed varies by location and gender. People of 25 years or older in urban areas have a higher level of education than similar people in age but living in rural zones. For instance, more than half of rural residents have at most completed primary education (52.1%). 27.9% of people in rural areas have completed secondary education and 13.1% have at most some years in kindergarten. On the other hand, a higher proportion of individuals living in urban areas report having completed secondary education (41.2%). Individuals in urban areas are also more likely to enroll in Higher Education than people in rural zones.[19] There are gender disparities in total years of education: more men have achieved secondary and Higher Education. According to the descriptive statistics from the Peruvian National Household Survey, 23.7% of men and 28.3% of women have primary education as the maximum level of education achieved. 42.9% of men and 34.4% of women have at most secondary education. 17.9% of men and 14.5% of women pursue college studies.

[17] In 2017, 92 out of 100 boys; and 91 out of 100 girls attended primary education.

[18] Despite advances in education enrollment and school attendance, in Peru still exists a great portion of individuals who have not completed enough years of education. In 2017, 5.2% of people who are 25 years old or older have not attended primary school (only kindergarten), 26% have attended primary school only but not secondary school, 38.6% have completed primary and attended high school but not enrolled in Higher Education. Finally, 30.1% of individuals aged 25 or older have pursued studies at university or technical studies.

[19] In urban and rural zones, 16.2% and 4.4% of individuals mention accomplishing Higher Education studies at a non-college/university institution. Similarly, 19.6% of people in urban zones and 2.5% of individuals in rural areas have enrolled in college or university.

3 Data

The main data for this study comes from the Center for Climatic Research, University of Delaware (UDel).[20] and the Peruvian National Household Survey (ENAHO) administered annually by the Peruvian National Institute of Statistics (INEI). I combine these two datasets to assess the effect of different El Niño events on educational outcomes.

The 1982-1983 El Niño had a huge impact on the North Coast of Peru with activity peaks between December 1982 to June 1983. I use the geographic and timing exposure to the 1982-1983 El Niño to assess the effect of in-utero exposure to weather shocks on the probability of school completion. In order to identify the exposure to floods in-utero, I match latitude and longitude coordinates of the individual's place of birth to the nearest point for which I have rainfall data.[21]

Using monthly precipitation data, I measure excess rainfall for each month during the shock (m) and closest Peruvian district[22] point (d) as the deviation of the observed precipitation in that month from the long-term mean (1970-2001) divided by the historical monthly standard deviation following Rosales-Rueda (2018).[23]

$$excess\_rainfall_{myd} = \frac{P_{myd} - \bar{P}_{md}}{\sigma_{md}} \tag{1}$$

Where P_{myd} is the precipitation for a given month (m) in the year (y) at the closest grid point from the center of the district where the individual was born (d). $\bar{P}_{md}$ is the long-term mean (1970-2001) for month (m) at location (d), and σ_{md} is the historical standard deviation.

At the district of birth, I calculate exposure to the 1982-1983 El Niño as the number of months (between December 1982 and June 1983) when the excess of rainfall was equal to or greater than one historical standard deviation.

$$nino\_shock_d = \sum_{m=dec82}^{Jun83} \mathbb{1}[excess\_rainfall_{dm} \geq 1] \tag{2}$$

Figure 1 shows the intensity of the 1982-1983 El Niño and the 1997-1998 El Niño by district

[20] UDel's dataset provides geo-referenced information on global monthly terrestrial precipitation (in mm) over the period 1900-2017 for each node at a spatial resolution of 0.5 × 0.5 degrees.

[21] Precise coordinates of the district where the individual was born are not available, however, I use coordinates of the center of each of the districts where the individual was born.

[22] The Peruvian territory is divided into three administrative units: i) regions, ii) provinces, and districts (municipalities). Regions and districts are the largest and smallest administrative units in Peru, respectively. There are in total 1874 districts across the Peruvian territory.

[23] There is no consensus in the literature on how long the historical rainfall series should be to identify extreme monthly rainfall.

in Peru. Notice that the intensity of the floods during this time is heterogeneous among districts. For instance, districts more affected by the 1982-1983 shock are located in the north coastal region, while those located in the jungle and the south were less affected. Figure 2 depicts the precipitation in millimeters (mm) observed during the period 1970-2017 for the whole country and for Piura (one region more affected by El Niño shock); while Figure 3 describes the evolution of precipitation for Lambayeque and Tumbes, other regions heavily impacted by the shock.

In order to measure the effect of in-utero and early-life exposure to severe floods on educational outcomes, I use data from repeated annual cross-sections of the Peruvian National Household Survey (ENAHO) administered annually by the Peruvian National Institute of Statistics (INEI). The survey uses a probabilistic sample procedure and it is representative at the national and regional levels when using the annual cross-section. Educational outcomes are recorded in the module-specific to Education. ENAHO provides information on all the household members and their last level of education achieved.[24] An advantage of using ENAHO is that it provides information on the individual's place of birth, the individual's place of residence at the time of the survey, and the individual's date of birth. Contrary to previous studies that use place of residence as a proxy for place of birth, I can control for place of birth time invariant characteristics that could potentially affect individuals' development and school achievement. Also, this information allows to explore location of birth and time of birth variations in exposure to El Niño floods while in-utero. The date of conception and the gestation period of each individual is defined using information about the date of birth and assuming 9 months as an approximation of a normal-term pregnancy. For my analysis, I use the annual surveys from 2001 to 2017.[25]

In order to examine the effect of the 1982-1983 El Niño on education completion rates, I constraint the data to individuals (daughters or sons of the head of the household),[26] who were born during the period 1975-1983, this allows me to compare cohorts of individuals born very close and experienced similar changes in macroeconomic conditions. I can also compare across siblings with this restriction. In this sample, some individuals will be exposed to the 1982-1983 El Niño while in-utero or during early life (0-2 years old); while other subjects will not be exposed to the event. The sample comprises information from 36 057 individuals in 1301 districts.

I also explore the effect of in-utero exposure to a more predictable El Niño on education

[24] I construct three indicators of education: primary education completion, secondary education completion, and total years of education. Primary education completion is a dummy variable which equals to one whenever the individual's highest level of education is at least primary school completion, and zero otherwise. A similar approach is used to construct the secondary education completion indicator.

[25] In a complementary study that uses the Peruvian Demographic Health Survey (DHS), I investigate potential mechanisms of individuals' low-education achievement following an in-utero exposure to El Niño floods. I find that children born around the time of the 1997-1998 El Niño, a shock more predictable compared to the 1982-1983 El Niño, had lower weight at birth. Because of the absence of historical records around the 1980s in the DHS, I cannot perform a similar approach for the 1982-1983 El Niño. Nevertheless, given its less predictability, I expect stronger effects of in-utero exposure to the 1982-1983 El Niño on health outcomes.

[26] The households selected were those with both the head and spouse/wife living together.

completion (the 1997-1998 El Niño). For this purpose, I constraint the sample to individuals (daughters or sons of the head of the household), who were born during the period 1990-1998. The sample comprises information from 58 391 individuals in 1424 districts.

A possible concern is that because the total districts of birth included in the subsamples are different, any difference in the consequences of in-utero exposure to more or less predictable floods might be attributed to districts that are non-common between subsamples. I verified that this is not the case by restricting the 1982-1983 and the 1997-1998 sub-samples to districts that overlap (1400 districts). My main results still hold and they are robust to the change in the sample.

Table 1 and Table 2 show descriptive statistics of individuals born between 1975 and 1983. On average, individuals have 12 years of education and 79% (95%) of them have completed high school (primary school). 47% of the sample are women and 13% reported to be married. 84% of the individuals in the sample are living in urban areas.[27] Moreover, individuals in the sample are on average 26 years old and 93% of them reported Spanish as a mother tongue. The average household's size is 7 members. 8% of individuals were exposed to floods that happened during 1982-1983 while in-utero, and the average length of exposure while in-utero was 2 months. Similarly, 18% of respondents experienced the event during early childhood (0-2 years old) with an average length of exposure of also 2 months. Table 2 shows differences in demographic characteristics by zone of residence (urban versus rural). Individuals in rural zones complete fewer years of education than their peers in urban zones. The average years of education in rural and urban zones in the sample is 9 and 12 years, respectively. While almost all individuals aged 17 years old or older, and who live in urban areas have completed primary education (97%), 81% of people similar in age in rural zones reported the same. Secondary completion rates are lower with 86% of individuals in urban areas and 45% of individuals in rural areas having completed secondary education. Net household monthly income per capita in urban and rural areas is 593 soles (USD 144) and 174 soles (USD 42), respectively, this confirms the presence of economic inequality in Peru. Individuals from rural areas have access to lower opportunities, and average net household income is more than three times higher in urban households.

4 Empirical Model

In this section, I describe the econometric model of the relationship between exposure to floods and long-term outcomes. For the identification, I exploit the 1982-1983 and the 1997-

[27]The urban area is defined by INEI as communities with at least 100 dwellings grouped contiguously (on average 500 inhabitants). As an exception, the capital of districts is considered an urban area even when it does not meet this requirement. 34% of the individuals in the sample are classified as poor. INEI classifies a household as poor based on the line of poverty methodology by selecting a welfare indicator (per capita expenses) and a poverty threshold following the rule: i) The household is poor when per capita expenses are less than the poverty cutoff, and ii) the household is classified as non-poor when per capita expenses are equal or higher than the poverty line. Similarly, extreme poverty condition is defined based on the level of expenditure and the poverty cutoff. To establish the poverty line INEI uses a basket of basic goods and services for consumption, and the poverty line is the money needed to acquire this basket of goods and services.

1998 El Niño in Peru as a natural experiment, and I use two sources of variation: i) cohort variation, ii) geographic variation.

$$Y_{idcps} = \alpha_1 treatment\_inutero_{idc} + X_{idcps}\alpha_g + \delta_c + \omega_d + \lambda_s + \gamma_p + \varepsilon_{idcps} \quad (3)$$

$$Y_{idcps} = \beta_1 shock\_inutero_{idc} + X_{idcps}\beta_g + \delta_c + \omega_d + \lambda_s + \gamma_p + u_{idcps} \quad (4)$$

Where i indexes the individual, d corresponds to the individual's district of birth, c indexes cohort of birth, p represents the province of residence, and s the survey year. Y is a dummy variable that equals one if the individual i answering survey s, living in province p, born in district d and at date c (quarter and year of birth) has completed primary education,[28] and zero otherwise. X is a vector of individual and socio-demographic characteristics. Regressions control for gender, age, and urban sector. The variable $shock\_inutero_{idc}$ in equation (4) measures the number of months of floods during 1982-1983 (1997-1998) El Niño experienced in-utero, and it is calculated based on the individual's district and date of birth. β_1 measures the effect of one additional month of exposure to El Niño floods while in-utero on primary education completion. Similarly, $treatment\_inutero_{idc}$ in equation (3) is the treatment variable which equals one if the individual was exposed to a flood while in-utero, and zero otherwise. α_1 indicates the effect of in-utero exposure to the 1982-1983 (1997-1998) El Niño on the likelihood of having completed primary education. While equation (3) explores the treatment effect, equation (4) analyzes the marginal effect of the event on educational outcomes.

The cohort fixed effects, δ_c, controls for any shock common to all individuals born in the same cohort. For example, it could be possible that individuals born in the second half of the year are more resilient towards climate change. Seasonal events at the time of birth (other shocks different from the 1982-1983 El Niño) could have impacted individuals' development. By controlling for cohort fixed effects I account for these unobserved effects on educational outcomes. Additionally, ω_d controls for the district of birth fixed effects, γ_p accounts for the province of residence fixed effects, and λ_s is the survey year fixed effect. ω_d and γ_p fixed effects account for local-specific characteristics that are invariant over time (such as social norms affecting the educational achievement of individuals in certain areas), and λ_s fixed effects control for survey year-specific factors that are common to all districts at the time of a survey that could affect survey outcomes. Finally, ε_{idcps} and u_{idcps} are the error terms. Standard errors are clustered at the district of birth level allowing the error terms to be correlated within each district.[29]

[28] Alternatively, I explore the effect of exposure to the 1982-1983 El Niño on secondary education completion.

[29] I compare the main specifications (equation 3 and equation 4) with alternatives that account for household fixed effects as well, to comment on how results change depending on specific characteristics of the households. The results are available upon request.

To consistently estimate causal effects of in-utero exposure to El Niño floods on individual outcomes (α_1), the main identification assumption requires the error term ε_{idcps} not to be correlated with the exposure measure, after controlling for fixed effects, and a set of observed characteristics X_{idcps}. In other words, my identification strategy of the causal effect of rainfall variation on education completion relies on the assumption that, conditional on several fixed effects, temporary rainfall deviations from the historical averages are uncorrelated with other latent determinants of education completion during gestation and through adulthood. A potential concern arises if districts that were affected by the 1982-1983 (1997-1998) El Niño had different pre-trends in the level of education of their residents compared to districts in the control group, under this case the identification assumption will not hold. One way to test for this assumption is by the assessment of pre-shock trends on educational outcomes and to see whether or not there is an association between in-utero exposure to El Niño floods and educational trends before the shock. Unfortunately, I cannot test for pre-shock trends because educational outcomes are not available before the El Niño event. However, I expect the evolution of educational outcomes to be very similar in control and treatment districts.

The main specification considers flood exposure while in-utero rather than exposure after birth (i.e. first or second year of life) because it has been demonstrated in previous studies that only exposure to shocks while in-utero has negative and significant effects on long-term outcomes such as children's academic performance [Almond (2006), Almond et al. (2015), Elaine (2009), Neelsen & Stratmann (2011)]. In addition, I have explored exposure to 1982-1983 El Niño early in life as regressor (for children up to two years old), and results are not statistically significant for flood exposure after the birth year.

5 Results

5.1 The Effect of the 1982-1983 El Niño: Educational Outcomes

In this section, I present the results of in-utero exposure to the 1982-1983 El Niño on long-term outcomes following the specification in equation (3).

Table 3 shows the treatment effects estimates of in-utero exposure to the 1982-1983 El Niño on the probability to have completed primary education for individuals born between 1975 and 1983, and who are 17 years old or older. Odd columns do not account for control variables.[30] The results show that this subsample of individuals born between 1975 and 1983 was not significantly affected by the floods. The estimates are not statistically significant and close to zero (see Panel A, Table 3). In Peru, there is a lack of educational opportunities, specially for those individuals located in marginalized regions in rural zones. Therefore, the

[30] Columns 2 and 4 in Table 3 show the effect of in-utero exposure to the 1982-1983 El Niño on primary education completion rates including covariates. I control for gender, age, and urban zone indicator.

effect of in-utero exposure to El Niño might be different depending on the place of residence. Furthermore, rural and urban areas' adaptation to floods, resilience to natural phenomenons and quality of infrastructure could play a role in how well these areas face disasters.

In Panel B and Panel C of Table 3, I split the sample by zone of residence. The 1982-1983 event did not significantly affect primary education completion rates during adulthood for those individuals exposed to the shock in-utero and living in rural areas at the time of the survey. The no significant effect found in rural zones may be because individuals in rural zones have already low primary education completion rates (18% and 3% of individuals in rural and urban areas do not complete primary education). In contrast, individuals living in urban areas were significantly impacted by the event. In urban areas, individuals older than 17 years old and who were exposed to the 1982-1983 El Niño have 1.5 percentage points (significant at 5%) less probability to have completed primary education. The estimates are robust to the inclusion of covariates.

In Table 4, I investigate the effect of in-utero exposure to the 1982-1983 El Niño on secondary education completion. For the full sample of individuals born between 1975-1983 and who are older than 17 years old, the 1982-1983 El Niño did not affect their probability to have completed secondary education (see Panel A, Table 4). Similarly, I explore heterogeneous effects by zone of residence on secondary education completion rates in Panel B and C. While in-utero exposure to the 1982-1983 El Niño seems not to have affected secondary education completion rates in urban areas, the probability to complete secondary education increases by 9 percentage points (significant at 5%), for individuals living in rural areas and exposed to the 1982-1983 El Niño. The estimates remain stable after controlling for covariates. Recall that the average rate of high school completion in the subsample is 46 percent for members of rural zones, so this is equivalent to a 20% increase.[31] It would be important to understand why the 1982-1983 El Niño had opposite effects on long-term outcomes, education completion rates in rural and urban zones. However, because of data limitations, this study cannot clearly identify possible mechanisms of this observed heterogeneity. One possible mediator could be the effect on crop production. Households in rural areas depend on agriculture, therefore, a high intake of rain can have positive effects on household income in rural zones with further implications for educational outcomes. Finally, I also explore the effect of in-utero exposure to the 1982-1983 El Niño floods on total years of education completed. The results show that prenatal exposure to floods increases total years of education by 7-8 months in rural areas only. Given that the average total years of education in the control group and rural area is 9 years (less than secondary education), this corresponds to an increase of 7.2% (see Panel C, Table 5).

[31] At the baseline (treatment=0), 46% of individuals in rural areas have completed high school.

5.2 The Effect of the 1997-1998 El Niño: Educational Outcomes

In this section, I investigate the effect of a more predictable El Niño (1997-1998) on educational outcomes following equation (3). Panel A of Table 6 reports the estimates on the probability to complete primary education for the full sample of individuals older than 16 years old and who were born between 1990-1998. The estimates are not statistically significant and at most, they are marginally significant at 10% level (see columns 3 and 4, Table 6). In addition, Panel B of Table 6 shows the effect of in-utero exposure to the 1997-1998 El Niño on secondary education completion. The more predictable El Niño did not have an impact on secondary completion rates in urban zones or for the full sample of individuals. In rural zones, the estimate is negative and marginally significant at 10%. Individuals aged 18 years or older, in rural areas and exposed to floods while in-utero have 7-8 percentage points less probability to complete secondary education.[32] Finally, I evaluate the effect of the floods on total years of education, and the estimates remain statistically insignificant. To summarize the main results, Figure 4 shows the point estimates of prenatal exposure to a more and a less predictable El Niño by zone of residence, and 95% confidence intervals. While in-utero exposure to a less predictable El Niño of 1982-1983 had significant effects on long-term educational outcomes, an exposure to a more predictable El Niño of 1997-1998 did not affect the education achievement of individuals during adulthood.

5.3 The Intensity of Exposure to the 1982-1983 El Niño

In the previous section, I evaluated the effect of at least one month of exposure to floods during pregnancy on long-term outcomes. While the treatment dummy variable reflects the effect of exposure to a flood while in-utero, it would be interesting to also explore the marginal effect of the event on educational outcomes (see equation 4). Panel A of Table 7 shows that one additional month of exposure to floods while in-utero reduces the probability that the individual has completed primary education by 0.69 percentage points (significant at 5%) in urban areas. In contrast, in rural areas, the estimates are imprecise and the effect is positive but marginally significant at 10%. Panel B of Table 7 reports the estimates on secondary education completion. Different from the results found for primary education completion rates, one additional month of in-utero exposure to the 1982-1983 El Niño increases the chance to complete secondary education by 4 percentage points (significant at 1%) and for the subgroup of individuals living in rural dwellings. Similarly, I found that in rural areas, individuals exposed to one additional month of floods before birth date have completed 4 additional months of education than their peers (see Panel C of Table 7). It would also be interesting to investigate why exposure to the 1982-1983 El Niño floods negatively affected primary education completion in urban areas but it had a positive and significant effect on total years of education in rural zones and on secondary

[32] The population is still too young to have completed secondary education by the time of the survey. Moreover, the less precise estimates respond to the less variability in treatment status.

education completion rates.

The heterogeneous effects by place of residence suggest that the 1982-1983 El Niño impacted living conditions around the time but the effects and magnitude of the event were not the same in rural and urban locations.[33]

5.4 The Intensity of Exposure to the 1997-1998 El Niño

Similar to the previous section, I assess the marginal effect of in-utero exposure but rather than exploring the variation of exposure to the 1982-1983 El Niño, I investigate the extent to which a less predictable phenomenon, the 1997-1998 El Niño, could have affected educational outcomes. At first glance, the results show that a more predictable El Niño could have a positive effect on the probability to complete more years of education and primary education. For instance, individuals exposed by one additional month to the 1997-1998 floods are more likely to have completed primary education during adulthood by 0.71 percentage points (significant at 1%).[34] Moreover, one additional month of exposure to floods during the 1997-1998 phenomenon increases total years of education by 2.9 percentage points (significant at 10%). The effect is driven by individuals living in urban areas (3.7 percentage points, significant at 5%).[35]

5.5 El Niño and its effects on other outcomes

The effect of in-utero exposure to extreme weather conditions can have additional effects on other outcomes such as health and income. I explore the effect of the 1982-1983 and the 1997-1998 El Niño on other outcomes during adulthood such as self-employment status, marital status, poverty condition, and the probability to have a chronic disease. Table A1 in the Appendix shows that prenatal flood exposure to the 1997-1998 El Niño had long-term negative effects on health outcomes during adulthood. Individuals who experienced prenatal exposure to floods are more likely to have a chronic disease later in life (2.4 percentage points, significant at 5%). In contrast, the estimates on income variables remain statistically insignificant. The increase in the probability to develop a chronic disease affects those living in urban areas but does not impact the health conditions of people in rural zones.[36]

[33]Unfortunately, ENAHO does not have detailed information to explore possible mechanisms at this time. In future projects, I would explore possible mechanisms using administrative data of the Peruvian Education Office and students' academic performance.

[34]See for instance Table 8.

[35]See for example column 3-4, Panel C of Table 8.

[36]The main objective of this study is not to analyze the underlying mechanisms of in-utero exposure to El Niño floods on education outcomes. However, since I found no effects for exposure to extreme weather conditions during early life (0-2 years old), I suspect the "Fetal Origins" hypothesis plays an important role in the Peruvian context. The period of gestation has significant impacts on the individual well-being and health. During the 1982-1983 event the supply of food was affected due to the destruction of roads, infrastructure, lack of transportation, and the increase in the volume of water of the main rivers. The lack of food could have affected the food intake of pregnant women.

5.6 Early in life exposure to the 1982-1983 El Niño

Previous studies have argued that early in life exposure to natural disasters and extreme weather conditions can have long-term effects on children's development. In this section, I investigate the effect of exposure to the Niño event after birth on long-term educational outcomes. Different from in-utero exposure to floods, an early in life exposure to floods does not have an effect on the probability that adults have completed primary (secondary) education (See Table A3 and A4, Appendix).[37]

5.7 Family Background

Unobserved households' characteristics could determine children's education outcomes. For example, parents with a high level of education are more likely to prioritize the education of children. Therefore, I expect children born in families where parents are highly educated to be less impacted by in-utero exposure to the 1982-1983 El Niño. To overcome this issue, I include household fixed effects in the regressions. After the inclusion of household fixed effects, the negative estimates of in-utero exposure to the event on primary education completion are not significant anymore. Moreover, the treatment effect estimates on secondary education completion become insignificant. Thus, this might suggest that household unobserved characteristics explain the level of education completed by children in the household.

5.8 Transmission Channels

In this section, I discuss possible mechanisms that can explain the impact of pre-natal shock on human capital development. One mechanism is through the effect on human brain development (biological channel), which starts in the first trimester of pregnancy. In addition, shocks generate maternal stress during the pre-natal period and can play an important role in the infant behavior later in life.[38]. Another channel is the nutritional channel. For instance, unexpected variation in rainfall can affect long-term education outcomes through an impact on yields and consumption. This is particularly important in developing countries and in rural areas where families live out of what they produce and agriculture is their main economic activity. Notice that the effect on crop production varies depending on the type of crop, the usage of technology, and the ability to predict weather conditions. A negative impact on crop production, yields, and consumption can decrease the mother's consumption of nutrients during pregnancy with further implications on weight at birth of the newborn and human capital development.

[37] Similarly, early in life exposure to the 1997-1998 El Niño does not affect primary education completion rates during adulthood. The results are available upon request.

[38] A recent study by Aizer et al. (2016) shows that in-utero exposure to high levels of the stress hormone cortisol affects children's academic performance and health.

6 Robustness Checks and Heterogeneous Effects

6.1 Robustness Checks

6.1.1 Balance Test

A potential threat to the identification assumption is that the exposure to El Niño floods may be confounded by similar unobserved characteristics that vary across districts and over time. It could be possible that the exposure to El Niño floods captures any changes in demographic characteristics of households giving birth in more affected municipalities rather than the exposure to the shock itself.

In order to check this selection problem, I test for balance in covariates between the treatment and the control groups by regressing each of the covariates on the treatment variable controlling for fixed effects and clustering the standard errors at the district of birth. The results show no significant differences in most demographic and individual characteristics between treatment and control groups. (see Table A5-A6, in the Appendix). Except for individuals' age and gender, and parental education, there are no differences in covariates between those exposed and those not exposed to the floods. I control for age and gender in the specifications and I evaluate heterogeneous effects of the event on educational outcomes by dividing the sample based on parental education.[39] The results are robust to the inclusion of covariates.

6.1.2 Falsification Test

The main identifying assumption to consistently estimate the causal effect of in-utero exposure to El Niño floods on educational outcomes requires the treatment and the error term not to be correlated, after controlling for fixed effects and control variables. Unfortunately, I cannot test for pre-event trends on educational outcomes for treatment and control districts because survey data on educational outcomes do not exist before 1982-1983. Furthermore, it could be possible that the negative effects of in-utero exposure to the El Niño flood on education completion may be confounded with omitted variables. To verify this is not the case, placebo regressions are estimated using the sample of individuals born between 1985 and 1988. I replicate the geographic intensity of the 1982-1983 shock using a different period, 1985-1986.[40] Then, I proceed to generate the dummy for treatment in-utero, and the exposure to the shock (intensity-in number of months exposed to floods while in-utero). The treatment dummy takes the value of one whenever the individual was exposed to floods at least one month while in-utero between December 1985 and June 1986, and zero otherwise. Since these individuals are part of the comparison group, this placebo test is key to validate

[39] In families where the parents reported not to have completed secondary education, the in-utero exposure of the children to the 1982-1983 El Niño reduced the probability that the children complete primary education later in life. In contrast, I do not find significant effects on primary education completion in families where parents reported to have completed secondary education.

[40] In particular, I restrict the period to December 1985-June 1986.

that there are no different trends between locations affected and not affected by the floods for individuals that were not exposed to the 1982-1983 El Niño. I do not observe statistically significant estimates in the placebo regressions.

The construction of the treatment variable uses precipitation data of the nearest node to the center of the district where the individual was born.[41] I perform a falsification test by choosing a far node from the center of the district. Using nodes located in the 5th position or 10th position in a ranking from nearest (1st) to furthest node from the center of the district, the effect of exposure to floods while in-utero on the probability of secondary/primary education completion disappears.[42] The findings are robust to the inclusion of even far nodes.

Finally, I use a probit model to estimate the effect of exposure to floods on the probability to complete secondary/primary education. The marginal effects are comparable in sign and size to the estimates using a linear probability model.[43]

6.2 Heterogeneous Effects

6.2.1 Trimester of Pregnancy

The exposure to extreme weather conditions can affect individuals' outcomes differently depending on the trimester of pregnancy. Some studies have suggested that extreme weather conditions in the first trimester, when the major organs form, could contribute to certain birth defects, whereas exposure in the second or third trimester, when the fetus undergoes rapid growth, may contribute to preterm birth, low maternal weight gain, and a significantly greater risk of intrauterine growth retardation [Strauss & Dietz (1999)]. I verify in which trimester of pregnancy an in-utero exposure to the Niño has strong effects on educational outcomes. The results suggest that one additional month of exposure to the 1982-1983 El Niño in the second or third trimester reduced the probability that the individual has completed primary education, and the results are significant for those living in urban dwellings.

6.2.2 Exposure to El Niño by gender

In this section, I explore whether an in-utero exposure to El Niño has different effects on education outcomes by gender. It could be the case that women and men are differently affected by the event. In order to test for it, I estimate equation (3) and (4) separately for women and men. The effects of a prenatal exposure to El Niño floods on primary education completion are statistically significant for men but not for women. For example,

[41] The average minimum distance from the node to the center of the district is 22 km with a maximum distance of 50 km and a minimum distance of 1km.

[42] The node positioned in place 5 is located on average 70 km away from the center of the district where the individual was born, with a minimum distance of 56 km and a maximum distance of 107 km. Similarly, the node positioned in place 10 is located on average 101 km from the center of the district with a minimum of 87 km and a maximum of 157 km.

[43] The results are available upon request.

one additional month of in-utero exposure to the 1982-1983 floods decreased the probability that boys who were exposed to the floods and living in urban areas have completed primary education by the age of 17 years old.

Boys and girls are affected differently by disasters. A growing body of literature suggest that female fetuses are more resilient to stress due to shocks than men fetuses [Rosenfeld (2015)]. For instance, Walsh et al. (2019) find that maternal stress leads to a higher probability of pre-term birth and a greater risk to male fetuses. My findings are according to previous evidence suggesting that for health and education outcomes, boys are disadvantaged when affected in utero or early life due to biological factors. In addition, if labor needs increase following exposure to floods, boys are more likely to be taken out of schools to work in the agricultural sector. [Erman et al. (2021)]

6.2.3 Grouping by Parental Education

If more disadvantaged families fail to adequately cope with extreme weather conditions, it is plausible that the effect of exposure to the Niño floods on later human capital outcomes is stronger for less-educated families, suggesting that prenatal shocks might exacerbate pre-existing inequalities. In this section, I proceed to divide the sample into two groups: i) individuals with parents who have not completed secondary education, ii) individuals with parents who have at least completed secondary education at the time of the survey. Then, I explore the effect of in-utero exposure to the 1982-1983 and 1997-1998 El Niño on education outcomes, separately for these two groups. The results suggest that the effects are negative and statistically significant for primary education completion of the individual when the individual's father reported not to have completed secondary education. Alternatively, I estimate my baseline equation (3) but include an interaction term to verify how an in-utero exposure to the 1982-1983 El Niño affects primary education completion differently for individuals with parents who have completed secondary education versus those with parents with incomplete secondary education. The estimates on both the interaction term and the treatment indicator are not statistically significant. On the other hand, the coefficient of the dummy for parental secondary education completion is positive and statistically significant. Thus, parental education plays an important role in determining children's ability to complete primary education.

7 Conclusion

This study shows evidence that the less predictable El Niño flood (1982-1983) generated long-term consequences on education outcomes of the Peruvian population that had experienced prenatal exposure to the floods. This adverse and unpredictable event, affecting the evolution of babies while in-utero, in particular during the nine months of gestation, reduced the probability that the exposed individual had completed primary education (by the time of 17 years old or older) in urban areas while the effects on rural zones were statistically insignificant. On the other hand, the same in-utero exposure but to a more predictable El Niño had opposite effects on education outcomes and most of the estimates were insignificant or marginal significant at the 10%. I find different estimates in terms of levels and significance if I replicate the same analysis using the El Niño event of 1997-1998, which was less intense and more anticipated according to reports of the National Meteorology and Hydrology Service of Peru. Thus, public policies oriented to protect pregnant women from adverse shocks such as pandemics, famine, and extreme weather conditions should direct funds towards the investment in the creation of knowledge and new technology to forecast the occurrence of these events.

A potential issue that could contaminate the estimates of the effect of in-utero exposure to El Niño floods on later outcomes is the fact that I only observe individuals who survived. If extreme El Niño floods increase neonatal and infant mortality, then the estimated effects could be downward biased due to selective mortality.[44] The selective mortality problem has been discussed in previous literature and it refers to a sample selection issue given that weaker babies, in terms of health condition, should have been less likely to survive. In the context of the paper, this transmits in only observing individuals that had better health outcomes while in-utero. In particular, I evaluate the impact of the event on the population that could have survived due to a better allocation of resources and health status during the 1982-1983 El Niño. In the hypothetical case that I could have observed individuals that did not survive, then the impact of the event should be even more negative.[45]

For further research, I plan to evaluate possible channels that could explain why exposure to the 1982-1983 floods in-utero affected the formation of human capital, and the heterogeneous effects found by place of residence and predictability of the event. Also, while this study mainly looks at secondary and primary education completion rates, other outcomes could be evaluated following a similar approach (for example, test scores, academic performance). Finally, it is important to remark the close connection between in-utero conditions of the baby from the first month of conception and the development of the individual later in life. This study suggests that it is impossible to separate what happens during the formation of the person while in-utero of the mother from the development of humans after birth.

[44] Paxson & Schady (2005) mention that children born during the 1980's macroeconomic crisis in Peru are more likely to die as infants.

[45] Using Peruvian Census data I calculated the size of selection mortality bias by counting the number of individuals who live in Treatment and Control districts for each cohort of birth, especially restricting cohorts to individuals up to 5 years old. The Census data also allows verifying whether the individual lives in the district where he/she was born. In the case individuals were not living in the place they were born, I know in which district the individual was born, and I use that information to compute the population. I proceed to perform a test of equality of means by treatment status. From the results of the test, I cannot reject the presence of selective mortality because the average population in treatment and control districts are very different, and the difference is statistically significant at the 5%.

References

Aguilar, A. & Vicarelli, M. (2018), 'El niño and mexican children: medium-term effects of early-life weather shocks on cognitive and health outcomes', *Working Paper* .

Agüero, J. (2014), 'Long-term effect of climate change on health: Evidence from heat waves in mexico', *Technical Report Inter-American Development Bank* .

Aizer, A., Stroud, L. & Buka, S. (2016), 'Maternal stress and child outcomes: Evidence from siblings', *Journal of Human Resources* **51**(3), 523–555.

Almond, D. (2006), 'Is the 1918 influenza pandemic over? long-term effects of in-utero influenza exposure in the post-1940 u.s. population', *Journal of Political Economy* **114**(4), 672–712.

Almond, D. & Currie, J. (2011), 'Killing me softly: The fetal origins hypothesis', *Journal of Economics Perspectives* **25**(3), 153–172.

Almond, D., Edlund, L., H., L. & J., Z. (2007), 'Long-term effects of the 1959-1961 china famine: Mainland china and hong kong', *NBER Working Paper Series* .

Almond, D., Mazumder, B. & van Ewijk, R. (2015), 'In utero ramadan exposure and children's academic performance', *The Economic Journal* **125**, 1501–1533.

Andalón, M., Azevedo, J., Rodríguez-Castelán, C., Sanfelice, V. & Valderrama-González, D. (2016), 'Weather shocks and health at birth in colombia', *World Development* **82**, 69–82.

Banerjee, A., Dufflo, E., Postel-Vinay, G. & Watts, T. (2010), 'Long-run health impacts of income shocks: Wine and phylloxera in nineteenth-century france', *The Review of Economics and Statistics* **92**, 714–728.

Barker, D. (1995), 'Fetal origins of coronary heart disease', *British Medical Journal* **311**, 171–174.

Bayer, A., Danysh, H., Garvich, M., Gonzálvez, G., Checkley, W., Alvarez, M. & Gilman, R. (2014), 'The 1997-1998 el niño as an unforgettable phenomenon in northern peru: a qualitative study', *Disasters* **38**(2), 351–374.

Black, S., Devereux, P. J. & Salvanes, K. G. (2007), 'From the cradle to the labor market? the effect of birth weight on adult outcomes', *Quarterly Journal of Economics* **122**(1), 409–439.

Bongkyun, K., Carruthers, C. & Harris, M. (2017), 'Maternal stress and birth outcomes: Evidence from the 1994 northridge earthquake', *Journal of Economic Behavior & Organization* **140**, 354–373.

Brando, J. & Santos, R. (2015), 'La niña y los niños: Effects of an unexpected winter on early life human capital and family responses', *Documento CEDE* **25**.

CAF (2000), 'El fenómeno del niño 1997-1998: Memoria, retos y soluciones'.

Camacho, A. (2008), 'Stress and birth weight: Evidence from terrorist attacks', *American Economic Review* **98**(2), 511–515.

Carlson, K. (2015), 'Fear itself: The effects of distressing economic news on birth outcomes', *Journal of Health Economics* **41**, 117–132.

Carlson, K. (2018), 'Red alert: Prenatal stress and plans to close military bases', *American Journal of Health Economics* **4**(3), 287–320.

Carrillo, B., Da Mata, D., Emanuel, L., Lopes, D. & Sampaio, B. (2020), 'Avoidable environmental disasters and infant health: Evidence from a mining dam collapse in brazil', *Health Economics* **29**(12), 1786–1794.

Chang, G., Favara, M. & Novella, R. (2022), 'The origins of cognitive skills and non-cognitive skills: The long-term effect of in-utero rainfall shocks in india', *Economics and Human Biology* **44**.

Corcuera-García, P. (2016), 'Fenómeno el niño y capital humano en el perú impactos sobre el peso al nacer peso/talla por edad y educación acumulada', *Tesis de licenciatura en Economía, Universidad de Piura* .

Currie, J. & Rossin-Slater, M. (2013), 'Weathering the storm: Hurricanes and birth outcomes', *Journal of Health Economics* **32**(3), 487–503.

Elaine, K. (2009), 'The scourge of asian flu: in utero exposure to pandemic influenza and the development of a cohort of british children', *Journal of Human Resources* **46**, 669–694.

Erman, A., De Vries Robbe, S., Thies, S., Kabir, K. & Maruo, M. (2021), 'Gender dimensions of disaster risk and resilience'.

Fedorov, A., Harper, S., Philander, S., Winter, B. & Wittenberg, A. (2003), 'How predictable is el niño?', *Bulletin of the American Meteorological Society* **84**(7).

Florian, S. (2019), 'Indicadores de educación por departamento 2008-2018', *Instituto Nacional de Estadística e Informática* .

Galdo, J. (2013), 'The long-run labor-market consequences of civil war: Evidence from the shining path in peru', *Economic Development and Cultural Change* **61**(4), 789–823.

Glantz, M. (2001*a*), 'Currents of change: Impacts of el niño and la niña on climate and society', *Cambridge University Press* .

Glantz, M. (2001*b*), 'Once burned, twice shy? lessons learned from the 1997-1998 el niño', *United Nations University Press* .

Groppo, V. & Kraehnert, K. (2016), 'Extreme weather events and child height: Evidence from mongolia', *World Development* **86**, 59–78.

Hoynes, H., Schanzenbach, D. W. & Almond, D. (2016), 'Long-run impacts of childhood access to the safety net', *American Economic Review* **106**(4), 903–934.

INEI (2018), 'Perú: Indicadores de educación por departamento, 2007-2017'.

Karbownik, K. & Wray, A. (2019), 'Long-run consequences of exposure to natural disasters', *Journal of Labor Economics* **37**(3), 949–1007.

Koppensteiner, M. & Manacorda, M. (2016), 'Violence and birth outcomes: Evidence from homicides in brazil', *Journal of Development Economics* **119**, 16–33.

Kumar, S., Molitor, R. & Vollmer, S. (2016), 'Drought and early child health in rural india', *Population and Development Review* **42**(1), 53–68.

Lee, C. (2014), 'Intergenerational health consequences of in utero exposure to maternal stress: Evidence from the 1980 kwangju uprising', *Social Science & Medicine* **119**, 284–291.

Leight, J., Glewwe, K. & Park, A. (2015), 'The impact of early childhood rainfall shocks on the evolution of cognitive and non-cognitive skills', *Working paper* .

Maccini, S. & Yang, D. (2009), 'Under the weather: Health, schooling, and economic consequences of early-life rainfall', *The American Economic Review* **99**(3), 1006–1026.

MINAM & SENHAMI (2014), 'El fenómeno el niño en el perú'.

Neelsen, S. & Stratmann, T. (2011), 'Effects of prenatal and early life malnutrition: Evidence from the greek famine', *Journal of Health Economics* **30**, 479–488.

Oliveira, V. D., Lee, I. & Quintana-Domeque, C. (2021), 'Natural disasters and early human development: Hurricane catarina and infant health in brazil', *The Journal of Human Resources* .

Paxson, C. & Schady, N. (2005), 'Child health and economic crisis in peru', *The World Bank Economic Review* **19**(2), 203–223.

Persson, P. & Rossin-Slater, M. (2018), 'Family ruptures, stress, and the mental health of the next generation', *American Economic Review* **108**(4-5), 1214–1252.

Quintana-Domeque, C. & Ródenas-Serrano, P. (2017), 'The hidden costs of terrorism: The effects on health at birth', *Journal of Health Economics* **56**, 47–60.

Rabassa, M., Skoufias, E. & Jacoby, H. (2014), ‘Weather and child health in rural nigeria’, *Journal of African Economies* **23**(4), 464–492.

Rocha, A. (2007), ‘El meganiño 1982-1983, la madre de todos los niños’.

Rocha, R. & Soares, R. (2015), ‘Water scarcity and birth outcomes in the brazilian semiarid’, *Journal of Development Economics* **112**, 72–91.

Rosales-Rueda, M. (2018), ‘The impact of early life shocks on human capital formation: evidence from el niño floods in ecuador’, *Journal of Health Economics* **62**, 13–44.

Rosales-Rueda, M. & Triyana, M. (2019), ‘The persistent effects of early-life exposure to air pollution’, *The Journal of Human Resources* **54**(4), 1037–1080.

Rosenfeld, C. (2015), ‘Sex-specific placental responses in fetal development’, *Endocrinology* **156**(10), 3422–3434.

Scholte, R. S., van den Berg, G. J. & Lindeboom, M. (2015), ‘Long-run effects of gestation during the dutch hunger winter famine on labor market and hospitalization outcomes’, *Journal of Health Economics* **39**, 17–30.

Shah, M. & Steinberg, B. M. (2017), ‘Drought of opportunities: Contemporaneous and long-term impacts of rainfall shocks on human capital’, *Journal of Political Economy* **125**(2), 527–561.

Strauss, R. & Dietz, W. (1999), ‘Low maternal weight gain in the second or third trimester increases the risk for intrauterine growth retardation’, *The Journal of Nutrition* **129**(5), 988–993.

SUNEDU (2020), ‘Ii informe bienal sobre la realidad universitaria en el perÚ’.

Torche, F. (2011), ‘The effect of maternal stress on birth outcomes: Exploiting a natural experiment’, *Demography* **48**(4), 1473–1491.

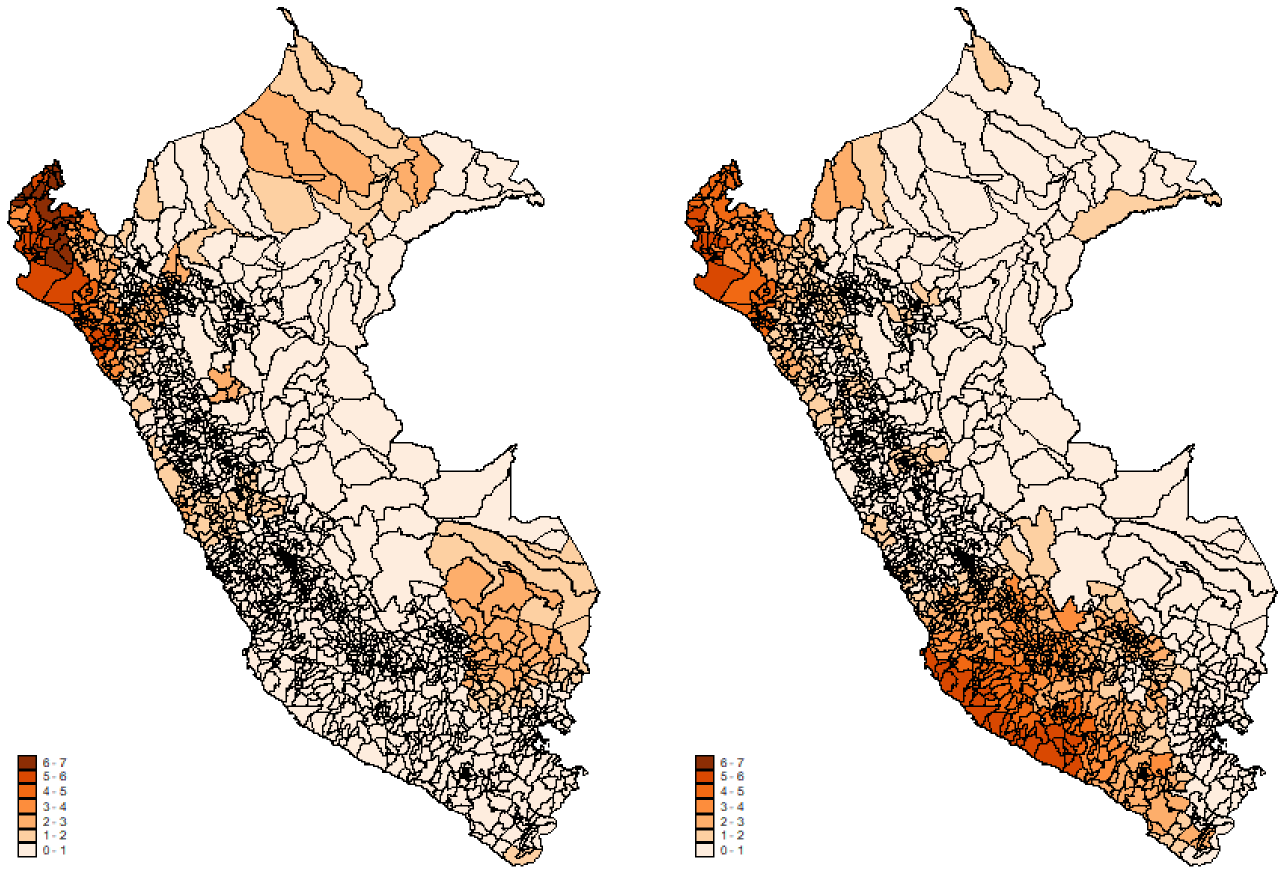
Torche, F. & Villarreal, A. (2014), ‘Prenatal exposure to violence and birth weight in mexico: Selectivity, exposure, and behavioral responses’, *American Sociological Review* **79**(5), 966–992.

Valente, C. (2015), ‘Civil conflict, gender-specific fetal loss, and selection: A new test of the trivers–willard hypothesis’, *Journal of Health Economics* **39**, 31–50.

Walsh, K., C., M., Webster, R., Pinto, A., Lee, S., Feng, T., Krakovsky, H., O’Grady, S., Tycko, B., Champagne, F., Werner, E., Liu, G. & Monk, C. (2019), ‘Maternal prenatal stress phenotypes associate with fetal neurodevelopment and birh outcomes.’, *PNAS* **116**(48), 23996–24005.

Figures and Tables

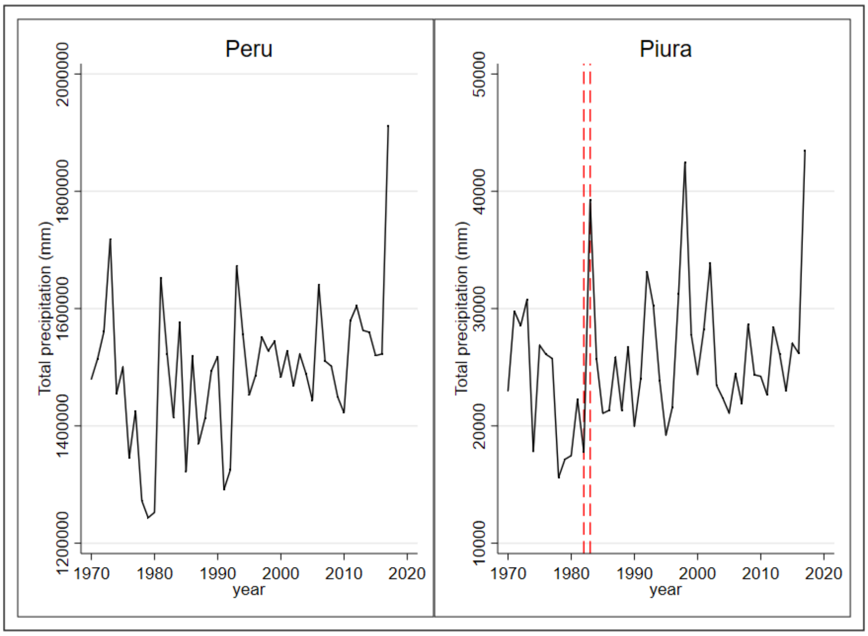
Figure 1: Prevalence of excess rainfall by Peruvian district



((a)) Number of months of intense floods during the 1982-1983 El Niño

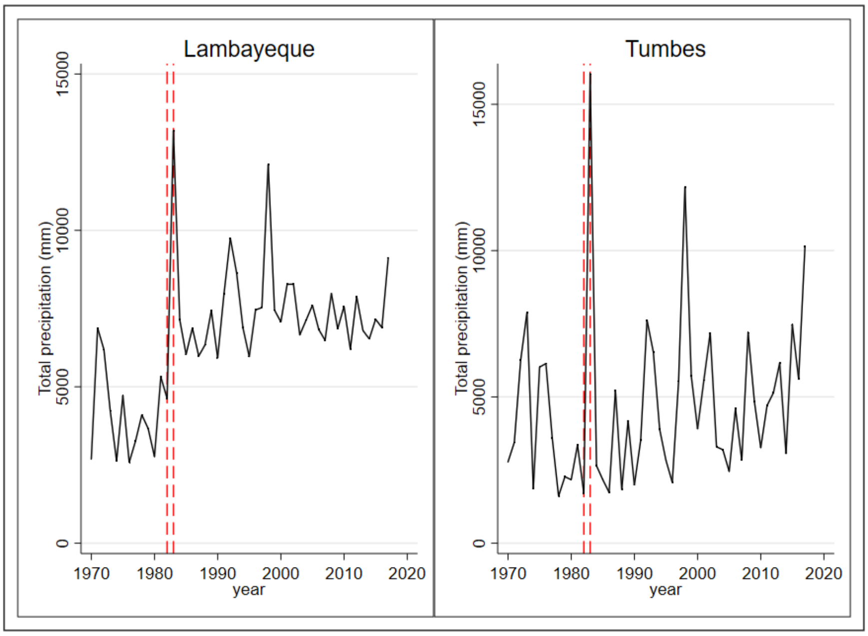
((b)) Number of months of intense floods during the 1997-1998 El Niño

Figure 2: Historical Records of Precipitation (mm): 1970-2017



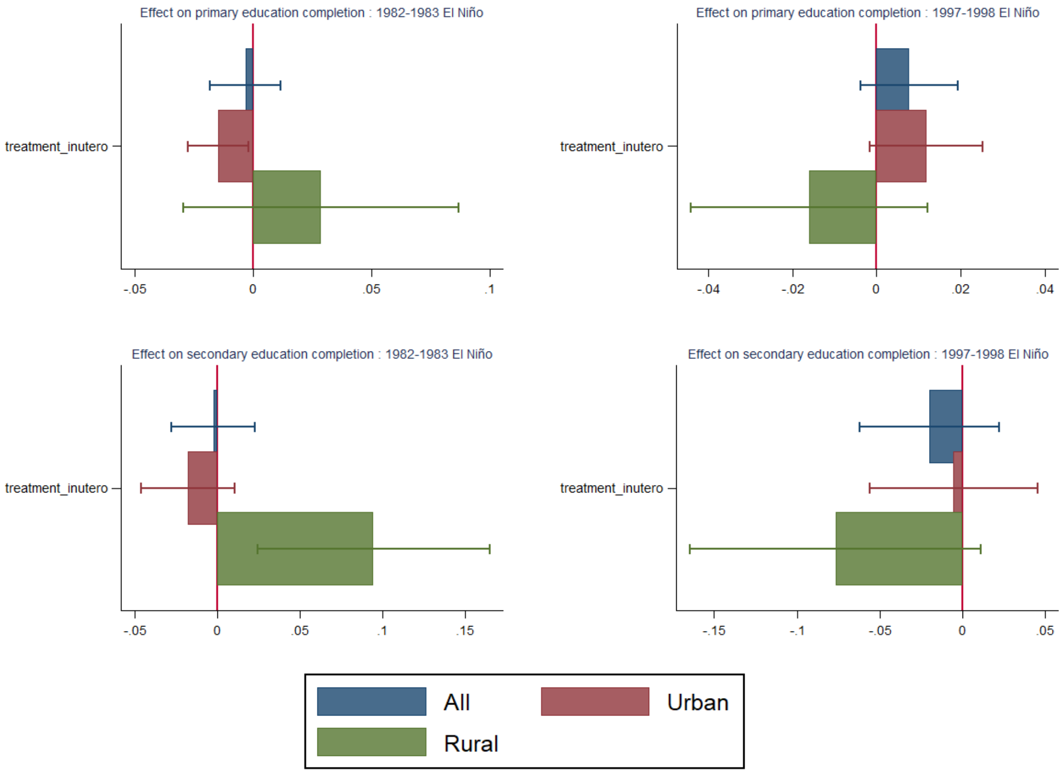
Notes: This figure shows annual historical records of precipitation in mm for the period 1970-2017. The red vertical dashed line is the total annual precipitation in mm observed during the 1982-1983 El Niño. Source: Data from the University of Delaware's Terrestrial Precipitation project: http://climate.geog.udel.edu/~climate/html_pages/download.html#P2017.

Figure 3: Historical Records of Precipitation (mm): 1970-2017



Notes: This figure shows annual historical records of precipitation in mm for the period 1970-2017. The red vertical dashed line is the total annual precipitation in mm observed during the 1982-1983 El Niño. Source: Data from the University of Delaware's Terrestrial Precipitation project: http://climate.geog.udel.edu/~climate/html_pages/download.html#P2017.

Figure 4: Effect of Exposure to a More Predictable and a Less Predictable El Niño on Long-Term Education Outcomes



Notes: This figure shows the point estimates of in-utero exposure to El Niño floods on long-term education outcomes: i) primary education completion, ii) secondary education completion following equation (3). Horizontal spikes denote 95% confidence intervals.

Table 1: Summary Statistics

	All				
Covariate	N	Mean	Sd	Min	Max
Years of education	35622	11.74	(3.16)	1	18
Primary Educ Completion	36053	0.95	(0.22)	0	1
Secondary Educ Completion	36053	0.79	(0.41)	0	1
Age	36057	25.52	(4.58)	17	43
Urban	36057	0.84	(0.37)	0	1
Is Female	36057	0.47	(0.50)	0	1
Net HH income per capita (monthly)	36057	525.34	(595.14)	0	12291.29
Spanish mother tongue	21747	0.93	(0.26)	0	1
Household Size	36057	6.50	(2.32)	3	25
Married	36047	0.13	(0.33)	0	1
Mestizo (race)	19714	0.58	(0.49)	0	1
Treatment in utero*	36057	0.08	(0.27)	0	1
Treatment after birth*	36057	0.18	(0.39)	0	1
Intensity shock in-utero* (if Treatment in utero==1)	3487	2.10	(1.47)	1	6
Intensity early life shock* (if Treatment after birth ==1)	7950	2.27	(1.77)	1	6

Notes: *Exposure to the 1982-1983 El Niño.

Table 2: Summary Statistics by Zone of Residence

	Urban					Rural				
Covariate	N	Mean	Sd	Min	Max	N	Mean	Sd	Min	Max
Years of education	27420	12.28	(2.76)	1	18	8202	8.92	(3.62)	1	17
Primary Educ Completion	27593	0.97	(0.16)	0	1	8460	0.81	(0.39)	0	1
Secondary Educ Completion	27593	0.86	(0.35)	0	1	8460	0.45	(0.50)	0	1
Age	27596	25.78	(4.58)	17	43	8461	24.19	(4.35)	17	42
Is Female	27596	0.48	(0.50)	0	1	8461	0.41	(0.49)	0	1
Net HH income per capita (monthly)	27596	593.14	(621.09)	0	12291.29	8461	173.76	(207.61)	6.05	7782.6
Spanish mother tongue	16949	0.96	(0.19)	0	1	4798	0.71	(0.45)	0	1
Household Size	27596	6.38	(2.27)	3	25	8461	7.10	(2.46)	3	20
Married	27589	0.12	(0.33)	0	1	8458	0.14	(0.35)	0	1
Mestizo (race)	15269	0.60	(0.49)	0	1	4445	0.45	(0.50)	0	1
Treatment in utero*	27596	0.07	(0.25)	0	1	8461	0.12	(0.33)	0	1
Treatment after birth*	27596	0.17	(0.37)	0	1	8461	0.26	(0.44)	0	1
Intensity shock in-utero* (if Treatment in utero==1)	2455	2.18	(1.54)	1	6	1032	1.86	(1.21)	1	6
Intensity early life shock* (if Treatment after birth ==1)	5758	2.33	(1.83)	1	6	2192	2.09	(1.54)	1	6

Notes: *Exposure to the 1982-1983 El Niño.

Table 3: The Effect of In-Utero Exposure to 1982-1983 El Nino Shock on Primary Education Completion

Dep. Variable:	**Primary Education Completion**			
	(1)	(2)	(3)	(4)
Panel A: Full Sample				
treatment_inutero	-0.00363	-0.00311	-0.00354	-0.00316
	(0.00769)	(0.00763)	(0.00737)	(0.00729)
Number of observations (N)	36,053	36,053	36,053	36,053
Adjusted R^2	0.173	0.186	0.173	0.186
Mean Dv (dependent variable) (Treatment==0)	0.95	0.95	0.95	0.95
Panel B: Urban				
treatment_inutero	-0.0147**	-0.0147**	-0.0146**	-0.0147**
	(0.00646)	(0.00645)	(0.00606)	(0.00605)
Number of observations (N)	27,593	27,593	27,593	27,593
Adjusted R^2	0.094	0.094	0.093	0.093
Mean Dv (dependent variable) (Treatment==0)	0.97	0.97	0.97	0.97
Panel C: Rural				
treatment_inutero	0.0235	0.0287	0.0235	0.0270
	(0.0297)	(0.0296)	(0.0283)	(0.0282)
Number of observations (N)	8,460	8,460	8,460	8,460
Adjusted R^2	0.181	0.197	0.180	0.197
Mean Dv (dependent variable) (Treatment==0)	0.81	0.81	0.81	0.81
Cohort of Birth FE	Yes	Yes	No	No
Month of Birth FE	No	No	Yes	Yes
Year of Birth FE	No	No	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes

Notes: This table reports the treatment effects estimates on primary education completion for individuals born between 1975-1983. Column 1 and Column 3 show the estimates without control variables while control variables are added in Column 2 and Column 4. Each regression includes survey-year fixed effect, district of birth fixed effect, and province of residence fixed effect. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Table 4: The Effect of In-Utero Exposure to 1982-1983 El Nino Shock on Secondary Education Completion

Dep. Variable:	**Secondary Education Completion**			
	(1)	(2)	(3)	(4)
Panel A: Full Sample				
treatment_inutero	-0.00216	-0.00241	-0.00183	-0.00229
	(0.0132)	(0.0129)	(0.0126)	(0.0123)
Number of observations (N)	35,977	35,977	35,977	35,977
Adjusted R^2	0.237	0.266	0.237	0.266
Mean Dv (Treatment==0)	0.80	0.80	0.80	0.80
Panel B: Urban				
treatment_inutero	-0.0165	-0.0176	-0.0151	-0.0161
	(0.0144)	(0.0144)	(0.0141)	(0.0142)
Number of observations (N)	27,543	27,543	27,543	27,543
Adjusted R^2	0.149	0.151	0.148	0.151
Mean Dv (Treatment==0)	0.87	0.87	0.87	0.87
Panel C: Rural				
treatment_inutero	0.0918**	0.0949***	0.0821**	0.0845**
	(0.0359)	(0.0357)	(0.0348)	(0.0346)
Number of observations (N)	8,434	8,434	8,434	8,434
Adjusted R^2	0.234	0.237	0.233	0.236
Mean Dv (Treatment==0)	0.46	0.46	0.46	0.46
Cohort of Birth FE	Yes	Yes	No	No
Month of Birth FE	No	No	Yes	Yes
Year of Birth FE	No	No	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes

Notes: This table reports the treatment effects estimates on secondary education completion for individuals born between 1975-1983. Column 1 and Column 3 show the estimates without control variables while control variables are added in Column 2 and Column 4. Each regression includes survey-year fixed effect, district of birth fixed effect, and province of residence fixed effect. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Table 5: The Effect of In-Utero Exposure to 1982-1983 El Nino Shock on Total Years of Education

Dep. Variable:	**Years of Education**			
	(1)	(2)	(3)	(4)
Panel A: Full Sample				
treatment_inutero	0.00609	0.000587	0.0256	0.0177
	(0.109)	(0.106)	(0.104)	(0.102)
Number of observations (N)	35,622	35,622	35,622	35,622
Adjusted R^2	0.282	0.315	0.282	0.314
Mean Dv (Treatment==0)	11.83	11.83	11.83	11.83
Panel B: Urban				
treatment_inutero	-0.158	-0.170	-0.125	-0.138
	(0.116)	(0.115)	(0.113)	(0.112)
Number of observations (N)	27,420	27,420	27,420	27,420
Adjusted R^2	0.200	0.205	0.199	0.204
Mean Dv (Treatment==0)	12.33	12.33	12.33	12.33
Panel C: Rural				
treatment_inutero	0.613***	0.647***	0.558**	0.585**
	(0.236)	(0.235)	(0.230)	(0.229)
Number of observations (N)	8,202	8,202	8,202	8,202
Adjusted R^2	0.279	0.285	0.278	0.284
Mean Dv (Treatment==0)	8.98	8.98	8.98	8.98
Cohort of Birth FE	Yes	Yes	No	No
Month of Birth FE	No	No	Yes	Yes
Year of Birth FE	No	No	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes

Notes: This table reports the treatment effects estimates on total years of education for individuals born between 1975-1983. Column 1 and Column 3 show the estimates without control variables while control variables are added in Column 2 and Column 4. Each regression includes survey-year fixed effect, district of birth fixed effect, and province of residence fixed effect. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 6: The Effect of In-Utero Exposure to 1997-1998 El Nino Shock on Education Outcomes

Sample:	Full	Full	Urban	Urban	Rural	Rural
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Primary Education Completion						
treatment_inutero	0.00808	0.00774	0.0118*	0.0118*	-0.0136	-0.0161
	(0.00593)	(0.00592)	(0.00685)	(0.00685)	(0.0144)	(0.0143)
Number of observations (N)	58,367	58,367	39,136	39,136	19,231	19,231
Adjusted R^2	0.072	0.076	0.065	0.065	0.080	0.084
Mean Dv (Treatment==0)	0.97	0.97	0.98	0.98	0.93	0.93
Panel B: Secondary Education Completion						
treatment_inutero	-0.0193	-0.0200	-0.00758	-0.00524	-0.0739*	-0.0767*
	(0.0214)	(0.0216)	(0.0257)	(0.0259)	(0.0442)	(0.0447)
Number of observations (N)	46,408	46,408	31,972	31,972	14,436	14,436
Adjusted R^2	0.178	0.199	0.100	0.104	0.195	0.196
Mean Dv (Treatment==0)	0.84	0.84	0.90	0.90	0.62	0.62
Panel C: Total Years of Education						
treatment_inutero	0.0421	0.0425	0.0515	0.0547	0.0513	0.0516
	(0.0333)	(0.0333)	(0.0375)	(0.0375)	(0.0551)	(0.0552)
Number of observations (N)	169,837	169,837	100,106	100,106	69,731	69,731
Adjusted R^2	0.833	0.836	0.856	0.856	0.754	0.754
Mean Dv (Treatment==0)	7.38	7.38	7.99	7.99	5.98	5.98
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

Notes: This table reports the effect of in-utero exposure to the 1997-1998 El Niño on long-term education outcomes for individuals born between 1990-1998. The variable treatment_inutero equals one if the individual was exposed to the 1997-1998 El Niño while in-utero, and zero otherwise. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 7: The Effect of Intensity of El Niño (1982-1983) on Long-Term Education Outcomes

Sample:	Full	Full	Urban	Urban	Rural	Rural
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Primary Education Completion						
shock_inutero	-0.00150	-0.00175	-0.00691**	-0.00691**	0.0228*	0.0251*
	(0.00338)	(0.00331)	(0.00292)	(0.00292)	(0.0132)	(0.0131)
Number of observations (N)	36,053	36,053	27,593	27,593	8,460	8,460
Adjusted R^2	0.173	0.186	0.094	0.094	0.181	0.198
Panel B: Secondary Education Completion						
shock_inutero	0.00540	0.00436	-0.000179	-0.000381	0.0360***	0.0373***
	(0.00478)	(0.00449)	(0.00476)	(0.00473)	(0.0136)	(0.0136)
Number of observations (N)	35,977	35,977	27,543	27,543	8,434	8,434
Adjusted R^2	0.238	0.266	0.149	0.151	0.234	0.237
Panel C: Total Years of Education						
shock_inutero	0.0145	0.00510	-0.0484	-0.0512	0.290***	0.303***
	(0.0381)	(0.0362)	(0.0361)	(0.0353)	(0.106)	(0.104)
Number of observations (N)	35,622	35,622	27,420	27,420	8,202	8,202
Adjusted R^2	0.282	0.315	0.200	0.205	0.280	0.286
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

Notes: This table reports the effect of intensity of exposure to the 1982-1983 El Niño on long-term education outcomes for individuals born between 1975-1983. The treatment variable is the number of months of exposure to intense floods. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01,^{**} p < 0.05,^{*} p < 0.1$.

Table 8: The Effect of Intensity of El Niño (1997-1998) on Long-Term Education Outcomes

Sample:	Full	Full	Urban	Urban	Rural	Rural
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Primary Education Completion						
shock_inutero	0.00711***	0.00709***	0.00828***	0.00840***	-0.00434	-0.00503
	(0.00256)	(0.00254)	(0.00273)	(0.00273)	(0.00695)	(0.00692)
Number of observations (N)	58,367	58,367	39,136	39,136	19,231	19,231
Adjusted R^2	0.072	0.076	0.065	0.065	0.080	0.084
Panel B: Secondary Education Completion						
shock_inutero	0.00495	0.00529	0.0112	0.0129	-0.0330	-0.0336
	(0.0102)	(0.0102)	(0.0120)	(0.0120)	(0.0300)	(0.0305)
Number of observations (N)	46,408	46,408	31,972	31,972	14,436	14,436
Adjusted R^2	0.178	0.199	0.100	0.104	0.195	0.195
Panel C: Total Years of Education						
shock_inutero	0.0282	0.0289*	0.0356*	0.0375**	0.0170	0.0173
	(0.0172)	(0.0167)	(0.0183)	(0.0183)	(0.0306)	(0.0306)
Number of observations (N)	169,837	169,837	100,106	100,106	69,731	69,731
Adjusted R^2	0.833	0.836	0.856	0.857	0.754	0.754
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

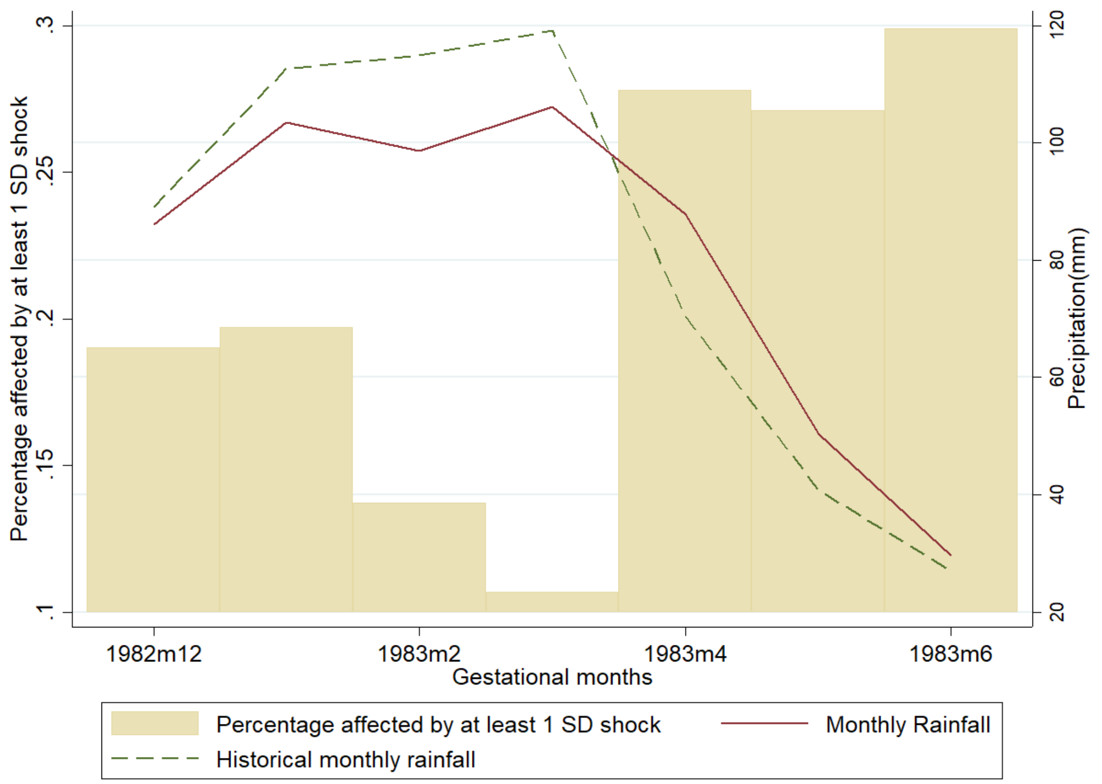
Notes: This table reports the effect of intensity of exposure to the 1997-1998 El Niño on long-term education outcomes for individuals born between 1990-1998. The treatment variable is the number of months of exposure to intense floods. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Online Appendix

Figures in Appendix

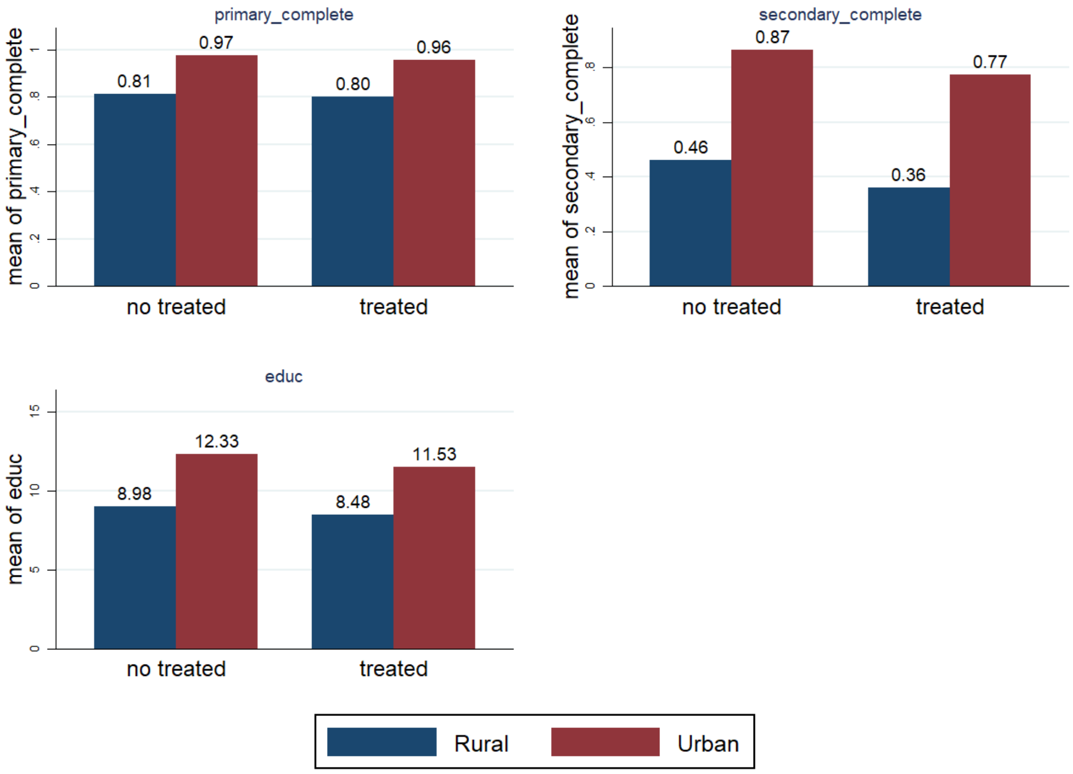
Tables in Appendix

Figure A1: Average monthly rainfall, historical mean and proportion of individuals hit by intense floods (positive rainfall shock) during the in-utero period and the 1982-1983 El Niño



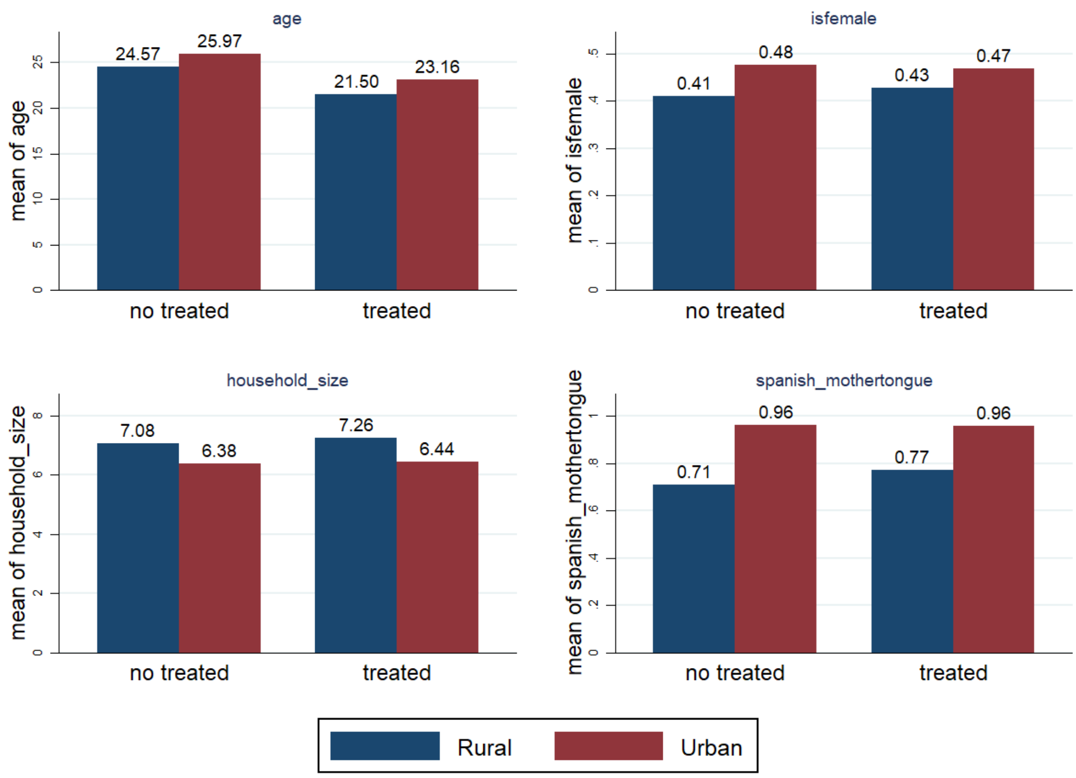
Notes: The monthly rainfall reported in the figure (solid line) is calculated averaging the monthly precipitation across the ENAHO districts for the period December 1982-June 1983. The historical monthly rainfall (dashed line) corresponds to the average monthly precipitation registered in each district (municipality) during the period 1970-2001. Rainfall is measured in millimetres and reported on the right y-axis. The bars represent the proportion of individuals exposed to intense floods (a positive rainfall shock of at least 1 SD) in each gestational month (left y-axis)

Figure A2: Descriptive Statistics (1982-1983 El Niño): Dependent Variables



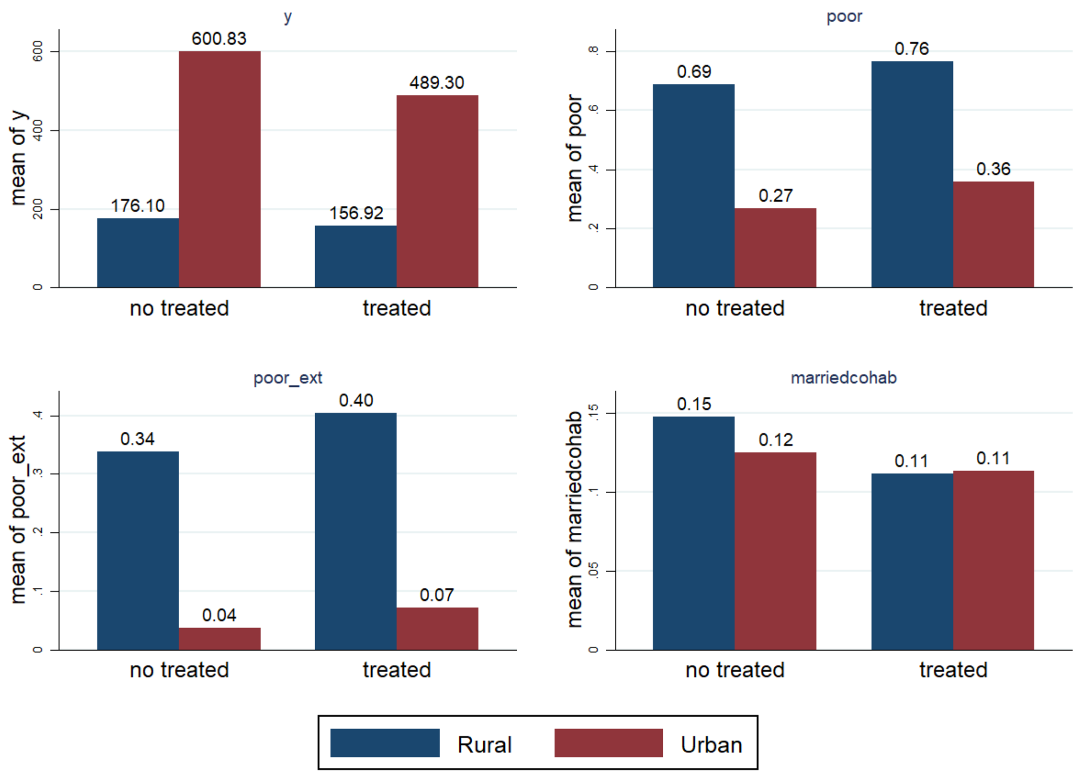
Notes: The figure shows summary statistics (average) of long-term educational outcomes by treatment status and zone of residence."*primary_complete*" is a dummy variable that equals one if the individual reported to have completed primary education and zero otherwise. Similarly, "*secondary_complete*" is a dummy variable that equals one if the individual reported to have completed secondary education and zero otherwise. "*educ*" denotes total years of education completed by the individual.

Figure A3: Descriptive Statistics (1982-1983 El Niño): Covariates



Notes: The figure shows summary statistics (average) of individual's demographic characteristics by treatment status and zone of residence.

Figure A4: Descriptive Statistics (1982-1983 El Niño): Covariates (continued)



Notes: The figure shows summary statistics (average) of individuals and households' characteristics by treatment status and zone of residence."*y*" denotes net household monthly income per capita. "*poor*" and "*poor_ext*" are poor and extreme poor indicators for the household, respectively. "*marriedcohab*" is an indicator which equals one if the individual reported to be married or to reside with another as if married, and zero otherwise.

Table A1: Intensity of El Niño (1997-1998): Other Outcomes

Dep. Variable:	Self-employment	Extreme Poor	Poor	Marital Status	Net HH Income pc	Chronic Disease
	(1)	(2)	(3)	(4)	(5)	(6)
Full Sample						
shock_inutero	0.0148	-0.00486*	-0.00233	0.0148	-8.584	0.0241**
	(0.0171)	(0.00280)	(0.00928)	(0.0214)	(11.66)	(0.0122)
Number of observations (N)	29,556	46,431	46,431	46,431	46,431	46,431
Adjusted R^2	0.039	0.189	0.239	0.059	0.255	0.057
Urban						
shock_inutero	0.0121	-0.00347	-0.00496	0.0170	-15.92	0.0297**
	(0.0227)	(0.00214)	(0.0103)	(0.0234)	(13.64)	(0.0145)
Number of observations (N)	18,395	31,994	31,994	31,994	31,994	31,994
Adjusted R^2	0.038	0.121	0.160	0.061	0.197	0.044
Rural						
shock_inutero	0.00909	-0.00840	0.0113	-0.00351	5.887	8.87e-05
	(0.0172)	(0.00983)	(0.0165)	(0.0727)	(15.13)	(0.0137)
Number of observations (N)	11,161	14,437	14,437	14,437	14,437	14,437
Adjusted R^2	0.044	0.190	0.285	0.057	0.225	0.055
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports the effect of intensity of exposure to the 1997-1998 El Niño on health and income variables for individuals born between 1990-1998 and who are older than 17 years old. The treatment variable is the number of months of exposure to intense floods. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01,^{**} p < 0.05,^{*} p < 0.1$.

Table A2: Intensity of El Niño (1982-1983): Other Outcomes

Dep. Variable:	Self-employment	Extreme Poor	Poor	Marital Status	Net HH Income pc	Chronic Disease
	(1)	(2)	(3)	(4)	(5)	(6)
Full Sample						
shock_inutero	-0.00976*	-0.00182	-0.00413	0.00774	1.873	-0.00443
	(0.00553)	(0.00231)	(0.00611)	(0.0186)	(8.126)	(0.00466)
Number of observations (N)	26,261	35,981	35,981	35,971	35,981	35,981
Adjusted R^2	0.043	0.351	0.298	0.091	0.289	0.127
Urban						
shock_inutero	-0.0126*	-0.00335	-0.00506	0.00861	1.889	-0.00455
	(0.00656)	(0.00217)	(0.00704)	(0.00656)	(9.460)	(0.00539)
Number of observations (N)	19,320	27,546	27,546	27,539	27,546	27,546
Adjusted R^2	0.041	0.248	0.220	0.097	0.244	0.124
Rural						
shock_inutero	0.000648	-0.00167	0.000202	0.0213	5.999*	-0.00272
	(0.00884)	(0.0105)	(0.0110)	(0.0384)	(3.481)	(0.0104)
Number of observations (N)	6,941	8,435	8,435	8,432	8,435	8,435
Adjusted R^2	0.100	0.298	0.331	0.110	0.276	0.169
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports the effect of intensity of exposure to the 1982-1983 El Niño on health and income variables for individuals born between 1975-1983 and who are older than 17 years old. The treatment variable is the number of months of exposure to intense floods. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Table A3: The effect of both In-Utero and Early in Life Exposure to El Niño on Secondary Education Completion

Dep. Variable:	**Secondary Education Completion**					
	Full	Full	Urban	Urban	Rural	Rural
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Sample: Born between 1975-1983						
treatment_inutero	0.000885	0.000993	-0.0136	-0.0146	0.0931**	0.0962***
	(0.0128)	(0.0125)	(0.0142)	(0.0142)	(0.0371)	(0.0370)
treatment_2y	0.0123	0.0137	0.0123	0.0127	0.00428	0.00423
	(0.0109)	(0.0111)	(0.0117)	(0.0118)	(0.0281)	(0.0285)
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
Number of observations (N)	35,977	35,977	27,543	27,543	8,434	8,434
Adjusted R^2	0.238	0.266	0.149	0.151	0.234	0.237

Notes: This table reports the effect of in-utero exposure and early in life exposure to the 1982-1983 El Niño on secondary education completion for individuals born between 1975-1983 and who are older than 17 years old. The variable treatment_inutero equals one if the individual was exposed to the 1982-1983 El Niño while in-utero, and zero otherwise. The variable treatment_2y equals one if the individual was exposed to the 1982-1983 El Niño after birth up to two years old, and zero otherwise. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Table A4: The effect of both In-Utero and Early in Life Exposure to El Niño on Primary Education Completion

Dep. Variable:	**Primary Education Completion**					
	Full	Full	Urban	Urban	Rural	Rural
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Sample: Born between 1975-1983						
treatment_inutero	-0.00197	-0.00141	-0.0144**	-0.0144**	0.0305	0.0358
	(0.00813)	(0.00807)	(0.00690)	(0.00689)	(0.0311)	(0.0310)
treatment_2y	0.00664	0.00679	0.00106	0.00103	0.0234	0.0237
	(0.00647)	(0.00639)	(0.00535)	(0.00538)	(0.0225)	(0.0225)
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
Number of observations (N)	36,053	36,053	27,593	27,593	8,460	8,460
Adjusted R^2	0.173	0.186	0.094	0.094	0.181	0.197

Notes: This table reports the effect of in-utero exposure and early in life exposure to the 1982-1983 El Niño on primary education completion for individuals born between 1975-1983. The variable treatment_inutero equals one if the individual was exposed to the 1982-1983 El Niño while in-utero, and zero otherwise. The variable treatment_2y equals one if the individual was exposed to the 1982-1983 El Niño after birth up to two years old, and zero otherwise. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Table A5: Balance in covariates: 1982-1983 El Niño

	Control Group	Treatment Group	Dif T-C	Dif T-C	Dif T-C	Dif T-C	Dif T-C
Sample:	Full	Full	Full	Urban	Rural	Female	Male
Dep Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
sewage	0.799	0.680	-0.0114	-0.00545	-0.0346	-0.0192	-0.00487
			(0.00939)	(0.0105)	(0.0274)	(0.0172)	(0.0145)
water	0.815	0.703	-0.00568	-0.0160	0.0133	-0.0157	0.00400
			(0.0110)	(0.0116)	(0.0221)	(0.0167)	(0.0155)
electricity	0.888	0.781	-0.000857	-0.00614	0.0174	-0.00946	0.00559
			(0.00826)	(0.00698)	(0.0230)	(0.0106)	(0.0127)
household_size	6.487	6.646	-0.0138	-0.0380	0.0841	-0.133	0.0839
			(0.0739)	(0.0884)	(0.160)	(0.110)	(0.0951)
poor_extreme	0.083	0.156	0.00820	0.00419	-0.00975	0.0131	0.00256
			(0.00731)	(0.00690)	(0.0268)	(0.0127)	(0.0106)
poor	0.334	0.461	0.00679	0.00435	0.0236	0.00276	0.0163
			(0.0154)	(0.0179)	(0.0271)	(0.0208)	(0.0210)
urban	0.846	0.746	-0.000351			-0.00831	0.00754
			(0.00918)			(0.0139)	(0.0138)
age in years	25.75	22.74	-0.0163	-0.0239	0.0277	-0.0135	-0.0214
			(0.0177)	(0.0204)	(0.0250)	(0.0245)	(0.0261)
isfemale	0.467	0.458	0.0307*	0.0303	0.0465		
			(0.0169)	(0.0197)	(0.0367)		
spanish	0.928	0.919	0.00643	0.00426	-0.0123	0.0256	-0.0142
			(0.00979)	(0.0108)	(0.0261)	(0.0156)	(0.0121)
mother_moreprimary	0.333	0.239	-0.0242*	-0.0280*	-0.00301	-0.0727***	0.0188
			(0.0136)	(0.0162)	(0.0111)	(0.0247)	(0.0243)
father_moreprimary	0.466	0.350	-0.0329**	-0.0290*	-0.0194	-0.0234	-0.0453**
			(0.0149)	(0.0170)	(0.0211)	(0.0234)	(0.0201)
Test of joint significance	F-stat: 1.11 (p-value: 0.348)						

Notes: Column 1 and column 2 report the sample mean for individuals in the control and in the treatment group, respectively. The sample is restricted to individuals born between 1975-1983. Columns 3-7 display the estimate on the treatment dummy in a regression of each variable on treatment. The regression controls for cohort of birth fixed effects, province of residence fixed effects, district of birth fixed effects, and survey year fixed effects. Standard errors clustered at the district of birth are shown in parentheses. A test for the joint significance of the coefficients is performed after running a regression of the treatment dummy on the baseline covariates. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A6: Balance in covariates: 1997-1998 El Niño

	Control Group	Treatment Group	Dif T-C	Dif T-C	Dif T-C	Dif T-C	Dif T-C
Sample:	Full	Full	Full	Urban	Rural	Female	Male
Dep Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
sewage	0.754	0.735	0.0127	-0.0216	0.0611*	-0.0136	0.0373
			(0.0168)	(0.0167)	(0.0337)	(0.0246)	(0.0234)
water	0.811	0.865	-0.00708	-0.0114	-0.00200	-0.0223	0.0128
			(0.0174)	(0.0170)	(0.0327)	(0.0269)	(0.0231)
electricity	0.928	0.951	-0.000184	-0.00308	0.00188	-0.0114	0.0109
			(0.00844)	(0.00515)	(0.0279)	(0.0112)	(0.0117)
household_size	5.697	5.363	-0.112	-0.121	0.125	-0.191	-0.0286
			(0.0816)	(0.0959)	(0.156)	(0.137)	(0.111)
poor_extreme	0.040	0.024	-0.00645	-0.00391	-0.0155	-0.00426	-0.00608
			(0.00684)	(0.00471)	(0.0208)	(0.00858)	(0.0106)
poor	0.202	0.140	-0.0167	-0.0199	-0.00905	0.0111	-0.0315
			(0.0151)	(0.0156)	(0.0312)	(0.0207)	(0.0211)
urban	0.782	0.779	-0.00169			-0.0128	0.0105
			(0.0142)			(0.0198)	(0.0189)
age in years	19.69	17.78	-0.0223	0.000692	-0.0730**	-0.0216	-0.00936
			(0.0219)	(0.0283)	(0.0296)	(0.0300)	(0.0313)
isfemale	0.463	0.460	-0.0586**	-0.0488	-0.0586		
			(0.0271)	(0.0338)	(0.0372)		
spanish	0.885	0.884	-0.00468	0.00511	-0.0340	-0.0190	0.00786
			(0.0140)	(0.0152)	(0.0277)	(0.0248)	(0.0153)
mother_moreprimary	0.397	0.433	0.0164	0.0208	0.00840	-0.0146	0.0435
			(0.0260)	(0.0330)	(0.0223)	(0.0384)	(0.0320)
father_moreprimary	0.529	0.558	0.0246	0.0244	0.0470	0.00968	0.0407
			(0.0220)	(0.0273)	(0.0300)	(0.0346)	(0.0280)
Test of joint significance		F-stat: 0.93 (p-value: 0.520)					

Notes: Column 1 and column 2 report the sample mean for individuals in the control and in the treatment group, respectively. The sample is restricted to individuals born between 1990-1998 and who are older than 16 years old. Columns 3-7 display the estimate on the treatment dummy in a regression of each variable on treatment. The regression controls for cohort of birth fixed effects, province of residence fixed effects, district of birth fixed effects, and survey year fixed effects. Standard errors clustered at the district of birth are shown in parentheses. A test for the joint significance of the coefficients is performed after running a regression of the treatment dummy on the baseline covariates. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Table A7: Falsification Test: El Niño 1985-1986

	Full	Full	Urban	Urban	Rural	Rural
	(1)	(2)	(3)	(4)	(5)	(6)
Sample: Born between 1985-1988						
Panel A: Primary Education Completion						
treatment_inutero	0.00746	0.00703	0.00366	0.00371	0.0321	0.0286
	(0.00608)	(0.00605)	(0.00561)	(0.00563)	(0.0207)	(0.0203)
Number of observations (N)	33,664	33,664	23,454	23,454	10,210	10,210
Adjusted R^2	0.143	0.148	0.124	0.124	0.144	0.155
Panel B: Secondary Education Completion						
treatment_inutero	0.00416	0.00424	0.00134	0.00188	0.0230	0.0198
	(0.0128)	(0.0126)	(0.0147)	(0.0147)	(0.0308)	(0.0309)
Number of observations (N)	29,178	29,178	20,705	20,705	8,473	8,473
Adjusted R^2	0.240	0.267	0.137	0.141	0.246	0.249
Panel C: Years of Education						
treatment_inutero	0.0149	0.0116	0.0152	0.0217	0.126	0.119
	(0.0624)	(0.0623)	(0.0741)	(0.0751)	(0.127)	(0.127)
Number of observations (N)	46,374	46,374	31,233	31,233	15,141	15,141
Adjusted R^2	0.524	0.541	0.513	0.517	0.398	0.401
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

Notes: This table reports the effect of in-utero exposure to a placebo 1985-1986 El Niño on primary education completion (Panel A), on secondary education completion (Panel B), and on total years of education (Panel C) for individuals born between 1985-1988. The variable treatment_inutero equals one if the individual was exposed to a false El Niño of 1985-1986 while in-utero, and zero otherwise. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A8: Falsification Test: El Niño 2000-2001

Dep. Variable: Sample	educ Full	educ Full	educ Urban	educ Urban	educ Rural	educ Rural	primary Full	primary Full
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Sample: Born between 2000-2003								
treatment_inutero	0.00218	0.000365	-0.00507	-0.00679	0.0180	0.0171	0.00162	-0.00164
	(0.0259)	(0.0254)	(0.0332)	(0.0331)	(0.0377)	(0.0377)	(0.00570)	(0.0168)
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Number of observations (N)	51,149	51,149	28,376	28,376	22,773	22,773	723	723
Adjusted R^2	0.901	0.903	0.922	0.922	0.862	0.862	0.609	0.609

Notes: This table reports the effect of in-utero exposure to a placebo 2000-2001 El Niño on education outcomes for individuals born between 2000-2003. The variable treatment_inutero equals one if the individual was exposed to the 2000-2001 El Niño while in-utero, and zero otherwise. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table A9: The effect of the 1982-1983 El Niño on Primary Education Completion: Heterogeneous Effects (by gender)

Sample: Born between 1975-1983						
Dep. Variable:	**Primary Education Completion**					
	Men	Men	Men Urban	Men Urban	Men Rural	Men Rural
	(1)	(2)	(3)	(4)	(5)	(6)
shock_inutero	-0.00191	-0.00247	-0.0105***	-0.0105***	0.0387***	0.0387***
	(0.00413)	(0.00402)	(0.00382)	(0.00382)	(0.0137)	(0.0138)
Number of observations (N)	19,702	19,702	14,622	14,622	5,080	5,080
Adjusted R^2	0.154	0.162	0.093	0.092	0.162	0.161
	Women	Women	Women Urban	Women Urban	Women Rural	Women Rural
	(1)	(2)	(3)	(4)	(5)	(6)
shock_inutero	-0.000113	-0.000101	-0.00130	-0.00131	0.0165	0.0166
	(0.00481)	(0.00475)	(0.00379)	(0.00378)	(0.0247)	(0.0246)
Number of observations (N)	16,351	16,351	12,971	12,971	3,380	3,380
Adjusted R^2	0.277	0.291	0.176	0.176	0.275	0.276
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

Notes: This table reports the effect of intensity of exposure to the 1982-1983 El Niño on primary education completion for individuals born between 1975-1983. The treatment variable is the number of months of exposure to intense floods. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Table A10: The effect of the 1982-1983 El Niño on Secondary Education Completion: Heterogeneous Effects (by gender)

Sample: Born between 1975-1983						
Dep. Variable:	**Secondary Education Completion**					
	Men	Men	Men Urban	Men Urban	Men Rural	Men Rural
	(1)	(2)	(3)	(4)	(5)	(6)
treatment_inutero	0.0108	0.00921	-0.00946	-0.00920	0.0932**	0.0932**
	(0.0196)	(0.0194)	(0.0232)	(0.0232)	(0.0434)	(0.0433)
Number of observations (N)	19,667	19,667	14,600	14,600	5,067	5,067
Adjusted R^2	0.218	0.244	0.143	0.143	0.244	0.244
Mean Dv (Treatment==0)	0.78	0.78	0.84	0.84	0.48	0.48
	Women	Women	Women Urban	Women Urban	Women Rural	Women Rural
	(1)	(2)	(3)	(4)	(5)	(6)
treatment_inutero	-0.0189	-0.0164	-0.0271	-0.0275	0.0629	0.0633
	(0.0201)	(0.0202)	(0.0209)	(0.0209)	(0.0695)	(0.0695)
Number of observations (N)	16,310	16,310	12,943	12,943	3,367	3,367
Adjusted R^2	0.305	0.333	0.203	0.203	0.303	0.302
Mean Dv (Treatment==0)	0.83	0.83	0.89	0.89	0.43	0.43
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

Notes: This table reports the treatment effects estimates on secondary education completion for individuals born between 1975-1983 and who are older than 17 years old. Column 1, column 3, and column 5 show the estimates without control variables while control variables are added in Column 2, column 4, and column 6. Each regression includes survey-year fixed effect, district of birth fixed effect, cohort of birth fixed effects, and province of residence fixed effect. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Table A11: The effect of the 1997-1998 El Niño on Primary Education Completion: Heterogeneous Effects (by gender)

Sample: Born between 1990-1998						
Dep. Variable:	**Primary Education Completion**					
	Men	Men	Men Urban	Men Urban	Men Rural	Men Rural
	(1)	(2)	(3)	(4)	(5)	(6)
treatment_inutero	0.00879	0.00848	0.0191***	0.0192***	-0.0232	-0.0237
	(0.00647)	(0.00648)	(0.00661)	(0.00663)	(0.0166)	(0.0167)
Number of observations (N)	31,755	31,755	20,658	20,658	11,097	11,097
Adjusted R^2	0.081	0.083	0.094	0.095	0.070	0.070
Mean Dv (Treatment==0)	0.97	0.97	0.98	0.98	0.94	0.94
	Women	Women	Women Urban	Women Urban	Women Rural	Women Rural
	(1)	(2)	(3)	(4)	(5)	(6)
treatment_inutero	0.00892	0.00949	0.0103	0.0102	0.0148	0.0147
	(0.0103)	(0.0104)	(0.0125)	(0.0125)	(0.0244)	(0.0244)
Number of observations (N)	26,612	26,612	18,478	18,478	8,134	8,134
Adjusted R^2	0.107	0.114	0.080	0.080	0.127	0.127
Mean Dv (Treatment==0)	0.97	0.97	0.99	0.99	0.92	0.92
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

Notes: This table reports the treatment effects estimates on primary education completion for individuals born between 1990-1998 and who are older than 16 years old. Column 1, column 3, and column 5 show the estimates without control variables while control variables are added in Column 2, column 4, and column 6. Each regression includes survey-year fixed effect, district of birth fixed effect, cohort of birth fixed effects, and province of residence fixed effect. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Table A12: The effect of the 1982-1983 El Niño on Primary Education Completion: Heterogeneous Effects (by parental education)

Dep. Variable:	**Primary Education Completion**					
	Mother no primary educ	Mother no primary educ	Mother no primary educ Urban	Mother no primary educ Urban	Mother no primary educ Rural	Mother no primary educ Rural
	(1)	(2)	(3)	(4)	(5)	(6)
treatment_inutero	-0.000483	-0.00101	-0.0188*	-0.0188*	0.0238	0.0241
	(0.0106)	(0.0106)	(0.00959)	(0.00960)	(0.0304)	(0.0304)
Number of observations (N)	26,151	26,151	17,987	17,987	8,164	8,164
Adjusted R^2	0.169	0.179	0.098	0.098	0.176	0.176
	Father no primary educ	Father no primary educ	Father no primary educ Urban	Father no primary educ Urban	Father no primary educ Rural	Father no primary educ Rural
	(1)	(2)	(3)	(4)	(5)	(6)
treatment_inutero	-0.00311	-0.00340	-0.0257**	-0.0257**	0.0242	0.0243
	(0.0124)	(0.0125)	(0.0117)	(0.0117)	(0.0323)	(0.0322)
Number of observations (N)	21,379	21,379	13,716	13,716	7,663	7,663
Adjusted R^2	0.177	0.185	0.126	0.126	0.174	0.174
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

Notes: This table reports the treatment effects estimates on primary education completion for individuals born between 1975-1983 and who are older than 16 years old. Column 1, column 3, and column 5 show the estimates without control variables while control variables are added in Column 2, column 4, and column 6. Each regression includes survey-year fixed effect, district of birth fixed effect, cohort of birth fixed effects, and province of residence fixed effect. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01,^{**} p < 0.05,^{*} p < 0.1$.

Table A13: The effect of the 1982-1983 El Niño on Primary Education Completion (continued): Heterogeneous Effects (by parental education)

Dep. Variable:	Primary Education Completion					
	Father primary educ	Father primary educ	Father primary educ Urban	Father primary educ Urban	Father primary educ Rural	Father primary educ Rural
	(1)	(2)	(3)	(4)	(5)	(6)
treatment_inutero	-0.00287	-0.00297	-0.00383	-0.00385	-0.00738	-0.00831
	(0.00504)	(0.00501)	(0.00485)	(0.00485)	(0.0911)	(0.0901)
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes
Number of observations (N)	14,674	14,674	13,877	13,877	797	797
Adjusted R^2	0.032	0.032	0.008	0.008	0.128	0.135

Notes: This table reports the treatment effects estimates on primary education completion for individuals born between 1975-1983 and who are older than 16 years old. Column 1, column 3, and column 5 show the estimates without control variables while control variables are added in Column 2, column 4, and column 6. Each regression includes survey-year fixed effect, district of birth fixed effect, cohort of birth fixed effects, and province of residence fixed effect. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$.

Table A14: The effect of the 1997-1998 El Niño on Primary Education Completion: Heterogeneous Effects (by parental education)

Dep. Variable:	**Primary Education Completion**					
Sample:	Full	Full	Urban	Urban	Rural	Rural
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Mother without primary education						
treatment_inutero	0.00675	0.00644	0.0130	0.0124	-0.0164	-0.0170
	(0.00875)	(0.00872)	(0.0117)	(0.0117)	(0.0150)	(0.0150)
Number of observations (N)	38,494	38,494	20,690	20,690	17,804	17,804
Adjusted R^2	0.073	0.076	0.073	0.073	0.080	0.080
Panel B: Mother with primary education						
treatment_inutero	0.00463	0.00464	0.00397	0.00402	0.0456	0.0480
	(0.00337)	(0.00334)	(0.00329)	(0.00326)	(0.0483)	(0.0487)
Number of observations (N)	19,873	19,873	18,446	18,446	1,427	1,427
Adjusted R^2	0.059	0.059	0.059	0.059	0.221	0.222
Panel C: Father without primary education						
treatment_inutero	0.00276	0.00253	0.0109	0.0107	-0.0209	-0.0213
	(0.00868)	(0.00865)	(0.0102)	(0.0102)	(0.0166)	(0.0166)
Number of observations (N)	31,115	31,115	15,147	15,147	15,968	15,968
Adjusted R^2	0.074	0.076	0.074	0.074	0.077	0.077
Panel D: Father with primary education						
treatment_inutero	0.00498	0.00503	0.00471	0.00477	-0.00521	-0.00567
	(0.00855)	(0.00855)	(0.00962)	(0.00962)	(0.0239)	(0.0242)
Number of observations (N)	27,252	27,252	23,989	23,989	3,263	3,263
Adjusted R^2	0.068	0.068	0.070	0.070	0.081	0.082
Cohort of Birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Province of residence FE	Yes	Yes	Yes	Yes	Yes	Yes
Survey year FE	Yes	Yes	Yes	Yes	Yes	Yes
District of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

Notes: This table reports the treatment effects estimates on primary education completion for individuals born between 1990-1998 and who are older than 16 years old. Column 1, column 3, and column 5 show the estimates without control variables while control variables are added in Column 2, column 4, and column 6. Each regression includes survey-year fixed effect, district of birth fixed effect, cohort of birth fixed effects, and province of residence fixed effect. Standard errors clustered at the district of birth are shown in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.