Impact of Early-Life Shocks on Human Capital Formation: Evidence from El Niño Floods in Ecuador

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Abstract

A growing body of research argues that adverse experiences in utero and during early childhood have lasting effects, not only on later health outcomes but also on human capital accumulation. In this paper, I investigate the persistent effect of negative shocks early in life on children's health and cognitive outcomes in a developing country and explore whether shocks at certain periods matter more than others. I exploit geographic intensity of extreme floods, during the 1997-1998 El Niño phenomenon in Ecuador, as a source of exogenous variation in children's exposure to a negative shock at different periods early in life. I show that children exposed to severe floods in utero, especially in the third trimester, experience a decline in height five and seven years later. Also, children affected by the floods in the first trimester of pregnancy score lower in cognitive tests. I explore potential mechanisms by studying how exposure to the El Niño shock affected key inputs to the production of children's human capital: birth weight and family inputs (income, consumption, and breastfeeding). Children exposed to El Niño floods, especially in the third trimester in utero, are more likely to be born with low birth weight. Regarding family inputs, households affected by El Niño 1997-98 suffered a decline in income, total consumption, and food consumption in the aftermath of the shock. Also, exposure to El Niño floods decreased the duration of exclusive breastfeeding, but increased the duration of non-exclusive breastfeeding. Falsification exercises suggest that selection concerns, such as selective fertility, mobility, and infant mortality, do not drive these results.

Keywords: Early-life shocks, weather shocks, human capital acumulation, family inputs

JEL codes: J13, Q54, I20, O12

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1 Introduction

A growing body of research argues that adverse experiences in utero and during early childhood have lasting effects not only on later health outcomes but also on human capital accumulation. This interest is inspired by the modern literatures in health and economics, which demonstrate that genetics do not play the exclusive role in explaining the evolution of health, cognitive and socio-emotional skills. In contrast, the environment and family investments play a major role in determining skill development and subsequent inequalities (Almond and Currie, 2011; Barker, 1995; Cunha and Heckman, 2007; Gluckman and Hanson, 2005; Heckman, 2007).

Because differences in early environments may be confounded with family unobserved characteristics, an increasing number of studies rely on natural experiments as sources of exogenous variation in negative conditions during early childhood in order to identify their causal impact on later child and adult outcomes. Such adverse circumstances include pandemics (Almond, 2006 (US); Kelly, 2011 (U.K)); famines (Almond et al., 2010; Meng and Qian, 2009 (China), Dercon and Porter, 2010 (Ethiopia), and Scholte et al., 2012 (Netherlands)); armed conflicts (Akresh et al., 2012 (Nigeria), Camacho, 2008); radioactive emissions (Almond et al., 2009, Black et al., 2013); and extreme weather shocks (Currie and Rossin-Slater, 2013 (US); Ugaz and Zanolini, 2011 (Philippines); Rabassa et al., 2012 (Nigeria), Shah and Steinberg, 2012 (India); Aguilar and Vicarelli, 2011 (Mexico)). While this literature initially focused on health outcomes, more recently, it has also considered the effect of negative shocks on educational and labor outcomes.

The empirical evidence suggests that experiences during early childhood can have long lasting effects on later outcomes. However, there remain some open questions. First, there is still little evidence about timing of exposure or whether events at certain periods matter more than others. A second related question is whether timing of exposure matters differentially by type of skills. For instance, is formation of cognitive skills more vulnerable to shocks in certain periods compared to health skills? Third, most of the previous literature looks at the impacts of negative shocks on long term human capital outcomes and rarely has explored potential mechanisms, thus making it difficult to inform potential remediating policies. I address these questions in this paper. In particular, I use geographic intensity of extreme floods, during the 1997-1998 El Niño phenomenon in Ecuador, as a source of exogenous variation in children's exposure to a negative shock at different periods early in life.

Extreme weather events constitute a relevant type of shock since recent trends in global climate change suggest that they may become more frequent and their intensity more unpredictable (Kovats et al., 2003). Income losses, consumption fluctuations, and infectious diseases are among the consequences of weather shocks (Baez et al., 2010). These changes can disrupt development before birth and during early childhood, both of which have been shown to be important periods for future human capital development. Because households, especially those disadvantaged ones, fail to protect consumption of food, health and education, uninsured extreme weather shocks can have considerable and lasting effects on children's human capital (Baez et al., 2010). Most of the research in developing countries has emphasized the effects of weather shocks on nutritional and health outcomes, while the evidence on cognitive and educational outcomes is still growing.[1]

Theoretically, the dynamic nature of skill formation explains the persistence of a negative shock early in life into later childhood and beyond. Two features of the production of human capital across the life cycle support this idea. First, the stock of future skills is directly affected by the stock of past skills, an effect that is known as "self-productivity"(Cunha and Heckman, 2007). This mechanism implies that, if a negative shock occurs at an influential stage of human capital formation, it will not only affect the child's current skill endowments,

[1] Regarding health outcomes, some studies have found full or partial recovery in terms of weight loss (Foster, 1995), but not in terms of height, especially among poor households (Del Ninno and Lundberg, 2005). Indeed, there is a large body of evidence that demonstrates persistent effects of exposure to natural disasters during pregnancy and early years on height in late childhood and adolescence (Aguilar and Vicarelli, 2011; Alderman et al., 2006; Hoddinott and Kinsey, 2001; Porter et al., 2008; Ugaz and Zanolini, 2011). Regarding lasting effects of natural disasters on cognitive test scores, Shah and Steinberg (2012) provide evidence that exposure to droughts in utero reduced test scores among school-aged children in India, both in math and reading. Aguilar and Vicarelli (2011) studied the medium-term effects of the El Niño phenomenon in Mexico on children's outcomes (four to five years later). They estimated that children exposed to the shock early in life scored 11-12 percent lower than same-aged children not exposed to the shock.

but also reduce future accumulation of skills. Second, the current level of skills influences the productivity of future investments, a feature known as "dynamic complementarity"(Cunha and Heckman, 2007). This mechanism implies that a negative shock to current skill endowments will also affect the evolution of future human capital by decreasing the productivity of investments.

To investigate the lasting effects of early-life exposure to severe floods on later child development and whether timing of exposure matters, I combine rainfall data with a dataset that collected children's health and cognitive outcomes five and seven years after the disaster. I identify exposure to severe floods using two sources of variation. First, I exploit timing-of-birth variation since the sampled children were born between 1998 (during the shock) and 2002 (fours years later). Second, I rely on geographic variation in the exposure to the floods since the sample includes villages in the coast and in the highlands. Findings suggest that children who were in utero during El Niño 1997-98 experience a decline in height, tend to be more anemic, and score lower in vocabulary tests five and seven years after the shock. Average effect sizes fall between 0.09 and 0.13 standard deviations. Further, the timing-of-exposure results are in line with the medical literature findings on sensitive periods for growth and brain development. The negative effect on height comes from exposure in the third trimester while the deficit in cognition comes from exposure in the first trimester of pregnancy.

To explore potential mechanisms behind the persistent effects, this paper also looks at the impact of El Niño floods on inputs to human capital production: birth endowments and family inputs (income, consumption, and breastfeeding). I match rainfall data with two Ecuadorian household surveys: the Reproductive and Health Surveys (RHS) and the Living Standard Measurement Studies (LSMS) surveys. Both have the advantage of having been collected both before the 1997-98 El Niño shock and afterwards. I find that children exposed to El Niño floods, especially in the third trimester of pregnancy, are more likely to be born with low birth weight. Regarding family inputs, I show that households affected by El

Niño 1997-98 suffered a decline in income, total consumption and food consumption. Also, I show that exposure to El Niño floods decreased the duration of exclusive breastfeeding but increased the duration of total breastfeeding (breast milk combined with formula and/or food).

The results presented in this paper are robust to an exhaustive set of falsification and specification tests that rule out the presence of confounding factors or changes in the composition of families living (giving birth) in villages more affected by the shock. I also directly examine selection concerns related to endogenous fertility and migration and find that they do not seem to drive the results. All of these tests provide support for the validity of my identification strategy.

My study builds on and contributes to both the early influences literature and the climate change literature in economics. First, this paper goes beyond analyzing the impact of early-life shocks on later outcomes and contributes to understanding how different inputs to the production of human capital respond to negative early childhood influences, evidence that is still rare in developing countries. To my knowledge, this paper is the first to document the responses of birth endowments to extreme weather shocks in a developing country as well as investment responses in terms of exclusive and total breastfeeding. Second, my analysis explores timing of exposure to the shock within the prenatal period and provides additional evidence of sensitive periods to the evolution of health and cognitive skills. Third, my findings highlight relevant implications for developing policies that improve the coping mechanisms against negative shocks that affect not only income but also parental stress and health. Those policies should target disadvantaged families with children and pregnant women not just before giving birth but early in pregnancy in order to prevent the negative consequences on children's development.

The remainder of the paper is organized as follows. Section 2 presents a theoretical framework to conceptualize the persistent effects of early-life shocks. Section 3 describes the 1997-1998 El Niño shock and outlines the sources of data. Section 4 discusses the empirical strategy and my findings regarding the lasting effects on children's health and cognitive outcomes. Section 5 presents the results of birth endowment responses, and the evidence on family input responses is presented in Section 6. Section 7 discusses some selection concerns. Section 8 presents further discussion and conclusions.

2 Theoretical framework

This section illustrates the role of early-life shocks on children's human capital using the dynamic model of human capabilities formation developed by Heckman (2007), Cunha and Heckman (2007), and Cunha et al. (2010). In contrast to the traditional static model, the life-cycle perspective is key to understanding the persistence of a negative shock early in life into later childhood and beyond. In this framework, the notion that "skills beget skills" interacts with family and environmental influences to explain the importance of early disadvantage. The model shows that an early-life shock can affect later outcomes through two main mechanisms: the self-productivity of human capital, and the family investment responses. First, the stock of future skills is directly affected by the stock of past skills, an effect that is known as "self-productivity" (Cunha and Heckman, 2007). If a shock occurs in an influential stage of human capital formation, it directly affects the skill endowment itself, and damages can persist. Second, the level of skills determines the productivity of future investments, a feature known as "dynamic complementarity" (Cunha and Heckman, 2007). Thus, investment responses also account for the influence of early-life shocks on later human capital formation.

In the model developed by Heckman and coauthors, capabilities, captured in the vector θ, are multidimensional and can be cognitive (C), socio-emotional (SE) or health-related skills (H)[2]. Because parents care about the quality of their children's human capital, they make investments that can take the form of goods such as food, books, clothing, toys, etc; and time such as breastfeeding, cognitive stimulation, etc. For simplicity, both type of investments are

[2] In this paper, I focus only on health and cognitive skills.

captured in the vector I. Investments interact with the previous stock of child's skills (θ_t), parental endowments (θ_P) and shocks (π) in the production of further skills (θ_{t+1}). Formally, following Cunha et al. (2010), the technology of skill formation for skill $k \in \{C, SE, H\}$ when the child is t years old can be written as[3]:

$$\theta_{k,t+1} = f_k(\theta_t, I_{k,t}, \theta_P, \pi_t) \tag{1}$$

where t denotes developmental periods: $t = -1(inutero), 0(birth)....., T$. However, investment decisions are endogenous and also affected by shocks:

$$I_{k,t} = q_k(\theta_t, \theta_P, \pi_t) \tag{2}$$

To better illustrate the effects of in-utero exposure to negative shocks, I assume two periods of childhood: birth/infancy ($t = 0$) and childhood ($t = 1$). The production of skill k at birth ($\theta_{k,0}$) and investment choices are:

$$\theta_{k,0} = f_k(\theta_{-1}, I_{k,-1}, \theta_P, \pi_{-1}) \quad \text{, and} \quad I_{k,-1} = q_k(\theta_{-1}, \theta_P, \pi_{-1}) \tag{3}$$

where $I_{k,-1}$ captures prenatal investments, θ_{-1} denotes genetic skills at conception and π_{-1} corresponds to shocks during pregnancy. Similarly, the production of skills during early childhood ($\theta_{k,1}$) and investments ($I_{k,0}$) are:

$$\theta_{k,1} = f_k(\theta_0, I_{k,0}, \theta_P, \pi_0) \quad \text{, and} \quad I_{k,0} = q_k(\theta_0, \theta_P, \pi_0) \tag{4}$$

where $I_{k,0}$ corresponds to investments during birth/infancy, and π_0 captures shocks in the form of disruptions to infancy environments. To examine the effects of a negative shock, this paper uses exposure to severe floods during 1997-98 in Ecuador, known as "El Niño

[3]The model assumes that f_k is monotonically increasing, and twice continuously differentiable in its arguments; and concave in investments.

phenomenon." This shock caused income losses, consumption fluctuations, and infectious diseases, among other negative consequences that will be described below.

We can use this framework to show how experiencing a negative shock in utero π_{-1} affects skills at birth and in later years. First, the total effect on child's skills k at birth (t=0) can be decomposed as follows:

$$\frac{d\theta_{k,0}}{d\pi_{-1}} = \underbrace{\frac{\partial \theta_0}{\partial \pi_{-1}}}_{\text{Biological}} + \underbrace{\frac{\partial \theta_0}{\partial I_{-1}} \frac{\partial I_{-1}}{\partial \pi_{-1}}}_{\text{Investment Channel}} \tag{5}$$

The first term on the right-hand side captures the biological effect of in utero exposure to a shock, which is expected to be negative. Seminal work from epidemiology has establish that due to disruptions in the prenatal environment fetus makes adaptations to increase the likelihood of survival (Barker, 1995; Gluckman and Hanson, 2005). These adaptations may be irreversible if shocks are intense causing damages that manifest later in life. The second term captures the investment responses to the shock and its sign is ambiguous. A negative shock can alter prenatal investments in several ways. First, severe floods increase infection diseases and parental stress, which can alter maternal endowments such as physical and mental health that further affect fetal development. Additionally, weather shocks can cause agricultural losses and infrastructure damages, which affect household wealth and maternal nutrition. These consequences can negatively affect prenatal investments. However, these direct consequences can lead to indirect effects such as changes in relative prices and wages, which are accompanied by income and substitution effects. On one hand, the income effect implies tighter budget constraints and fewer resources to invest prenatally (both time and goods investments). On the other hand, a decline in wages implies a decrease in the opportunity cost of time which could positively affect time investments like attending prenatal health care. Overall, the sign of second term on the right-hand side, the investment channel, is ambiguous which also makes the total effect of a negative shock in utero on child's skills at birth ambiguous.

Furthermore, exposure to shocks early in life can have lasting effects on children's future skills. Equation 6 shows the total effect of in utero exposure to a negative shock on child's skill k in the next period (t=1, early childhood):

$$\frac{d\theta_{k,1}}{d\pi_{-1}} = \underbrace{\frac{\partial\theta_1}{\partial\theta_0}\frac{d\theta_0}{d\pi_{-1}}}_{\text{Skills' Self-Productivity}} + \underbrace{\frac{\partial\theta_1}{\partial I_0}\frac{\partial I_0}{\partial\theta_0}\frac{d\theta_0}{d\pi_{-1}}}_{\text{Investment Channel}} \tag{6}$$

Note that the first term ("the biological effect") is augmented by the self-productive character of human skills: the stock of skills at one stage reinforces the skills attained later (Heckman, 2007). The second term captures parental investment responses to a negative shock to *previous* skills. Parental investments could reinforce or compensate the negative shock to skills, which again make this term ambiguous. Therefore, the total effect of in-utero exposure to adverse events on later human capital is ambiguous and is composed by the biological/self-productivity channel plus the parental investment responses.

Since the effects of early-life shocks are theoretically ambiguous, this paper uses exposure to severe floods in Ecuador to evaluate these effects empirically. Ideally, one would like to decompose the total effect on the two channels: the "biological" or "self-productivity" channel and the investment responses channel. However, this requires access to longitudinal data on children exposed to a shock that contains both investments and child skills from birth through later periods. I am unable to perform such analysis because that data is rare in developing countries. Thus, I estimate the net effects of exposure to a negative shock early in life on children's cognitive and health skills five and seven years later. Additionally, using secondary data, I analyze the effects on some family inputs/investments - family income, consumption and breastfeeding - which allows me to gain a better understanding of potential intermediate pathways. This analysis offers a more complete picture of the lasting effect of exposure to negative shocks early in life that go beyond the medium-term effects, evidence that is still rare in developing countries.

3 Background and data

3.1 El Niño 1997-1998 in Ecuador

El Niño is a recurrent climate event that causes several weather disasters, from heavy rainfall, severe flooding and landslides in the west coast of South America to extreme droughts in Indonesia. Because the cycle of this event is irregular and varies in length from two to seven years, the exact timing and intensity of each occurrence remains uncertain (Kovats et al., 2003).

The El Niño event of 1997-98 in Ecuador was extremely severe. In fact, it was the greatest in magnitude compared to the previous 28 events during the 20th century (FAO, 2010). The event was exceptionally intense and long, lasting 19 months from January 1997 through August 1998, with levels of precipitation more than five times normal levels (see Figure 1). Further, local and international media documented that the strength and timing of the floods were unpredictable (The Economist 1998). The total social and economic losses were $2.8 billions (13 % of Ecuador's GDP in 1996), with agriculture and infrastructure sectors suffering most of the negative consequences (ECLAC, 1998).

Losses in the agricultural sector accounted for approximately 6% of the GDP[4]. The area of crops damaged or lost was around 30% of the total area under cultivation in the country. Not only some of the cultivated area could not be harvested, but the next planting season was also altered. The most affected crops were rice, corn, sugar cane, coffee and cocoa (CAF, 2000). Geographically, the losses in the agricultural sector were concentrated in the coastal states, matching the regions most affected by extreme precipitation. (See figure 2).

Costs in the infrastructure and transportation sector corresponded to 3.7% of the GDP, where damages to roads and bridges led to an increase in transportation costs. These negative consequences to the agriculture and infrastructure sectors affected food and general prices. Housing, health centers and schools were also severely affected by the floods and landslides.

[4] Agriculture represented 14% of Ecuador's GDP between 1997-2000

Floods also caused damages to sanitation, drinking water and sewer infrastructure. Water contamination increased the risk of contracting diarrhea, cholera, malaria, dengue fever and other infectious diseases. Indeed, malaria cases increased by 160% and dengue fever cases by 100% compared to 1996 (PAHO, 2000).

3.2 Data

Rainfall data

To measure villages' exposure to the El Niño phenomenon, this study gathers rainfall data from 244 weather stations in Ecuador between 1971 and 2000. This rich dataset allows to measure the severe floods during El Niño 1997-1998 using the long-term mean precipitation (1971-2000) as reference.[5]

Exposure to El Niño

A key component of this paper is the identification of villages' exposure and the intensity of El Niño flooding. El Niño 1997-1998 lasted approximately 19 months, from January 1997 to August 1998 (CAF (2000); and, Ecuador Meteorological Department). Using monthly precipitation data for this period, I measure excess rainfall for each month (m) and weather station (s) as the deviation of the observed precipitation from the long-term mean (1971-2000) divided by the historical monthly standard deviation:

$$sd\_excess\_rainfall_{m,y,s} = \frac{(P_{m,y,s} - \overline{P_{m,s}})}{\sigma_{m,s}} \tag{7}$$

where $P_{m,y,s}$ is the observed precipitation for a given month m in year y at weather station s. $\overline{P_{m,s}}$ is the long term mean (1971-2000) for month m at location s, and $\sigma_{m,s}$ is the corresponding standard deviation. This index is known in the climatology literature as precipitation anomalies. According to climatologists, when analyzing extreme precipitation

[5] Results are robust to using as reference the mean precipitation during previous El Niño phenomenons to capture a more unexpected dimension of the 1997-98 shock.

events, excess of rainfall measures should be expressed in terms of standard deviations in order to provide more information about the magnitude of the anomaly after the influence of normal dispersion has been removed (The International Research Institute for Climate and Society, IRI).

Because the child and family data is geographically identified at the village level, the monthly excess of rainfall indicators are matched to the villages using the closest weather station to the center of each village[6] (Maccini and Yang, 2009). At the village level (v), I calculate the exposure to El Niño as the numbers of months between January 1997 and August 1998 where the observed excess of rainfall exceeded 1 historical standard deviation:

$$nino\_shock_v = \sum_{m=jan97}^{Aug98} 1\{sd\_excess\_rainfall_{v,m} \geq 1sd\} \quad (8)$$

However, the findings from this paper are robust to alternative measures of the El Niño shock, such as using a 1.5 cut-off or summing up the excess of rainfall z-scores[7].

Figure 3 shows the geographic variation in the intensity of El Niño shock among villages in Ecuador. As described in the reports about El Niño 97-98, the villages most affected by the floods were those located in the coastal regions while the ones situated in the highlands were less affected. For example, in the coast, villages experienced between 3 and 17 months of floods. While in the highlands, villages either did not suffered from severe floods or just experienced very few. The geographic and time variation provides a natural experiment in exposure to severe floods that disrupt early life environments.

Child data

To analyze the medium-term effects of early-life exposure to severe floods on child development, this paper uses data from a longitudinal survey that was collected to evaluate Ecuador's cash transfer (CT) program (Bono de Desarrollo Humano, BDH). The first wave

[6]The median distance to the center of a village is around 10 Km and the percentile 95 is 50 Km.

[7]See appendix A.2.

was collected in 2003-04 and it sampled 8000 children age 0-6 who were born to 5000 families that were potentially eligible to receive the cash transfer. The sampled households live in six different states: El Oro, Los Rios, and Esmeraldas, located in the coastal region, and Pichincha, Loja and Azuay, located in the highlands. These states were selected because roll-out of the CT program had not started at that time (Paxson and Schady, 2010). A second wave was collected in 2005-06 with a 7% attrition rate.

It is important to note that this sample of families is not nationally representative of Ecuador because it consists of households who were eligible to receive the cash transfer. Therefore, this sample corresponds to a low socio-economic status population. Table 1 presents means of selected characteristics for households in this sample and for households in a national representative sample, the Reproductive and Health Survey. Compared to national averages, households in the Ecuador cash transfer evaluation survey tend to be more disadvantaged. The fraction of mothers with more than primary education and that are married or cohabiting is lower. Households have fewer rooms and are less likely to have running water and indoor flush toilets. Also the families sampled are "younger" because the health component of the program required households to have no children above age 6.[8]

The CT surveys collected children's health and cognitive outcomes, as well as rich information on families' socio-demographic characteristics. The health outcomes considered in this paper include height-for-age, and anemia. Height-for-age z-scores were computed using the Center for Disease Control (CDC) growth charts. The cognitive outcome analyzed is the Peabody Picture Vocabulary Test (PPVT). Scores were standardized using norms published by test developers. The normed sample is composed of Mexican and Puerto Rican children. All three outcomes were collected in both waves (Paxson and Schady, 2007).

Because the PPVT was collected for children aged three and above, the sample used in this analysis includes children born between 1997 and 2002.[9] The bottom panel in Table 1 shows the descriptive statistics at baseline (2003-04) for the sample of children analyzed in

[8]This explains why the average age of the mothers is lower in this sample compared to national averages.
[9]Children born in 2003 and afterwards did not have PPVT measures in any survey wave.

this paper. Children's average height is one standard deviation below the reference population. Children's mean PPVT score is slightly below the normed sample.

Birth outcomes data

Information on birth outcomes comes from the 1994 and 1999 Reproductive and Health Survey (RHS). The RHS collects data on mothers' fertility histories, health, family planning and sexual behaviors; and on children's health and birth weight. The surveys are based on a nationally representative sample of woman in reproductive ages (15-49 years old) from around 20,000 households. This dataset provides measures before and after the 1997-98 El Niño, allowing for the analysis of the impact of this extreme weather shock on children's birth endowments. Descriptive statistics for the sample of households in 1994 are shown in Table B.2

Household data

To explore households' responses to El Niño 1997-98, this study uses repeated cross-section data from Ecuador Living Standards Measurement Study (LSMS) household surveys for years 1995, 1998, and 1999. These surveys are nationally representative and sample approximately 5000 households each year. The outcomes analyzed in this paper correspond to household income, as well as total and food consumption (proxied by expenditures). Additionally, this paper explores the effect of El Niño floods on investments in children in the form of food consumption and breastfeeding, information that is also gathered in this survey. The descriptive statistics for the sample of households in 1995 are displayed in Table B.1.

4 Lasting effects of the 1997-98 El Niño on children's human capital

To investigate the lasting effect a negative shock early in life on cognition and health, I use exposure to extreme floods during the 1997-1998 El Niño in Ecuador. Children's outcomes are collected in 2003 and 2005 (five and seven years after the shock) through the survey designed to evaluate a cash transfer (CT) program in Ecuador. To identify exposure to the El Niño floods, I exploit two sources of variation. First, I use cohort variation, given that the dataset sampled three sets of children: those who were alive (just born) during El Niño (born in 1997-98); those who were in utero (born in 1999); and those children who were born up to four years after the shock (born in 2002). Second, I exploit geographic variation, since these data contain information regarding families located in the coast (more affected by el Niño) and in the highlands (less affected). Therefore, to identify the impact of the El Niño shock, the empirical strategy uses cohort variation in child outcomes in villages more affected by El Niño compared to others less affected. I estimate the following model:

$$Y_{i,v,t,w} = \delta_1 nino\_utero_{i,v,t} + \delta_2 nino\_age01_{i,v,t} + X_{i,v,w}\beta + \theta_t + \eta_v + \omega_w + \varepsilon_{i,v,t,w} \qquad (9)$$

where t indexes cohort of birth (1998, 1999, 2000, 2001, 2002), v villages, i children and w survey round (2003 and 2005). Y corresponds to health and cognitive outcomes. $X_{i,v,w}$ is a vector of child and family socio-demographic characteristics[10]. The cohort fixed effects, θ_t, capture any shock common to all children born in the same cohort [11]. Similarly, village fixed effects, η_v, control for time-invariant characteristics of all children located in the same village. ω_w is a survey-wave fixed effect to control for variables common to all children surveyed in an specific wave. Finally, $\varepsilon_{i,v,t,w}$ is a random error term.

The variable $nino\_utero_{i,v,t}$ measures the number of months of El Niño floods experienced

[10]Specifically, child's gender, birth order, month of birth and age in months dummies, mother's and father's education, father at home, mother language, number of children less than age 14 at home, and inflation at the state-year of birth.

[11]Cohort fixed effects are defined ad quarter/year of birth

by children i in utero, which depends on village, month and year of birth.[12] Recall that floods are defined as monthly excess of rainfall greater that one historical standard deviation during the 1997-98 El Niño. The coefficient δ_1 measures the effect of in utero exposure to an additional month of El Niño floods on children's later outcomes. Similarly, $nino\_age01$ indicates the total months of floods during El Niño experienced during the first year of life.[13] δ_2 captures the impact of exposure to an extra month of El Niño floods during infancy on children's later outcomes. To address potential spatial and time correlation, I cluster standard errors at the village level.

The main identifying assumption required to consistently estimate the causal impact of early life exposure to El Niño floods on children's later outcomes is the independence between the error term and the measures of exposure, after controlling for village and cohort fixed effects as well for children's socio-demographic characteristics. Selection problems not controlled by these fixed effects could contaminate the results. For instance, if villages more affected by El Niño 1997-98 floods had differential growth in cognitive and health outcomes compared to villages less affected, this could violate the identification assumption. I cannot compare the pre-shock trends given the absence of child outcomes' data before El Niño 1997-98. However, household income data is available in two Living Standard Measurement Study (LSMS) surveys prior to El Niño 1997-98. Using income data from 1994 and 1995 LSMS surveys, Table B.3 tests for pre-El Niño 1997-98 trends. There is no statistically significant association between the intensity of El Niño floods and household income trends prior to the shock.

Another potential threat to the identification assumption is that exposure to El Niño floods may be confounded with similar unobserved influences that vary across villages and

[12] It is important to acknowledge that because there is no information on village-of-birth in the child dataset, I use village of residence. Looking data from the 1998 and 1999 LSMS, it seems that migration due to climate events is very low (3% of the families that migrate report as the reason weather or to improve income sources). In addition, in section 7 using information on maternal migration in the Reproductive and Health Survey, I show that is very unlikely that the results are contaminated by endogenous migration since I did not find evidence of migration responses to exposure to the 1997-198 floods.

[13] I chose the period from age 0 to1 because the oldest children in the sample were born in 1997.

over time. Along this line, one may be concerned that early-life exposure to El Niño floods is mistakenly capturing changes in the composition of families giving birth in villages more affected instead of exposure to the shock itself. To check for this potential selection problem, Table 2 presents the relationship between family socio-demographic characteristics and exposure to El Niño floods. Results show no significant differences in most family characteristics except for father's education.[14] In addition, in the next subsection, I present evidence from falsification tests that suggest that the results are not driven by unobserved omitted variables or trends.

Results

Table 3 presents the results of the medium-term effects of exposure to El Niño floods on children's health and human capital. The estimates in the first column suggest that one additional month of exposure to the 1997-98 El Niño in utero decreased height for age by 0.03 standard deviations (SDs) on average. Conditional on being exposed to El Niño floods, average exposure during pregnancy is 3 months. At this level of exposure, children's height-for-age decreased by 0.09 SDs five and seven years after the shock.

Regarding the medium-term effects on likelihood of being anemic, I find that exposure to El Niño floods in utero increased the probability of having anemia five and seven years later by 0.016 per month of exposure. This implies that children who experienced three months of floods in utero were 5.3 percentage points more likely to be anemic.

Regarding the impact of the shock on later cognitive development, column 3 shows the estimates for the Peabody Picture Vocabulary Test (PPVT). Exposure to severe floods in utero affects later cognitive performance. Results suggest that one month of exposure to the 1997-98 floods during pregnancy decreased cognitive scores by 0.042 standard deviations (SDs) on average. This implies that children exposed to three months of floods in utero

[14] A related concern is endogenous fertility and migration responses that could contaminate both treatment and comparison groups. I explore these concerns directly in section 7, but I do not find evidence of endogenous fertility and migration responses to the intensity of El Niño floods.

scored 0.13 SDs lower on the cognitive tests between five and seven years after the shock.[15]

A placebo test

One concern is that the negative effects of early-life exposure to el Niño on children's medium-term outcomes may be confounded with a trend or omitted variables. To verify that this is not the case, I performed some placebo regressions. The approach consists of simulating the geographic intensity of el Niño 1997-1998 on a different period, 2000-01, and calculating the corresponding exposure for children in utero and age 0 to 1 at that time. If my results are spurious and driven by a trend or an omitted variable, one would expect statistically significant estimates in these placebo regressions. As shown in columns 4-6 in table 3, there is no evidence of such an effect.

Timing of exposure to weather shocks in utero

Furthermore, I investigate the period during pregnancy when exposure to extreme weather shocks has the greatest impact on later child health and cognitive outcomes. The model estimated is:

$$\begin{aligned} Y_{i,v,t,w} &= \delta_1 nino\_1tri_{i,v,t} + \delta_2 nino\_2tri_{i,v,t} + \delta_3 nino\_3tri_{i,v,t} + \delta_4 nino\_age01_{i,v,t} \\ &\quad + X_{i,v,w}\beta + \theta_t + \eta_v + \omega_w + \varepsilon_{i,v,t,w} \end{aligned} \tag{10}$$

where $nino\_1tri_{i,v,t}$ measures the number of months of El Niño floods experienced by child i during the first trimester in utero. $nino\_2tri_{i,v,t}$ and $nino\_3tri_{i,v,t}$ are defined similarly. Results suggest that the negative effects on height-for-age are largest for exposure to floods in the third trimester in utero (table 4). Children who were exposed to one month of floods during the last trimester in utero are 0.08 SDs shorter in stature. In contrast, the deficit on cognitive scores is largest for exposure during the first trimester in utero. Children who

[15] These calculations at the mean exposure assume that the effect of being expose to El niño floods during pregnancy is linear. I examine the presence of non-linearities in the effect and the results are summarized in Figure B.1. I find little evidence of non-linearities since the estimates increase monotonically with exposure.

experienced one month of floods during the first trimester in utero scored 0.11 SDs lower on vocabulary tests. These results about the timing of exposure are consistent with medical literature about important periods for fetus growth and brain development (Altshuler, 2003). During first trimester of pregnancy, in particular during the embryonic period, spinal cord, brain, heart and other major organs start to develop and the baby is very susceptible to damages. In contrast, the third trimester of pregnancy is the period when the fetus grow dramatically (Harding and Alan, 2001).

Heterogeneous Effects

If more disadvantaged families fail to adequately cope with a negative shock early in life, it is plausible that negative impacts of exposure to extreme floods on later human capital are stronger for less educated families. To explore this, I interact the measure of exposure to El Niño floods with mother's years of schooling. Results presented in Table 5 (column 1 and 2) show that the interaction term is positive and statistically significant for vocabulary performance, which suggests that the negative impact of exposure to El Niño during the first trimester of pregnancy is attenuated if the mother is more educated.

Similarly, one may expect the effects of exposure to El Niño floods to be larger for rural families since agriculture was the sector most severely affected by the shock. As a check, I interact the exposure to El Niño floods with a dummy variable for rural households. As expected, the negative effects on both height and vocabulary are stronger for children in rural families[16] (see columns 3-4 in Table 5).

Some robustness checks

In an attempt to understand the sources of the lasting effects of in utero exposure to extreme weather shocks on children's human capital, I explore the sensitivity of the effects

[16]These specifications include interactions with exposure in the trimester of pregnancy most vulnerable given the specific outcome (first trimester for vocabulary and third trimester for height for age). However, point estimates from fully interacted measures of exposure are similar while the standard errors increase more than 50%.

on cognition to inclusion of child's health as a control variable. This exercise assumes that, if the initial effect of exposure to weather shocks early in life occurs through health, it will be captured in child's height-for-age. Then, if the main effect of this shock on later cognitive outcomes operates through poor child health, inclusion of height-for-age in the regression of vocabulary scores would lead to a decline in the coefficient of months exposed to El Niño during pregnancy.

The results from this exercise, shown in Table 6, suggest that exposure to El Niño directly affected later cognitive performance, rather than solely through health deficits because the estimate of the coefficient of month exposed to El Niño in pregnancy declines very little. In other words, this result suggests that El Niño alters other inputs to the production of human capital besides health. Presumably, they may be related to family processes such as parental stress. It is important to acknowledge that these regressions are just informative since they may be subject to omitted variable bias or reverse causality concerns. For instance, height only captures a part of child health, and the remaining dimensions may be both affected by the floods and correlated with cognition.

Magnitudes

Overall, I provide evidence of the persistent effects of early-life exposure to severe floods on later human capital. On average, children who were in utero during El Niño 1997-98 are 0.09 SDs shorter and score 0.13 SDs lower on cognitive tests than their peers who were born in less affected areas or were born after the shock. To give a sense of the magnitude of these effects, I compare them with the effects of positive early childhood interventions (ECIs) in developing countries. This is also informative of whether the persistent consequences of negative shocks can be offset by interventions. Nores and Barnett (2010) summarized the impacts from ECIs conducted in developing countries on several domains including cognition and health, and report larger effects. Average effect sizes on cognition were around 0.3 SDs both in short-term and long-term outcomes. Average effect sizes on health were around 0.36

SDs in short-term outcomes and 0.15 SDs in long-term outcomes.

5 Impact of the 1997-98 El Niño on birth endowments

From a policy perspective, evidence of the long-term effects of exposure to weather shocks early in life says little about the extent to which these consequences can be mitigated. Therefore, in the next sections I attempt to explore potential mechanisms by looking at birth endowments and family inputs' responses to weather shocks. However, since the child dataset was collected five and seven years after the 1997-98 El Niño and cannot be used for this analysis, I use secondary data from households surveys collected before and after the shock.

Birth endowments are considered a key input for the production of human capital (Heckman, 2008). Birth weight is often used in the economic literature as a proxy of health endowments at birth that may reflect prenatal inputs (Bharadwaj et al., 2010; Rosenzweig and Zhang, 2009). Furthermore, birth weight strongly predicts adult outcomes such as educational attainment and earnings (Behrman and Rosenzweig, 2004; Black et al., 2007; Currie and Hyson, 1999).

In this section, I investigate the impact of in utero exposure to the 1997-98 El Niño on birth outcomes. I estimate equation 9 using data from the 1994 and 1999 Reproductive and Health Surveys (RHS) which collect information for all children below the age of five. To minimize contamination from recall error, I restrict the sample to children less than age 2 in each wave. As before, the empirical strategy exploits time variation on month and year of birth as well as geographic variation on village of birth.

One potential threat to the validity of the identification assumption is that the composition of mothers giving birth is correlated with the timing and intensity of exposure to El Niño floods. To informally test this concern, I regress a rich set of measures of maternal socio-demographic characteristics in 1994 and 1999 on exposure to the 1997-98 El Niño during pregnancy and infancy, controlling for village and survey-year fixed effects. The estimated coefficients, presented in Table 7, show that there are no statistically significant relationships.

Results

Table 8 shows estimates of the impact of in utero exposure to the 1997-98 El Niño on birth outcomes. Results suggest that exposure to extreme floods during pregnancy increased the likelihood of low birth weight by 0.7 percentage points per month of exposure (column 2). This effect is not driven by preterm births since the results are robust to their exclusion (column 4). This result implies that children exposed to three months of floods were 2.2 percentage points more likely to be born with low birth weight.[17] Column 3 shows no effect of in utero exposure to El Niño on the probability of preterm birth.[18] Further, columns 5 - 7 in table 8 examine the effect of El Niño on prenatal investments: prenatal care and provision of vaccinations. These effects are small and statistically insignificant suggesting that the deterioration of birth weight as a result of exposure to floods is not explained by a lack of health care access but may be related to poor maternal nutrition or stress.

Timing of exposure to weather shocks in utero

Next, I examine the period during pregnancy when exposure to extreme weather shocks has the largest impact on health at birth. According to the epidemiology literature, birth outcomes are most sensitive to maternal stress during the first trimester of pregnancy (Bozzoli and Quintana-Domeque, 2010; Camacho, 2008; Currie and Rossin-Slater, 2013; Mulder et al., 2002). In contrast, nutritional deficits impact birth weight mostly in the third trimester of pregnancy (Kramer, 1987; Stein et al., 2000). Table 9 present the estimates disentangling the timing of in utero exposure. Results show that in utero exposure to the 1997-98 El Niño

[17] I examine the presence of non-linearities in the effect and the results are summarized in Figure B.2. I find little evidence of non-linearities since the estimates increase monotonically with exposure.

[18] Preterm is defined as gestational age less than nine months.

during the third trimester has the strongest effect compared to other trimesters. Exposure to floods during the third trimester increases the probability of low birth weight by 2.3 percentage points. This evidence suggests that the increase in low birth weight during El Niño may be explained by nutritional deprivation. The estimates are robust to the exclusion of preterm babies. In addition, these results go in line with the estimates on height, which are also larger for exposure in the third trimester in utero.

I explore the impacts of El Niño floods by socio-economic status (SES). I construct an index of SES based on quality of the housing, household density, access to utilities, mother's education, and assets. Table 10 presents the estimation of the model separately for households in the bottom and top two quintiles of the SES index.[19] The negative effect of exposure to extreme floods in the third trimester occurs mainly for children in more disadvantaged families. Indeed, for these children the likelihood of low birth weight increased by 4 percentage points.

A placebo test

Negative shocks after birth should not have a causal impact on birth outcomes. The last column in Table 9 presents a "placebo test" that estimate the impact of El Niño floods that occurred after birth on the probability of low birth weight. If the estimated effects of in utero exposure to the 1997-98 El Niño on birth outcomes were biased by the presence of omitted variables or a trend, then these placebo regressions may show significant effects as well. I find no impact of extreme floods during the first year of life on the likelihood of low birth weight, which helps to validate the results shown above.[20]

Magnitudes

[19]The construction of the SES index is based on the information employed in the development of the poverty index used by Ecuador's government to target social programs. It is similar but not the same due to availability of information in this survey. The motivation is to examine the effects on a population similar to the one targeted in the dataset that collected child cognitive and health outcomes (the dataset used for the evaluation of the cash transfer program).

[20] A similar test is performed by Currie and Rossin-Slater (2013).

Overall, I find that exposure to El Niño floods increased the average likelihood of low birth weight by 2.3 percentage points (4 pp for low SES children).[21] To put these results in context, I review effects of micronutrient intervention in Nepal and Tanzania.[22] These interventions are associated with a reduction of 6-8 pp in the incidence of low birth weight, effects larger than the impacts shown in this paper. This comparison also inform us whether the early-disadvantage generated by a negative shock in the form of floods can be offset by existing positive interventions.

6 Impact of El Niño on family inputs

This section looks at household responses to the 1997-98 El Niño in the aftermath of the shock. Because the child dataset was collected several years later and did not gather household income information, this analysis uses the Living Standard Measurement Study (LSMS) surveys that have the advantage that were collected two years before the shock (1995), during (1998) and one year after the disaster (1999). Using a difference-in-difference approach, I exploit two sources of variation to identify the effects of exposure to el Niño: time (before and after) and geographic variation:

$$\begin{aligned} m_{h,v,t} &= \alpha + \delta_{1998} nino\_floods_v * d\_year98_{h,v} + \delta_{1999} nino\_floods_v * d\_year99_{h,v} + \\ &\quad + X_{h,v,t}\beta + \theta_t + \eta_v + \varepsilon_{h,v,t} \qquad (11) \end{aligned}$$

where h indexes household, v villages and t survey years. m captures the different household inputs such as household income or consumption. The model controls for households' socio-demographic characteristics (X)[23], survey year fixed effects (θ_t) and villages fixed effects (η_v). The variable $nino\_floods$ indicates the total months of floods during the 1997-98 El

[21] This corresponds to a 15% increase compared to the mean low birth weight.

[22] Micronutrient interventions include multiple vitamins and minerals in addition to routine iron and folic supplements.

[23] $X_{h,v,t}$ includes age, gender, marital status and education of the household head, family size, number of members age 14 and older, and trimester of survey.

Niño experienced by village v. Standard errors are clustered at the village level.

δ_{1998} and δ_{1999} are the parameters of interest, which capture the effects of El Niño floods on household outcomes. These parameters are identified under the assumption that household income and consumption trends would be the same in regions more affected and less affected in the absence of the El Niño floods. I find no evidence of different pre-shock trends in income (table B.3).[24]

Another threat to the validity of the estimated specification is that households may sort or migrate for significant periods of time, altering the demographic composition of the villages most affected by El Niño (Anttila-Hughes and Hsiang, 2011). If specific types of households migrate out of these villages, then the impact of El Niño could be confounded with the effects of this sorting. To explore this concern, I regress households' socio-demographic characteristics in 1995, 1998 and 1999 on exposure to El Niño floods, survey-year fixed effects and village fixed effects. Results show no evidence that potential sorting may contaminate the effects of El Niño on family inputs and children's outcomes (Table 11).[25]

6.1 Household income and consumption

I examine whether exposure to El Niño 1997-1998 and its direct consequences (losses in agricultural productivity, damages to infrastructure, increases in infectious diseases) affected family income. Parental income is an important source of investments in children and numerous studies have shown an association between family income (especially that in early years) and child development and achievement (Caucutt and Lochner, 2012; Duncan and Brooks-Gunn, 1997; Duncan et al., 2011; Levy and Duncan, 2000).

Exposure to El Niño resulted in household income losses (see Columns 1-3 of Table 12). The results suggest that labor income fell by 1.2% in 1998 and by 1.9% in 1999 for each

[24] I could only perform the pre-shock trends test for household income because other variables like consumption and breastfeeding were not comparable in the 1994 and 1995 LSMS surveys. The reason is that the 1994 LSMS was the first survey of this kind in Ecuador and there were some sampling problems that were corrected in 1995 and onwards.

[25] Additionally, section 7 explore directly maternal migration responses to El Niño floods.

additional month of floods during El Niño 1997-98. Similarly, total household income (labor plus non labor income[26]) decreased by 1.6% in 1998 and by 2.2% in 1999 per month of floods. This implies that at the mean exposure (5 months), total income fell by 8.2% in 1998 and by 11.2% in 1999.[27]

The reduction in income could translate to a decline in consumption if households were not able to cope with it. I explore household consumption responses in Table 12 columns 4-5.[28] Total consumption declined by 1.1% in 1998 and by 2.04% in 1999 for each additional month of floods during El Niño. This implies that at the mean exposure, household total expenditures declined by 5.65% in 1998 and by 10.18% in 1999. These results suggest that Ecuadorian households were not able to smooth their consumption in the aftermath of the 1997-98 natural disaster, since the declines in consumption mirror the negative effects on household income.

Food expenditures decreased in 1999 but not in 1998.[29] Food consumption decreased by 2% in 1999 for each additional month of floods during El Niño. At the mean level of exposure, average household food expenditures decreased by 9.75% in 1999.

Table 13 shows the results separately by socio-economic status.[30] The negative effects of exposure to El Niño on both household income and consumption are stronger for households in the bottom two quintiles. This is expected since those families are more likely to be rural and depend on agricultural activities, which were the economic sector most affected by the

[26]Non-labor income includes remittances, transfers, interest earned, and rents.

[27]These calculations at the mean exposure assume that the effect of being expose to El Niño floods is linear. I examine the presence of non-linearities and the results are summarized in Figure B.3. I find that estimates increase monotonically with exposure until some point (10-11 months of floods) where it reaches a plateau.

[28]Total household consumption corresponds to expenditures on food and other household goods, education, durable goods, housing, electricity, clothing, transportation. According to the Ecuador Bureau of Statistics, health expenditures were not included because the questions about it were not homogeneous across surveys.

[29]Since the proxy of consumption analyzed here corresponds to expenditures, they combine the quantity and price effect. Thus, finding no effect of the shock on food consumption in 1998 may not be the result of consumption smoothing. Because of the scarcity of some food items and increases in prices, quantities consumed in 1998 could have gone down but the overall effect of expenditure could be zero because it was offset by the increase in prices. This result will be further explored.

[30]The SES index was constructed using information from housing quality, population density, access to water and sanitation, household head education, and assets.

shock. Also, these families tend to be more vulnerable, lacking mechanisms to cope with the negative consequences of extreme floods.

6.2 Investments in children

The disruption in early environment caused by a negative shock can change parental investments, which in turn affect later skills. This section explores the effects of exposure to severe floods early in life on investments in children. Two dimensions of investments are analyzed: breastfeeding and child food consumption. The LSMS surveys asked mothers about duration of both exclusive breastfeeding and total breastfeeding (breast milk combined with formula, food or other supplements). Additionally, mothers reported children's food consumption in terms of servings of meat, milk, eggs, fruits and vegetables and grains per week.

Breastfeeding

Breastfeeding is considered a key determinant of children's health and human capital. Very few studies have look at the relationship between exclusive breastfeeding and later child outcomes. Using a randomized control trial intervention in Belarus that promoted exclusive breastfeeding, Kramer et al. (2008) show that exclusive breastfeeding is associated with better child cognitive development. Most of the studies focus on total breastfeeding duration (duration of breastfeeding of any kind, exclusive or non-exclusive) and find a positive relationship with health and educational outcomes (Anderson et al., 1999; Belfield and Kelly, 2010; Rees and Sabia, 2009; Umapathi, 2009).

To the best of my knowledge, this is the first study that explores breastfeeding responses to extreme weather shocks.[31] Extreme weather shocks in the form of floods could affect breastfeeding practices in several ways. The floods may directly affect maternal health

[31] Thai and Myrskylä (2012) study the effect of rainfall on breastfeeding in rural Vietnam. They hypothesize that positive rainfall shocks are a proxy for positive transitory income shocks leading to an increase in the opportunity cost of time. However, they mention that they exclude extreme shocks like floods (pg 11) which are the focus of this paper.

through contaminated water, infectious diseases and dehydration, which in turn would decrease the amount of milk produced by the mother, leading to a decline in breastfeeding duration. Furthermore, because breastfeeding is a time-consuming activity, the income reduction could affect mother's time allocation through income and substitution effects that operate in opposite directions. The income effect implies that mothers afford less time for breastfeeding. But the substitution effect makes breastfeeding cheaper. Therefore, the overall direction of the effect of extreme floods on breastfeeding is ambiguous.

I look at duration of both exclusive breastfeeding and total breastfeeding. This information is asked in the three repeated cross-sections LSMS surveys in 1995, 1998 and 1999. I focus on children less than age two at the time of the survey. To address right-censoring on the duration of breastfeeding, because some children have not been weaned, I estimate an OLS version of equation (11) that includes age (in months) fixed effects (Jayachandran and Kuziemko, 2011):

$$\begin{aligned} months\_bf_{i,v,a,t} &= \alpha + \delta_{1998} nino\_floods_v * d\_year98_{i,v} + \delta_{1999} nino\_floods_v * d\_year99_{i,v} + \\ &\quad + X_{i,v,t}\beta + \lambda_a + \theta_t + \eta_v + \varepsilon_{i,v,t} \end{aligned} \tag{12}$$

where, as before, i denote children, v villages, a age in months and t survey year. Even though OLS estimates are easier to interpret, I also estimate a proportional hazard model that better accounts for the fact that some children have incomplete spells of breastfeeding duration.

Results are shown in Table 14. For each additional month of exposure to floods, average exclusive breastfeeding declined by -0.06 months for children aged 0-2 in 1998. This implies that at the mean level of exposure (5 months), exclusive breastfeeding decreased by 0.3 months. Similarly, the hazard estimation suggests that one extra month of exposure to El Niño floods is associated with a 3.6% increase in the probability of stopping exclusive breastfeeding in any given month during 1998.[32]

Regarding total breastfeeding, results show that exposure to El Niño 1997-98 increased the duration of total breastfeeding. According to the OLS estimates (column 3), a one month increase in exposure to El Niño is associated with a 0.14 month increase in total breastfeeding duration for children 0-2 in 1999. The hazard estimation shows an increase in duration of total breastfeeding both in 1998 and 1999. These results may suggest that exclusive breastfeeding and total breastfeeding are substitutes in the aftermath of a weather shock. Exclusive breastfeeding depends largely on maternal health status as well as on maternal time availability (mother has to be available every 3-4 hours to breastfeed the child). The negative consequences of the floods could deteriorate mother's health or demand that mothers go back to work, leading to a decrease in duration of exclusive breastfeeding (see appendix table B.4). However, breastfeeding has no monetary costs and also it could be used to insure the child against contaminated water, factors that could explain an increase in total breastfeeding.

To better understand the breastfeeding responses, table 15 shows estimates by SES and urbanity. This evidence suggests that the negative responses in terms of exclusive breastfeeding are stronger for rural and low-SES families (point estimates are larger), while the increase in total breastfeeding is larger for urban households.

Children's food consumption

Children's consumption of meat, fruits and vegetables and grains declined during El Niño. Since the dependent variable is a count variable, food servings per week, I use a negative binomial count model instead of OLS to account for over-dispersion. Table 16 shows the corresponding marginal effects of the interaction between the dummy for 1998 and the measure of El Niño floods (with year 1995 as the baseline category). Results suggest that, in 1998, the average number of servings of meat per week declined by 0.14 for each additional

[32] The hazard estimates have the opposite sign because they estimate the conditional probability of stopping exclusive breastfeeding.

month of floods during El Niño. Similarly, servings of fruit and vegetables decreased by 0.27 servings per week and those of grains fell by 0.48 servings per week for each additional month of floods.

7 Selection issues

One may be concerned that exposure to the shock affected families' fertility and migration decisions, which in turn could contaminate the evidence presented regarding the impact of early-life shocks on child development. That is, one may be worried that the estimates presented are not a causal effect but are confounded with selection issues[33]. In this section, I directly explore these potential sources of selection bias using the data from the Reproductive and health Survey (RHS).[34]

Fertility

Women may change their fertility decisions in response to extreme floods, which could contaminate the estimates of the effect of early-life shocks on later outcomes. Because exposure to extreme floods combine both an income effect and a change in the opportunity cost of time, it is ambiguous whether more advantaged or more disadvantaged families would delay fertility. If more advantaged families delay pregnancies after a flood, the comparison group is negatively selected and estimates of the effect of exposure to an in utero shock on child outcomes may be a lower bound. In contrast, if less advantaged families delay their fertility, the comparison group is positively selected and this may bias the results upward. Additionally, because of the long duration of El Niño 97-98, fertility responses could also contaminate the composition of the treated children born towards the end of the shock.

[33]Another potential selection concern is that exposure to the shock could affect children's likelihood of survival. If extreme floods increase neonatal and infant mortality, selection to survival could bias the results downwards. Results that explore the effects of el Niño floods on infant mortality are presented in appendix A.3 and show no evidence of changes in children's likelihood of survival

[34]In this analysis I use the RHS data because it contains information of the three dimensions of selection: fertility, migration and infant mortality.

Using information of women fertility histories from the 1994 and 1999 RHS, I test whether exposure to the 1997-98 El Niño floods has an effect on women pregnancy status,[35] as well as on whether she has giving birth in the 12 months prior to the survey.[36] I estimate a difference-in-difference model, similar to the one depicted in equation 11 and interact the measure of exposure to the shock with socio-demographic characteristics to explore evidence of endogenous fertility responses.

Table A.1 shows that exposure to El Niño floods did not affect the pregnancy status of women in 1999 or in the 12 months before. Also, I do not find differential responses by several socio-demographic characteristics such as education, age, marital status, SES, etc.

Migration

Any analysis that addresses the impact of negative shocks on households should be concerned with selection issues related to endogenous migration. One may be worried that exposure to the shock influenced family migration decisions and that these responses may differ by family characteristics. If more advantaged families living in places more affected by El Niño migrated, then exposure to the floods could be confounded with family SES.

The surveys asked mothers whether they were living in their current residence five years ago. Thus if a mother moved just before, during or after the 1997-98 El Niño, she would respond "No" in the 1999 wave indicating that she migrated. I use this information to assess whether there are differences in the probability of migration between villages more affected by El Niño and villages less affected. I examine migration responses both looking at responses in terms of a trend (using the 1994 and 1999 data) as well as looking the relationship between migration and varying degrees of exposure to the floods (just 1999 data). The outcome of interest is a dummy variable equal to 1 if a woman migrated between the time of the survey and 5 years ago. Both set of results are shown in Table A.2.

I find that there is not a statistically significant relationship between the likelihood of

[35] Women pregnant in the 1999 survey would have conceived at the end of the El Niño or after.

[36] Giving birth during the 12 months prior to the 1999 survey captures pregnancy status during the shock

migrating and exposure to El Niño floods either in trends or in levels. Additionally, when interacting exposure with family characteristics, there is no evidence of endogenous mobility responses (see columns 2 and 4).

8 Discussion and Conclusion

A growing literature has demonstrated that shocks in utero and early in life can have lasting effects not only on later health but also on human capital formation. However, most of this literature has looked separately at the impacts of shocks on later human capital outcomes and intermediate inputs. In this paper, I study both human capital inputs and outputs under the same type of negative shock in a developing country setting. I exploit geographic intensity of extreme floods, during the 1997-1998 El Niño phenomenon in Ecuador, as a source of exogenous variation in children's exposure to a negative shock at different periods early in life.

I combine detailed rainfall data with a rich dataset collected five and seven years after the disaster, which compiled children's health and cognitive outcomes. I find that children exposed to severe floods during El Niño are 0.09 SDs shorter in stature and score 0.13 SDs lower on cognitive tests. The timing-of-exposure results are in line with the medical literature findings on sensitive periods for growth and brain development. The negative effect on height-for-age comes from exposure in the third trimester while the deficit in cognition comes from exposure in the first trimester of pregnancy.

I explore potential channels behind these lasting effects on children's human capital. I find that increases in the likelihood of low birth weight, deterioration of family resources and family investments may explain the negative, persistent impact of exposure to severe floods in utero and early in life. Children exposed to El Niño floods, especially in the third trimester of pregnancy, are more likely to be born with low birth weight. On the family inputs side, I show that households affected by El Niño 1997-98 suffered a decline in income, total expenditures, and food expenditures. Additionally, exposure to El Niño floods decreased the duration of exclusive breastfeeding but increased the duration of total breastfeeding (breast milk combined with formula or other foods).

Some "back-of-the envelope" calculations may be helpful to put the estimated magnitudes in perspective. It is relevant to know how much of the negative effects on height could come from the impact of the shock on birth weight. I estimate that in-utero exposure to a negative shock in the form of floods is associated with a decline of 0.10 SDs in height-for-age (table 3). I also find that exposure to floods increased the likelihood of low birth weight (LBW) by 3.2 percentage points (table 10).[37] However, I do not observe the relationship between low birth weight and height for the Ecuador's children dataset, thus I take it from the literature in developing countries. Alderman and Behrman (2006) review the economic benefits of reducing LBW in low-income countries and cite that the height-gap between low birth weight children and children of normal weight is around 0.5 SDs. This implies that the increase in 3.2 pp in the likelihood of low birth weight due to El Niño would translate into a decline in height-for age of approximately 0.016 SDs, which accounts for 16% of the total negative effect of El Niño on children's height.

Another relevant question is to translate the decline in cognitive development to wages. The literature in developing countries documents the relationship between wages and IQ measured using instruments such as WISC (Wechsler Intelligence Scale for Children), thus for this calculation I consider PPVT as a proxy for IQ.[38] Alderman and Behrman (2006) document that a 0.5 SD decrease in IQ is associated to 5%-12% decline in wages. Thus, a "back-of-the envelope" calculation suggests that the observed reduction in IQ due to El Niño (0.13 SDs) would translate to a decline in wages between 1.3% and 3.2%. These effects are smaller than the ones found by Almond for the Spanish flu pandemic in the US (5%-12% reduction in wages). However, this computation just considers the effects on wages through

[37]in the bottom SES population that is the target population in the children data.

[38]PPVT developers document that correlations between PPVT and several cognitive ability test (including WISC) ranged from 0.62 to 0.91 (Dunn and Dunn, 1997)

IQ and ignores the effects that operate through the decline in height, which is also affected by El Niño.

The evidence presented in this paper has important public policy implications. First, policies, such as social protection and safety nets, should improve the coping mechanisms against negative shocks that affect not only income but also parental stress and health, specially in disadvantage families with children and pregnant women. Second, in terms of timing of social programs that aim to mitigate damages from shocks, policies should target pregnant women not just before giving birth but early in pregnancy in order to prevent the negative consequences on children's cognitive and health skills.

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Figures and Tables

Figure 1: Excess of rainfall during el Niño 97-98 in selected weather stations in Ecuador

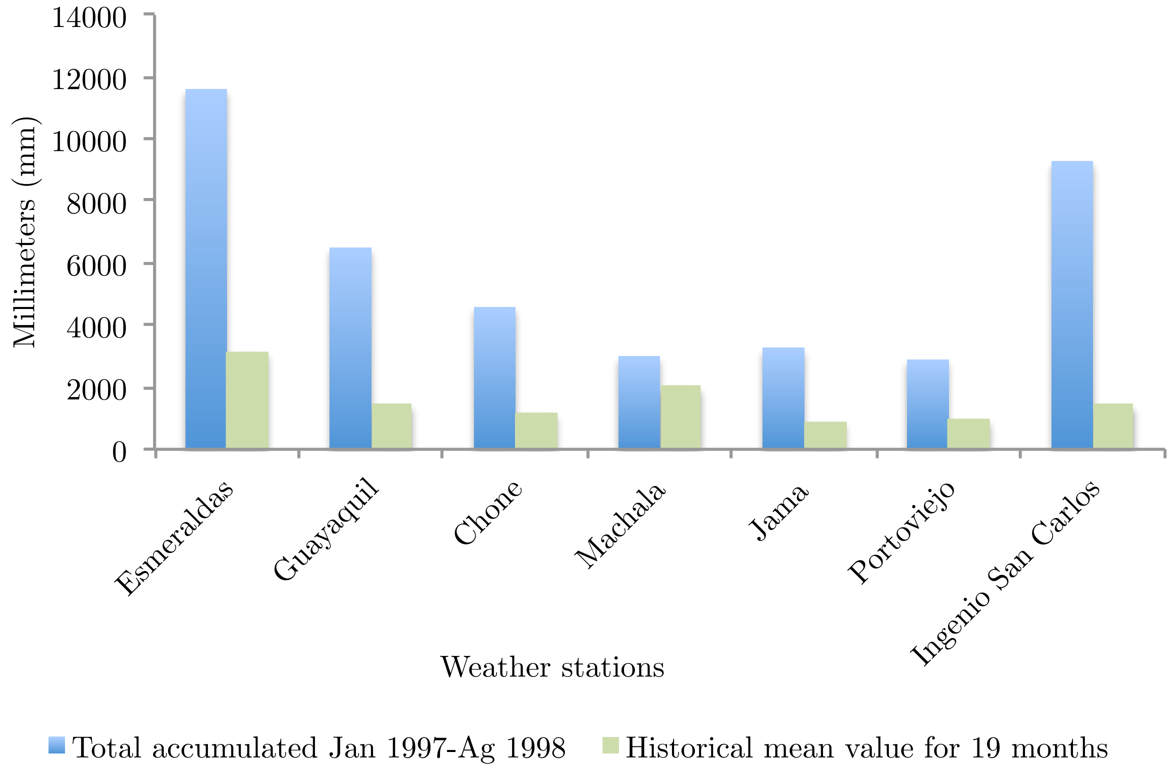


Figure 2: Agricultural losses during el Niño 97-98 by states in Ecuador

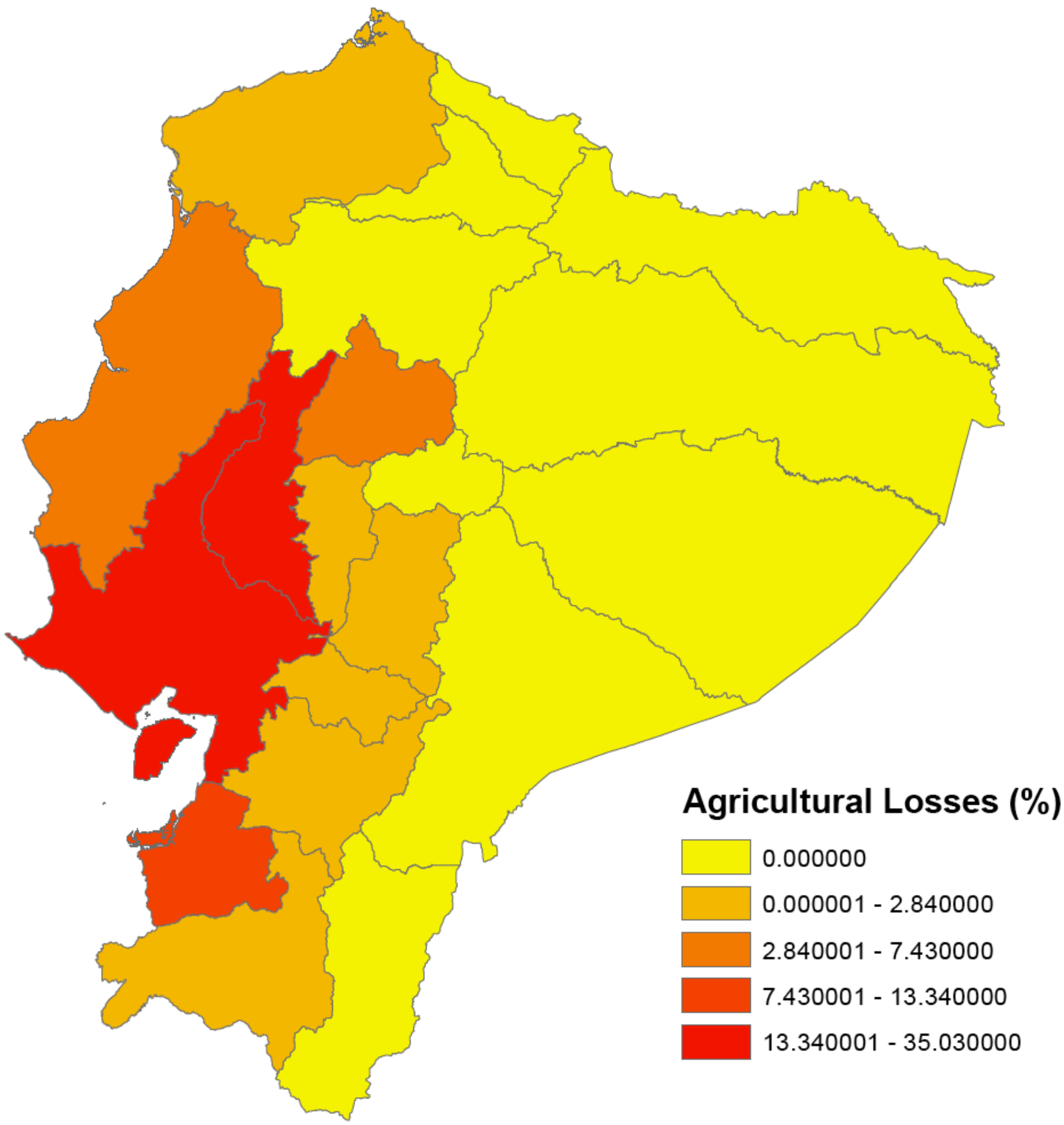
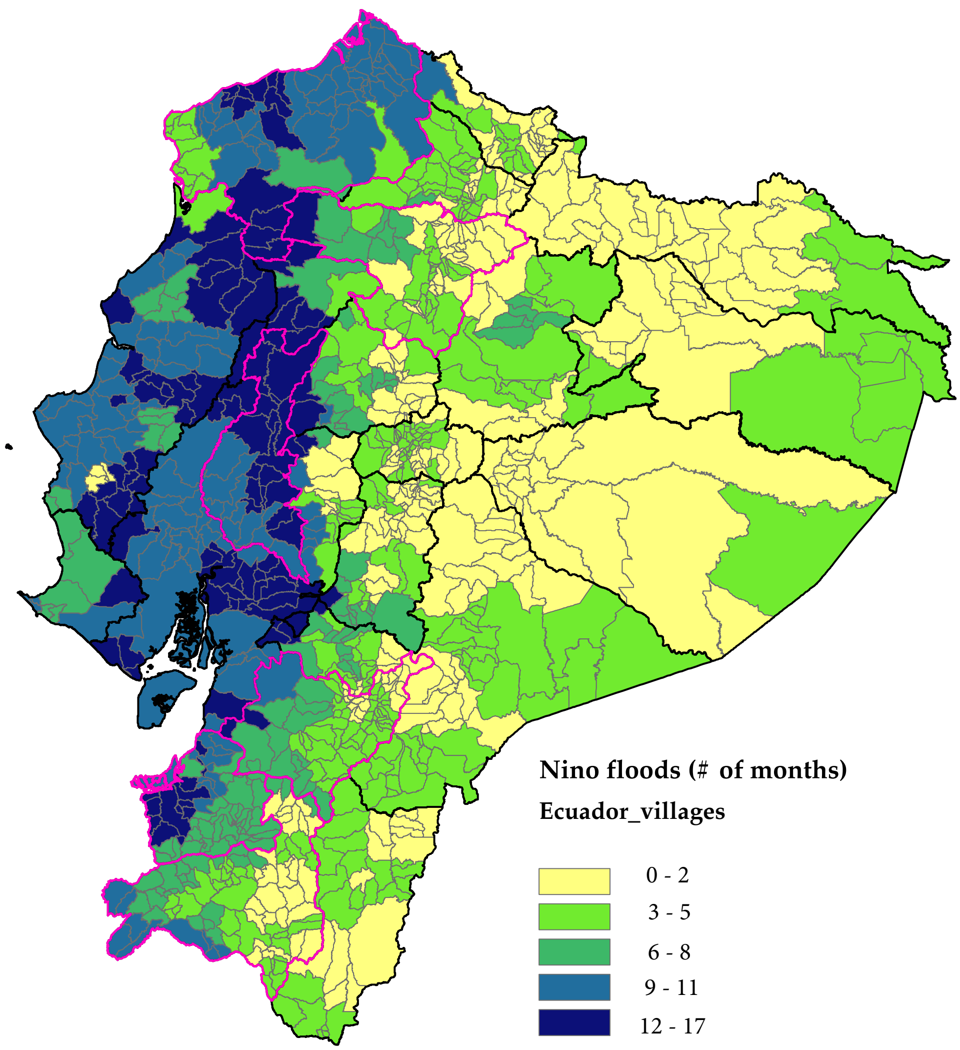


Figure 3: Prevalence of floods during el Niño 97-98 by Ecuadorian villages



Notes: Number of months of floods correspond to monthly excess of rainfall (observed rain deviations from historical mean) greater that one historical standard deviation. The six states selected in fuchsia correspond to the states sampled in the children dataset.

Table 1: Summary statistics - Ecuador's cash transfer evaluation survey - 2003/04

	(1) Ecuador Children's data 2003-04 (from cash transfer evaluation survey)	(2) Reproductive and health Survey 2004 (females with preschool children)	(3) RHS 2004 - All Ecuador
Mother Characteristics			
More than primary school	0.472	0.535	0.602
Married or cohabiting	0.784	0.832	0.592
Age	24.718	28.903	29.499
Household characterisitics			
Family size	4.829	5.575	5.290
Number of rooms	2.141	2.790	3.219
Piped water	0.724	0.783	0.816
Flush toilets	0.518	0.602	0.659
Children Characteristics			
If male	0.51		
Age in months	40.02		
If first born	0.72		
Height for age (z score)	-1.00		
Standarized PPVT score (SDs)	-0.93		
If anemic	0.58		

Note: The first column correspond to the dataset that contains children medium-term outcomes (data from the survey collected to evaluate the cash transfer program in Ecuador). The survey sample families with children at most six years old (pres-school age) and that are elegible to receive the cash transfer. The sample used in this paper correspond do children born betweenn 1998 and 2002. To compare the demografic characterisitcs to Ecuador's population, the last two columns used data from the Reproductive and Health Survey (RHS) 2004. PPVT: Peabody Picture Vocabulary Test. SDs: Standard Deviations.

Table 2: Checking for selection in observables: family characteristics and exposure to the 1997-98 El Niño floods (2003-04 Child data)

	(1) Married or Cohab	(2) Mom edu: more than primary sch	(3) Dad edu: more than primary sch	(4) Dad lives at home	(5) Family size	(6) Number of children less than 5	(7) Number of children less than 14 at home
Nino floods - in utero	0.007	0.000	0.014*	0.009	-0.022	0.024	0.006
	(0.008)	(0.000)	(0.007)	(0.009)	(0.036)	(0.020)	(0.023)
Nino floods - age 0-1	0.020	0.000	0.010	0.017	0.074	0.043	-0.022
	(0.016)	(0.000)	(0.017)	(0.026)	(0.088)	(0.041)	(0.056)
Observations	6,614	6,614	6,614	6,507	6,614	6,614	6,614

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses clustered at the village level. The units of observation are children in the cash transfer (CT) data. Each column is a separate regression that includes quarter/year of birth, month of birth and village fixed effects. Nino floods - in utero is the number of months of floods experienced in utero. Nino floods - age 0-1 is the number of months of floods experienced in the first year of life.

Table 3: Medium-term effects of exposure to the 97-98 El Niño floods on child's human Capital

	Height-for-age (SD)	Anemic	Cognition (PPVT, SD)	Placebo (simulate the shock for children born in 2000) Height-for-age (SD)	Anemic	Cognition (PPVT, SD)
	(1)	(2)	(3)	(4)	(5)	(6)
Nino floods - in utero	-0.031**	0.018**	-0.042*	0.003	0.001	-0.009
	(0.015)	(0.008)	(0.022)	(0.011)	(0.004)	(0.009)
Nino floods - age 0-1	-0.031	-0.011	-0.033	-0.009	0.004	-0.008
	(0.031)	(0.020)	(0.048)	(0.009)	(0.004)	(0.011)
Observations	11,983	10,766	9,074	8,746	7,812	5,809
Y mean	-1.00	0.518	-0.93			
@Avg. exposure in utero (3m)	-0.09	0.053	-0.13			

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. Medium-term refers to five and seven years after the 1997-98 El Niño. The units of observation are children in the cash transfer (CT) data. Anemic is a dummy variable equal to one if the child was anemic. Anemia is defined using the Center for Disease and Control Guidelines. PPVT is the Peabody Picture Vocabulary Test standardized to mean 0 and SD of 1 in the norming sample. Each column is a separate regression that includes as controls: child's gender, age, and birth order; mother's and father's education, father at home, mother's language, number of children less than 14 at home: and month of birth, cohort, village and survey-wave dummies. Nino floods - in utero is the number of months of floods experienced in utero. Nino floods - age 0-1 is the number of months of floods experienced in the first year of life. The table presents estimates from equation 10 explained in the text and correspond to marginal effects per month of exposure to floods. Placebo regression simulate the occurance of the 97-98 El Niño in 2000 and analyze the effects on children born in 2000 and afterwards. SD: standard deviations. Y mean: mean of the dependent variable. Avg. exposure in utero is the average months of floods experienced in utero and is equal to 3 months.

Table 4: Medium-term effects of exposure to the 97-98 El Niño floods on child's human capital: exploring timing of exposure

	Height-for-age (SD)	Anemic	PPVT (SD)
	(1)	(2)	(3)
Nino floods - 1st trimester	-0.016	0.022	-0.110***
	(0.037)	(0.018)	(0.041)
Nino floods - 2nd trimester	-0.024	0.012	0.017
	(0.036)	(0.027)	(0.067)
Nino floods - 3rd trimester	-0.078*	0.016	0.031
	(0.040)	(0.029)	(0.079)
Nino floods - age 0-1	-0.018	-0.009	-0.073
	(0.033)	(0.021)	(0.054)
Observations	11,983	10,766	9,074

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. Nino floods - 1st trimester is the number of months of floods experienced during the first trimester in utero. Nino floods - age 0-1 is the number of months of floods experienced in the first year of life. The table presents marginal effects per month of exposure to floods. See note in table 3 for additional definitions.

Table 5: Heterogeneous effects of exposure to the 97-98 El Niño floods on child's human capital

	Heterogeneous effects			
	Maternal Education		Urban Vs. Rural	
	Height-for-age (SD)	PPVT (SD)	Height-for-age (SD)	PPVT (SD)
	(1)	(2)	(3)	(4)
Nino floods - 1st trimester	-0.016	-0.274***	-0.017	-0.055
	(0.037)	(0.058)	(0.036)	(0.052)
Nino floods - 2nd trimester	-0.022	0.011	-0.026	0.015
	(0.036)	(0.067)	(0.036)	(0.067)
Nino floods - 3rd trimester	-0.019	0.040	-0.045	0.026
	(0.069)	(0.077)	(0.054)	(0.079)
Nino floods - age 0-1	-0.013	-0.074	-0.023	-0.070
	(0.032)	(0.053)	(0.034)	(0.053)
Interactions				
Nino floods - 1st trimesterXrural				-0.099**
				(0.046)
Nino floods - 3rd trimesterXrural			-0.059	
			(0.053)	
Nino - 1st trimesterX Mom years edu		0.022***		
		(0.007)		
Nino - 3rd trimesterXMom years edu	-0.008			
	(0.008)			
Observations	11,924	9,026	11,983	9,074

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The unit of observation are children in the cash transfer (CT) data. Each column is a separate regression that includes as controls: child's gender, age, and birth order; mother's and father's education, father at home, mother's language, number of children less than 14 at home: and month of birth, cohort, village and survey-wave dummies. Nino floods - 1st trimester is the number of months of floods experienced during the first trimester in utero. Nino floods - age 0-1 is the number of months of floods experienced in the first year of life. These specifications include interactions with exposure in the trimester of pregnancy most vulnerable given the specific outcome (first trimester for vocabulary and third trimester for height for age). However, point estimates from fully interacted measures of exposure are similar while the standard errors increase more than 50%. The table presents marginal effects per month of exposure to floods. SD: standard deviations.

Table 6: Exposure to the 97-98 El Niño floods and cognitive performance : effects beyond child's health

	Cognition: PPVT (SD)		
Nino floods - in utero	-0.042*	-0.038*	
	(0.022)	(0.021)	
Nino floods - 1st trimester			-0.107***
			(0.041)
Nino floods - 2nd trimester			0.020
			(0.067)
Nino floods - 3rd trimester			0.037
			(0.079)
Nino floods - age 0-1	-0.021	-0.030	-0.071
	(0.035)	(0.047)	(0.053)
Height-for-age (SD)		0.095***	0.095***
		(0.012)	(0.012)
Observations	9,074	9,074	9,074

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are children in the cash transfer (CT) data. Anemic is a dummy variable equal to one if the child was anemic. Anemia is defined using the Center for Disease and Control Guidelines. PPVT is the Peabody Picture Vocabulary Test standardized to mean 0 and SD of 1 in the norming sample.Each column is a separate regression that includes as controls: child's gender, age, and birth order; mother's and father's education, father at home, mother's language, number of children less than 14 at home: and month of birth, cohort, village and survey-wave dummies. Nino floods - in utero is the number of months of floods experienced in utero. Nino floods - age 0-1 is the number of months of floods experienced in the first year of life. The table presents marginal effects per month of exposure to floods. SD: standard deviations.

Table 7: Maternal characteristics and exposure to the 97-98 El Niño floods using data from RHS 1994 (before) and 1999 (after)

	Married or cohab	Age less than 20	Age more than 45	No education	Primary school	High school	College	Health ins.	Number of children
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Nino floods - in utero	0.003	-0.004	0.000	0.001	-0.002	0.004	-0.002	-0.002	-0.021
	(0.003)	(0.003)	(0.000)	(0.002)	(0.004)	(0.005)	(0.003)	(0.003)	(0.020)
Nino floods - age 0-1	-0.006**	0.004	-0.000	0.001	0.002	-0.004	0.001	0.001	0.006
	(0.003)	(0.003)	(0.001)	(0.002)	(0.005)	(0.004)	(0.003)	(0.003)	(0.019)
Observations	7,129	7,129	7,129	7,129	7,129	7,129	7,129	7,129	7,129

note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors in parentheses clustered at the village level. The units of observation are children age 0-2 in the Reproductive and Health Surveys (RHS) 1994 and 1999. Each column is a separate regression that includes quarter/year of birth, month of birth and village fixed effects. Nino floods - in utero is the number of months of floods experienced in utero. Nino floods - age 0-1 is the number of months of floods experienced in the first year of life. Cohab: Cohabiting. Health insurance: if mother had any form of health insurance.

Table 8: Effects of exposure to the 97-98 El Niño floods on birth outcomes

	Birth outcomes				Prenatal investments		
	Weighted at birth	Low birth weight	Preterm birth	Low birth weight (drop preterm)	If prenatalcare	N prenatalcare	If tetanus vac
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Nino floods - in utero	0.004	0.007**	0.000	0.006*	0.003	0.027	-0.003
	(0.004)	(0.004)	(0.002)	(0.004)	(0.004)	(0.032)	(0.004)
Observations	7,087	5,324	7,075	4,981	7,107	7,087	7,088
Y mean	0.751	0.158	0.060	0.130	0.777	4.488	0.587
@Average exposure in utero (3m)		0.022		0.019			

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are children age 0-2 in the Reproductive and Health Surveys (RHS) 1994 and 1999. Each column is a separate regression that includes as controls: child's gender, birth order, quartert of birth/year dummie; mother's age, marital status, education, if living in urban, ses index, survey year and village fixed effect. Nino floods - in utero is the number of months of floods experienced in utero. Nino floods - age 0-1 is the number of months of floods experienced in the first year of life. The table presents marginal effects per month of exposure to floods. N Prenatal care: number of prenatal care controls. If tetanus vac: whether mother recieved a tetanus vaccination. Y mean: Mean of the dependend variable.

Table 9: Effect of the 97-98 El Niño floods on birth outcomes - timing of exposure & placebo

	Weighted at birth	Low birth weight	Preterm birth	Low birth weight (drop preterm)	Placebo Low birth weight	Placebo Low birth weight (drop preterm)
	(1)	(2)	(3)	(4)	(6)	(7)
Nino floods - 1st trimester	0.007	0.004	0.003	-0.002		
	(0.008)	(0.009)	(0.006)	(0.008)		
Nino floods - 2nd trimester	0.007	-0.003	-0.002	-0.001		
	(0.010)	(0.010)	(0.006)	(0.010)		
Nino floods - 3rd trimester	-0.005	0.023**	0.000	0.024**		
	(0.009)	(0.010)	(0.007)	(0.010)		
Nino floods - age 0-1					0.003	0.003
					(0.004)	(0.004)
Observations	7,087	5,324	7,075	4,981	5,324	4,981

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are children age 0-2 in the Reproductive and Health Surveys (RHS) 1994 and 1999. Each column is a separate regression that includes as controls: child's gender, birth order, quartert of birth/year dummie; mother's age, marital status, education, if living in urban, ses index, survey year and village fixed effect. Nino floods - 1st trimester is the number of months of floods experienced during the first trimester in utero. Nino floods - age 0-1 is the number of months of floods experienced in the first year of life. The table presents marginal effects per month of exposure to floods.

Table 10: Heterogeneous effects of El Niño floods on birth outcomes - by SES

	Low SES (quintile 1-2)		High SES (quintile 4-5)	
	Low birth weight	Low birth weight (drop preterm)	Low birth weight	Low birth weight (drop preterm)
Nino floods - 1st trimester	-0.023	-0.016	0.013	0.001
	(0.015)	(0.015)	(0.017)	(0.012)
Nino floods - 2nd trimester	-0.011	-0.012	0.002	0.009
	(0.017)	(0.017)	(0.016)	(0.015)
Nino floods - 3rd trimester	0.032*	0.040**	0.018	0.011
	(0.018)	(0.018)	(0.016)	(0.016)
Observations	2,538	2,410	1,735	1,588

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The unist of observation are children age 0-2 in the Reproductive and Health Surveys (RHS) 1994 and 1999. Each column is a separate regression with covariates as in Table 9. The subsamples come from a socio-economic status (SES) index based on quality of the housing, household density, access to utilities, mother's education, and assets.

Table 11: Is there any evidence of household sorting after the 97-98 El Niño?

	Household head (HH) age	HH male	HH married	Household size	HH less than high school
	(1)	(2)	(3)	(4)	(5)
Nino floodsX1998	0.092	-0.002	-0.001	0.002	0.001
	(0.077)	(0.002)	(0.002)	(0.010)	(0.003)
Nino floodsX1999	0.126	-0.005*	-0.002	0.010	0.005
	(0.104)	(0.003)	(0.002)	(0.012)	(0.004)
Observations	17,425	17,424	17,421	17,427	17,422

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are families in the Living Standard Measurement Studies (LSMS) surveys 1995, 1998 and 1999.. Each column is a separate regression that includes village and year fixed effect. Nino floods is the number of months of Nino floods according to the village of residence. Estimates correspond to interaction of shock measure with year dummies with 1995 (before Niño) as the beseline year.

Table 12: Effect of the 97-98 El Niño floods on household monthly income and consumption

	ln hh labor income	ln hh non labor income	ln hh total income	ln_total consumption (monthly)	ln_food consumption (monthly)
	(1)	(2)	(3)	(4)	(5)
Nino_shockX1998	-0.012*	-0.003	-0.016**	-0.0113***	-0.0003
	(0.006)	(0.022)	(0.008)	(0.0042)	(0.0031)
Nino_shockX1999	-0.019***	-0.020	-0.022***	-0.0204***	-0.0195***
	(0.006)	(0.024)	(0.007)	(0.0044)	(0.0055)
Observations	16,283	8,595	17,079	17,318	17,152
Effect at the mean level of exposure (5 months)					
1998	-5.8%		-8.2%	-5.65%	
1999	-9.3%		-11.2%	-10.18%	-9.75%

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are families in the Living Standard Measurement Studies (LSMS) surveys 1995, 1998, and 1999. Each column is a separate regression that includes as controls: age, gender, marital status and education of the household head, family size, number of members >=age 14, trimester of survey, years and village dummies. Nino floods is the number of months of floods during el niño experienced by the village of residence. The table presents marginal effects per month of exposure to floods. Dependent variables are the following montly household income: ln hh labor income: log of labor income, ln hh non labor income: log of non-labor income, and ln hh total income: log of total income.

Table 13: Heterogeneous effects of El Niño floods on income and consumption - by SES

	Low SES (quintile 1-2)				
	ln hh labor income	ln hh non labor income	ln hh total income	ln_total consumption (monthly)	ln_food consumption (monthly)
	(1)	(2)	(3)	(4)	(5)
Nino_shockX1998	-0.014	-0.024	-0.020*	-0.0036	0.0092
	(0.011)	(0.023)	(0.011)	(0.0059)	(0.0060)
Nino_shockX1999	-0.016	-0.027	-0.024**	-0.0225***	-0.0263**
	(0.013)	(0.029)	(0.013)	(0.0085)	(0.0108)
Observations	6,601	2,918	6,904	7,053	6,965
	High SES (quintile 4-5)				
	ln hh labor income	ln hh non labor income	ln hh total income	ln_total consumption (monthly)	ln_food consumption (monthly)
Nino_shockX1998	0.004	0.021	-0.002	-0.0052	0.0053
	(0.007)	(0.031)	(0.010)	(0.0053)	(0.0045)
Nino_shockX1999	-0.010	0.003	-0.013	-0.0114***	-0.0134**
	(0.008)	(0.027)	(0.008)	(0.0044)	(0.0060)
Observations	6,387	3,976	6,741	6,805	6,760

Notes: * p<0.10 ,** p<0.05, *** p<0.01.Robust standard errors in parentheses clustered at the village level. The units of observation are families in the Living Standard Measurement Studies (LSMS) surveys 1995, 1998, and 1999. Each column is a separate regression with covariates as in Table 12. The subsamples come from a socio-economic status (SES) index based on quality of the housing, household density, access to utilities, mother's education, and assets.

Table 14: Effects of exposure to El Niño floods on duration of breastfeeding - children less than age 2

	Exclusive BF (months)		BF in months	
	OLS	Hazard	OLS	Hazard
Nino_floodsX1998	-0.062*	0.036*	0.090	-0.047**
	(0.035)	(0.019)	(0.062)	(0.020)
Nino_floodsX1999	0.006	0.004	0.140**	-0.055**
	(0.044)	(0.025)	(0.062)	(0.022)
Observations	3,829	3,476	3,826	3,706
Y mean	3.3		8.9	

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are children age 0-2 in the Living Standard Measurement Studies (LSMS) surveys 1995, 1998, and 1999. Each column is a separate regression that includes as controls: child's gender, age in months; age, gender, marital status and education of the household head, family size, number of members >=age 14, trimester of survey, years and village dummies. Nino floods is the number of months of floods during el niño experienced by the village of residence. The table presents marginal effects per month of exposure to floods. Dependent variables are duration of exclusive and total breastfeeding in months. The hazard models estimates have the opposite sign because they estimate the conditional probability of stopping exclusive breastfeeding. Y mean: mean of dependent variable.

Table 15: Exposure to El Niño floods and breastfeeding - heterogeneous effects by SES

	Exclusive BF (months)		BF in months	
	rural	urban	rural	urban
Nino_floodsX1998	-0.158**	-0.061*	0.068	0.096
	(0.080)	(0.033)	(0.107)	(0.078)
Nino_floodsX1999	-0.252**	0.049	0.014	0.192***
	(0.116)	(0.038)	(0.136)	(0.071)
Observations	1,893	1,936	1,891	1,935
	Low SES (quintil 1-2)	High SES (quintil 3-4)	Low SES (quintil 1-2)	High SES (quintil 3-4)
Nino_floodsX1998	-0.105*	-0.064	0.094	0.025
	(0.054)	(0.057)	(0.088)	(0.122)
Nino_floodsX1999	-0.027	0.078	0.167	0.100
	(0.077)	(0.048)	(0.115)	(0.064)
Observations	1,928	1,070	1,926	1,069

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are children age 0-2 in the Living Standard Measurement Studies (LSMS) surveys 1995, 1998, and 1999. Each column is a separate regression with covariates as in Table 14. The subsamples come from a socio-economic status (SES) index based on quality of the housing, household density, access to utilities, mother's education, and assets.

Table 16: Effects of exposure to El Niño floods on child food consumption - children less than age 5

# servings per week	Meat	Milk	Eggs	Fruits and Veg.	Grains and cereals
Nino_floodsX1998	-0.140***	0.008	-0.004	-0.272**	-0.484**
	(0.040)	(0.083)	(0.019)	(0.130)	(0.217)
Observations	6,456	6,442	6,505	6,437	6,437
Y mean	5.290	9.551	2.804	11.521	12.781
Effect at the mean exposure 1998 (5 m)	-0.70			-1.36	-2.42

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. Dependent variables are counts of number of food servings per week. Negative binominal counts model were used. Controls: child's gender, age in months, age in months sqr; age, gender, marital status and education of the household head, family size, number of members >=age 14, trimester of survey, years and village dummies. Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are children age 0-5 in the Living Standard Measurement Studies (LSMS) surveys 1995, and 1998 (1999 data was not consistent). Each column is a separate regression that includes as controls: child's gender, age in months, age in months sqr; age, gender, marital status and education of the household head, family size, number of members >=age 14, trimester of survey, years and village dummies. Nino floods is the number of months of floods during el niño experienced by the village of residence. The table presents marginal effects per month of exposure to floods. Y mean: mean of dependent variable. m: months.

A Appendix: Additional Robustness and Specification tests

A.1 Appendix: Exploring selection concerns

Table A.1: Fertility responses to the 1997-98 El Niño floods

	Pregnant at the time of survey		Childbirth 12 months before the survey	
	(1)	(2)	(3)	(4)
Year_1999	-0.0060	-0.0055	-0.0044	-0.0047
	(0.0074)	(0.0074)	(0.0096)	(0.0096)
Nino_floodsX1999	0.0007	0.0006	-0.0003	-0.0005
	(0.0007)	(0.0010)	(0.0009)	(0.0014)
Interactions with maternal char.				
Married_cohabitingXshock_99		0.0009		-0.0023**
		(0.0009)		(0.0010)
Age less than 20Xshock_99		0.0012		0.0006
		(0.0011)		(0.0015)
Age more than 45Xshock_99		0.0001		0.0020
		(0.0008)		(0.0013)
Primary scholing Xshock_99		-0.0004		0.0003
		(0.0007)		(0.0009)
Health insuranceXshock_99		0.0001		0.0011
		(0.0009)		(0.0010)
Number of childrenXshock_99		-0.0002		0.0003
		(0.0002)		(0.0002)
Low SES Xshock_99		-0.0000		-0.0003
		(0.0010)		(0.0010)
RuralXshock_99		-0.0004		-0.0010
		(0.0009)		(0.0013)
Observations	27,646	27,646	27,785	27,785
Y mean	0.07		0.13	

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are women age 15 to 49 in the Reproductive and Health Surveys (RHS) 1994 and 1999. Each column is a separate regression that includes as controls: survey year dummies, villages dummies, and main effects of the covariates. Nino floods is the number of months of floods experienced in the village of residence during the 1997-98 El Niño. Triple interactions of the shock, dummy for year 1999 and demografic characteristics are included to explore endogenous responses to the shock. SES: socio-economic status. Char.: chracteristics.

Table A.2: Migration responses to the 1997-98 El Niño floods

	If migrate between survey and 5 years ago			
	Trend (data from 1994 and 1999)		Cross-sect (just 1999 data)	
	(1)	(2)	(3)	(4)
Year_1999	-0.0347***	-0.0358***	Cross-sect	
	(0.013)	(0.013)		
Nino_floodsX1999	0.0011	0.0008	0.0003	0.0034
	(0.001)	(0.001)	(0.002)	(0.003)
Interactions with maternal char.				
Married_cohabitingXshock_99		0.0015		-0.0023
		(0.0011)		(0.0016)
Age less than 20Xshock_99		0.0010		0.0006
		(0.0013)		(0.0020)
Age more than 45Xshock_99		0.0018		0.0004
		(0.0014)		(0.0020)
Primary scholing Xshock_99		0.0007		0.0019
		(0.0009)		(0.0015)
Health insuranceXshock_99		-0.0012		-0.0004
		(0.0010)		(0.0018)
Number of childrenXshock_99		-0.0003		0.0002
		(0.0002)		(0.0003)
Low SES Xshock_99		0.0004		0.0007
		(0.0009)		(0.0016)
RuralXshock_99		0.0009		0.0009
		(0.0014)		(0.0023)
Observations	27,784	27,784	14,208	14,208
Mean	0.080			

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are women age 15 to 49 in the Reproductive and Health Surveys (RHS) 1994 and 1999. Each column is a separate regression that includes as controls: survey year dummies, villages dummies (states for the cross-section regressions in columns 3-4) , and main effects of the covariates. Nino floods is the number of months of floods experienced in the village of residence during the 1997-98 El Niño. Triple interactions of the shock, dummy for year 1999 and demografic characteristics are included to explore endogenous responses to the shock. SES: socio-economic status. Char.: chracteristics. Cross-sec: cross-section.

A.2 Appendix: Alternative measures of El Niño floods

This appendix shows that the estimates of the effect of exposure to el Niño floods on children's human capital formation presented in the paper are robust to alternative specifications of the shock. Specifically, two measures are used. First, I define a flood month if the standardized monthly rainfall exceeded 1.5 standard deviations (instead of one SDs). Second, the excess of precipitation during El Niño is calculated as the simple summation of the z-scores of excess of precipitation. Results are presented in the following tables and show that the evidence is robust to these alternative specifications.

Table A.3: Alternative excess of rainfall measures: children outcomes

	Height for age_z coef/se	If Anemic coef/se	PPVT coef/se
	Cut-off: 1.5 sdev		
Nino floods - 1st trimester	-0.024	0.025	-0.091**
	(0.035)	(0.019)	(0.044)
Nino floods - 2nd trimester	-0.016	-0.005	0.027
	(0.030)	(0.028)	(0.069)
Nino floods - 3rd trimester	-0.083*	0.021	0.023
	(0.047)	(0.033)	(0.084)
Nino floods - age 0-1	0.016	-0.006	-0.069
	(0.038)	(0.024)	(0.055)
Number of observations	11,983	10,766	9,074
	Sum of the z-scores during el niño		
Nino floods - 1st trimester	-0.004	0.010	-0.034**
	(0.013)	(0.007)	(0.014)
Nino floods - 2nd trimester	-0.005	0.002	0.009
	(0.013)	(0.009)	(0.027)
Nino floods - 3rd trimester	-0.032*	0.010	0.032
	(0.018)	(0.012)	(0.025)
Nino floods - age 0-1	0.012	-0.013	-0.162**
	(0.054)	(0.028)	(0.078)
Number of observations	11,983	10,766	9,074

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. Controls: Child's gender, age, and birth order; mother's and father's education, father at home, mother's language, number of children less than 14 at home, village and wave fixed effects.

Table A.4: Alternative excess of rainfall measures: birth outcomes

	Weighted at birth	Low birth weight	Preterm birth	Low birth weight (drop preterm)
	Cut-off: 1.5 sdev			
Nino floods - 1st trimester	0.007	-0.000	-0.003	-0.003
	(0.009)	(0.010)	(0.006)	(0.009)
Nino floods - 2nd trimester	0.007	0.000	0.001	-0.000
	(0.010)	(0.011)	(0.007)	(0.009)
Nino floods - 3rd trimester	-0.007	0.024**	0.003	0.022**
	(0.009)	(0.011)	(0.008)	(0.010)
Number of observations	7,108	5,338	7,096	4,995
	Sum of the z-scores during el niño			
Nino floods - 1st trimester	0.002	0.003	0.001	0.002
	(0.003)	(0.003)	(0.002)	(0.003)
Nino floods - 2nd trimester	0.001	-0.004	-0.004*	-0.002
	(0.003)	(0.003)	(0.002)	(0.003)
Nino floods - 3rd trimester	-0.001	0.010***	0.003*	0.008**
	(0.003)	(0.003)	(0.002)	(0.003)
Number of observations	7,108	5,338	7,096	4,995

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level.Controls: child's gender, birth order, quartert of birth/year dummie; mother's age, marital status, education, if living in urban, ses index, survey year and village fixed effect

A.3 Appendix: Robustness checks: adding province-specific trends

Another concern might be that the results are driven by different trends in places more affected by the floods relative to those less affected. I estimate specifications that allow for flexible province-specific trends (cubic). Results are presented in this appendix and show that the estimates are robust to including province specific cubic trends. A caveat from this type of specification is that even though it allows for different trends for each province it also imposes the variation to be used as deviation of an specific functional form of the trends.

Table A.5: Adding province-specific trends

Children outcomes

	Height for age_z coef/se	If Anemic coef/se	PPVT coef/se
Nino floods - 1st trimester	-0.011	0.021	-0.087**
	(0.038)	(0.018)	(0.042)
Nino floods - 2nd trimester	-0.024	0.010	0.040
	(0.041)	(0.027)	(0.061)
Nino floods - 3rd trimester	-0.077*	0.015	0.034
	(0.040)	(0.028)	(0.067)
Nino floods - age 0-1	-0.016	-0.009	-0.068
	(0.033)	(0.021)	(0.051)
Number of observations	11,983	10,766	9,074

Birth outcomes

	Weighted at birth	Low birth weight	Preterm birth	Low birth weight (drop preterm)
Nino floods - 1st trimester	0.005	0.001	0.000	-0.003
	(0.009)	(0.010)	(0.006)	(0.010)
Nino floods - 2nd trimester	0.007	-0.003	-0.004	-0.000
	(0.009)	(0.010)	(0.006)	(0.009)
Nino floods - 3rd trimester	-0.007	0.021*	-0.000	0.022**
	(0.009)	(0.011)	(0.008)	(0.010)
Number of observations	7,087	5,324	7,075	4,981

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. Cotrol covariates described in the paper.

Appendix: Infant Mortality responses to the El Niño shock

Another potential issue that could contaminate the estimates of the effect of early-life exposure to extreme weather on later outcomes is that I only observe children who survive and are observed years later. If extreme floods increase neonatal and infant mortality, selection to survival could bias the results. In the development literature, the evidence suggests a negative relationship between income shocks and infant mortality. Bhalotra (2010) find that recessions increase neonatal and infant mortality in rural India while booms decrease it. Similarly, Paxson and Schady (2005) argue that children born during the 1980's macroeconomic crisis in Peru are more likely to die as infants. Therefore, if exposure to extreme weather conditions in Ecuador during El Niño increased infant mortality and those who survived were stronger, then one would expect that my estimations are biased downward. However, the degree of scarring can dominate this selection effect and explains my findings of negative, long-lasting effects of exposure to early-life shocks (Deaton, 2007).

To explore this issue, I exploit the information on birth histories collected by the RHS in 2004 that target females between ages 15 and 49.[39] I restrict the sample to children older than 12 months in 2004 to avoid incomplete exposure to the infant mortality risk. Also, I drop children born before 1985 because of both recall bias and the small number of births occurring prior to 1985 in the sample. I estimate the following model:

$$d_{i,h,v,t} \quad = \quad \alpha + \Sigma_{t=1985}^{2003}\{\delta_t nino\_floods_v * d\_year\_t_{i,h,v,t}\} + X_{i,h,v,t}\beta + \theta_t + \eta_v + \varepsilon_{i,h,v,t}$$

where $d_{i,h,v,t}$ is a dichotomous indicator that captures if child i, born to mother m in year t and village v died by age 12 months. δ_{1997} captures the average effect of exposure to El Niño floods on the likelihood of infant mortality for children born in year 1997[40].

[39]For this analysis I did not use the 1999 RHS because children born in the twelve months prior to the survey would not be fully exposed to the infant mortality risk.

[40]I use a classical DID specification instead of computing exposure to El Niño according to month and year of birth because, as noted by Jayachandran (2009), samples are too small to analyze impacts by month of exposure. Instead, I focus on exposure according to year and place of birth.

Table A.6 presents the estimated coefficients for the interactions between year of birth and village exposure to El Niño floods (δ_t). There is no evidence of a relationship between infant mortality and early-life exposure to the El Niño phenomenon.

Table A.6: The 1997-98 El Niño floods and infant mortality responses

	Neonatal Mortality	Infant Mortality
nino_floodsX1991	-0.00102	0.00169
	(0.00150)	(0.00204)
nino_floodsX1992	-0.00107	0.00040
	(0.00132)	(0.00180)
nino_floodsX1993	0.00014	0.00235
	(0.00133)	(0.00166)
nino_floodsX1994	0.00077	0.00296
	(0.00173)	(0.00214)
nino_floodsX1995	-0.00180	-0.00004
	(0.00126)	(0.00172)
nino_floodsX1996	-0.00046	0.00174
	(0.00125)	(0.00167)
nino_floodsX1997	-0.00026	0.00116
	(0.00131)	(0.00178)
nino_floodsX1998	-0.00096	-0.00057
	(0.00141)	(0.00193)
nino_floodsX1999	-0.00158	0.00025
	(0.00168)	(0.00190)
nino_floodsX2000	-0.00089	0.00156
	(0.00137)	(0.00199)
nino_floodsX2001	-0.00057	0.00065
	(0.00138)	(0.00170)
nino_floodsX2002	-0.00171	-0.00081
	(0.00139)	(0.00182)
nino_floodsX2003	-0.00042	0.00247
	(0.00134)	(0.00180)
Observations	14,161	14,161
Y Mean	0.0251	0.0404

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Robust standard errors in parentheses clustered at the village level. The units of observation are children in the Reproductive and Health Surveys (RHS) 2004. 2004 data was used instead of 1999 because in the later children are not fully expose to infant mortality spell. Each column is a separate regression that includes as controls: child's gender, birth order, quartert of birth/year dummie; mother's age, marital status, education, if living in urban, ses index, survey year and village fixed effects. Nino floods is the number of months of floods experienced in the village of residence during the 1997-98 El Niño. Dependent variables are neonatal mortality (likelihood child died within a month of life) and infant mortality (if child died within a year of life).

B Appendix: Additional Tables and Figures

Summary statistics of Hou

Table B.1: Summary statistics - Living Standard Measurement Study 1995

	Mean	SD	N
Household head Characteristics			
Age	45.48	15.44	5808
If male	0.82	0.39	5807
Years of schooling	6.82	4.85	5795
Married or cohabiting	0.76	0.43	5805
If Salaried worker	0.48	0.50	5082
Household size	4.64	2.35	5810
Number of member age 14 or above	2.97	1.56	5810
Monthly total income (Ecu pesos 1995)	967589.20	1725923.00	5700
If urban	0.56	0.50	5810

Note: One dollar = 3000 Ecuadorian sucres in 1995. SD: standard deviation. N: number of observations
Source: Living Standard Measurement Study (LSMS) Survey 1995.

Table B.2: Summary statistics - Reproductive and Health Survey 1994

	Mean	SD	N
Mother characteristics			
Any health insurance	0.17	0.37	3620
Age	26.97	6.45	3620
Age less than 20	0.11	0.32	3620
Age more than 45	0.00	0.05	3620
Married or cohab	0.90	0.29	3620
Number of children	3.19	2.33	3620
urban	0.46	0.50	3620
Primary education completed or less	0.59	0.49	3620
Children charaterisitcs			
Male	0.52	0.50	3620
first born	0.28	0.45	3620
if weighted at birth	0.75	0.43	3619
Preterm	0.06	0.24	3613
Low birth weight	0.18	0.38	2714
if prenatal care	0.76	0.42	3619
Number of prenatal controls	4.33	3.64	3607

Note: SD: standard deviation. N: number of observations
Source: Reproductive and Health Survey (RHS) 1994.

Table B.3: Pre-Niño 1997-98 shock trends in household income

	(1)	(2)	(3)
	ln hh labor income	ln hh non labor income	ln hh total income
Nino_shockX1995	-0.003	0.016	-0.009
	(0.009)	(0.028)	(0.011)
Observations	9,493	3,845	9,933

Notes: * p<0.10 ,** p<0.05, *** p<0.01. Sample includes households in the LSMS 1994 and 1995 surveys. Nino_shock is the number of months of floods during el niño. Dependent variables are the following montly household income: ln hh labor income: log of labor income, ln hh non labor income: log of non-labor income, and ln hh total income: log of total income. Robust standard errors in parentheses clustered at the village level. Regression include village and survey year fixed effects.

Figure B.1: Is the effect on child outcomes linear on months exposed to floods?

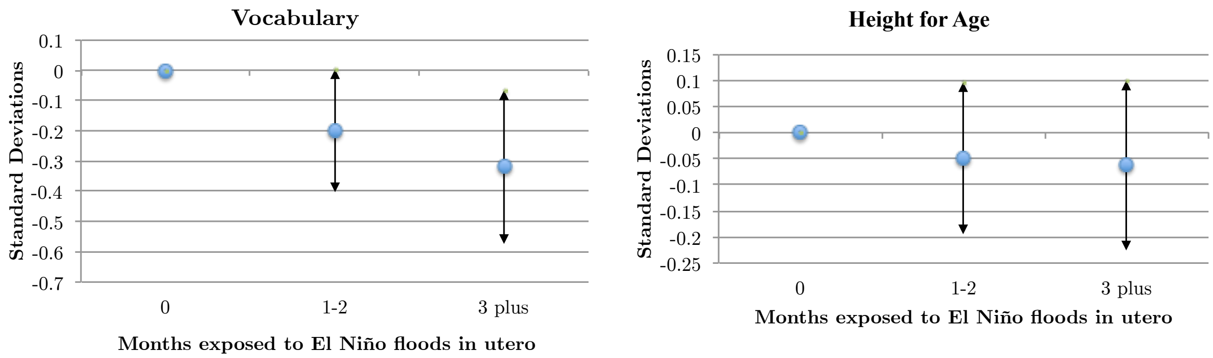


Figure B.2: Is the effect on birth weight linear on months exposed to floods?

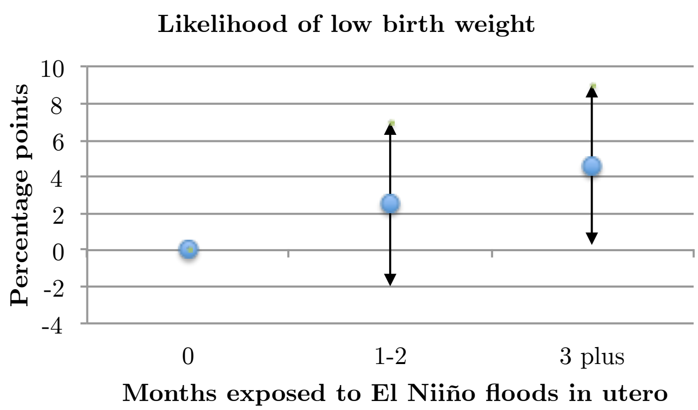
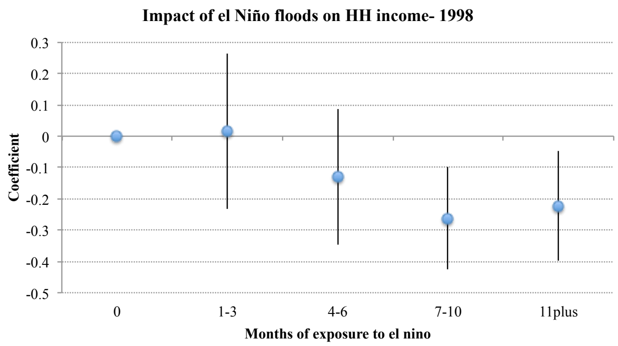


Figure B.3: Is the effect on HH income linear on months exposed to floods?



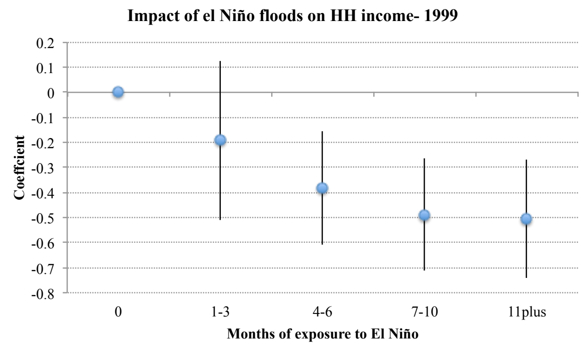


Figure B.4: Maternal labor responses to the shock

	Mother working coef/se
flood_shockX1998	0.005**
	(0.002)
flood_shockX1999	0.007*
	(0.003)
Number of observations	11,706

note: *** p<0.01, ** p<0.05, * p<0.1