The impact of early childhood shocks on the evolution of cognitive and non-cognitive skills

Jessica Leight[1], Paul Glewwe[2], and Albert Park[3]

[1]Williams College Department of Economics
[2]University of Minnesota Department of Applied Economics
[3]Hong Kong University of Science and Technology Department of Economics

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Abstract

The impact of early childhood health shocks on long-term outcomes has long been a major focus in the economics literature. This paper employs a detailed panel dataset in a poor, rural province in China to analyze the impact of early childhood shocks, proxied by rainfall in the county and year of birth, on the evolution of cognitive and non-cognitive skills over time. The results suggest that there is a significant impact of early shocks on cognitive skills that declines over time. However, there is no evidence of a significant impact of early shocks on non-cognitive skills at any age.

1 Introduction

There is increasing evidence that income and health shocks early in life can have long-term effects: in particular, the long-term effect of early childhood shocks on cumulative measures of physical health such as height-for-age is well-established in the nutrition literature (Stein et al., 2010; Prentice et al., 2013), and a growing literature in economics, summarized in more detail below, analyzes the effect of early childhood shocks on other economic outcomes. Rural households in developing countries are exposed to extremely high levels of income risk that risk-coping mechanisms cannot eliminate (Dercon, 2002; Townsend, 1995). Consequently, they face substantial fluctuations in consumption, as well as shocks to the disease environment, during children's crucial years of human capital accumulation.

There are two main types of shocks that can affect children in the first years of life (and in utero) and so can have consequences for their acquisition of cognitive and non-cognitive skills in later years: income shocks and disease shocks. First, weather shocks, along with price shocks and parental employment shocks, could lead to unexpected negative income shocks, which will reduce children's food consumption (and thus reduce child growth) in utero and in early childhood, and may also reduce parental time and the quality of that time due to increases in parental working hours and reductions in parental health. Second, weather shocks and environmental fluctuations could also worsen the disease environment through increased water contamination or vector-borne illnesses, which could directly impair children's health and thus slow their physical and neurological development. Shocks that affect the disease environment could also reduce the health of parents, reducing the quantity and quality of parental time with children. To the extent that all of these shocks reduce household income, they are likely to have long-term effects on households' asset stocks and thus on future household income, which could have consequences that continue to have impacts throughout the child's life.

Short-term fluctuations in consumption or in health could thus have major long-term implications if those fluctuations occur during a critical period of development in infancy, highlighting a channel for long-term persistence of negative shocks. However, no consensus has emerged as to whether "catch-up" is possible for individuals who experienced adverse shocks early in life. In addition, little evidence has been presented about the impact of early childhood shocks on non-cognitive skills, even though many economists have argued that non-cognitive skills are a major determinant of labor market and other economic outcomes in adulthood (Heckman, Stixrud and Urzua, 2006).

The objective of this paper is to present three strands of evidence about the relationship between early childhood shocks and later outcomes in rural China. First, we estimate the impacts of such shocks on both cognitive and non-cognitive skills. Second, we evaluate whether these effects persist or decay over time for a given cohort of students. Third, we evaluate whether longitudinal evidence about the gradual decay of these effects is consistent with the resource allocation strategies employed by both parents and teachers.

The data employed are from the Gansu Survey of Children and Families, an unusually detailed panel dataset that provides a rich set of outcome measures (including cognitive and non-cognitive skills, behavioral indices and schooling outcomes) for a cohort of 2000 children in 20 counties in one of the poorest provinces in China. The sample consists of children who were aged 9-12 at the time of the first survey and who were re-surveyed two more times, once in adolescence and once in young adulthood. We examine the impact of variation in rainfall in the county and year of birth on the outcomes of interest, and track the evolution of the observed effects over time. In addition, we seek to evaluate whether the resource allocation strategies employed by both parents and teachers reinforce or compensate for this quasi-random variation in early childhood shocks.

The results suggest that while there is a significant impact of adverse shocks on cognitive skills, that impact decays over time. We also find that there is no significant impact of shocks on non-cognitive skills. This pattern is consistent with children who have experienced more adverse shocks in infancy catching up over time in cognitive ability with those who did not experience those shocks. There is also evidence that household educational resource allocation favors children who have experienced more adverse shocks, comparing across villages and years. This compensatory behavior is also consistent with the decaying magnitude of effects over time.

This paper adds to a large literature that has evaluated how early shocks to nutritional availability or health, induced by adverse climatic or political events, can affect health and economic outcomes in both childhood and adulthood; Currie and Vogl (2013) provide a useful literature review of papers that evaluate the effect of shocks before age ten on outcomes in a developing country context. A number of papers have analyzed the long-term impact of famine caused by the Great Leap Forward in China, finding a significant impact on health outcomes (Luo, Mu and Zhang, 2006), labor market and economic outcomes (Almond et al., 2006; Shi, 2011), or both (Chen and Zhou, 2007; Meng and Qian, 2009). Almond (2006) and Almond and Chay (2006) exploit shocks to public health and social policy in the U.S. over time, while Banerjee et al. (2010) evaluate the impact of income shocks in nineteenth century France caused by a vineyard-destroying insect and find that the shocks decreased adult height, but had no detectable impact on other measures of health, including life expectancy. Alderman, Hoddinott and Kinsey (2006) analyze both civil war and drought shocks in Zimbabwe and find that adverse shocks lead to a delay in the initiation of schooling, and fewer years of schooling completed. A particularly closely related paper is the work of Maccini and Yang (2009), who demonstrate that adverse climatic shocks in early childhood lead to worse economic outcomes for adults in Indonesia.

A related literature has analyzed whether children disadvantaged by these type of shocks subsequently catch up relative to peers who did not experience similar adverse events. Deolalikar (1996) presents evidence of complete catch-up in height-for-age by age one (i.e., infants born with lower birth weight subsequently grow more rapidly), but no catch-up after age three. Martorell, Khan and Schroeder (1994) in a review of relevant papers similarly find little evidence of more rapid growth in height-for-age after early childhood for children stunted early in life.[1] Hoddinott and Kinsey (2001) contend that subsequent catch-up in growth in height is limited even for children aged 12-24 months at the time of a drought in Zambia.

By contrast, Koch and Linh (2001) find considerable catch-up in height-for-age for children up to age twelve in a period of rapid economic growth in Vietnam between 1993 and 1998, Similarly, Adair (1999) presents evidence of catch-up between ages 2 and 12 in the Philippines, and Coly et al. (2006) identify large positive changes in height-for-age even for children who were stunted while in preschool. Singh, Park and Dercon (2012) and Crookston et al. (2010) find evidence that deficits in height-for-age and weight-for-age can be reversed between 12 months and 5.5 years in India and Peru, respectively, with the latter paper also arguing that children who catch up following early stunting show no evidence of deficiencies in cognitive skills compared to their non-stunted peers. Mani (2012) finds evidence of partial recovery from chronic malnutrition up to age twelve in Indonesia.

Recent studies employing data from multiple sites have also found evidence of catch-up. Three papers employing the Young Lives data, a longitudinal study of cohorts in Ethiopia, India, Peru and Vietnam, argue that there is catch-up in height-for-age between ages one and eight (Crookston et al., 2013; Lundeen et al., 2013; Schott et al., 2013). A recent long-term follow-up of a nutritional intervention in The Gambia found that a nutritional supplement to mothers during pregnancy that had significant and positive effects on infant outcomes had no long-term impact on health or cognitive ability at ages 6-22 (Alderman et al., 2014). While this cannot necessarily be interpreted as evidence of catch-up, it does suggest that early differences in infant outcomes were not necessarily correlated with later differences in cognitive skills.

Thus despite the fact that many nutritionists regard the period before roughly age three as a defined "critical period" in which targeted interventions can have an impact on height-for-age, preventing or reversing stunting, there is clearly no consensus that

[1] The precise definition of early stunting varies in the papers that the authors discuss, but generally stunting is identified prior to 24-36 months of age.

growth deficits persisting after age three are irreversible. In addition, there is little systematic evidence about the potential for catch-up in cognitive and non-cognitive skills that directly impact future labor productivity.

There has also been a new focus in labor economics in recent years on the returns to non-cognitive skills in education and the labor market. A number of papers exploiting data from the U.S. and U.K. have argued that non-cognitive skills have a large impact on adult economic outcomes, including earnings and labor productivity (Heckman and Rubinstein, 2001; Heckman, Stixrud and Urzua, 2006; Carneiro, Crawford and Goodman, 2007). One author has argued that gender differentials in non-cognitive skills account for a substantial portion of the gap in attainment in higher education between men and women in the U.S (Jacob, 2002).

The evidence on non-cognitive skills in developing countries is still nascent, though data from the same survey in Gansu province used in this paper suggests that non-cognitive skills among children 9-12 do have an impact on their subsequent schooling and labor market decisions (Glewwe, Huang and Park, 2013a). In light of the increasing salience of non-cognitive skills and their impact on economic outcomes, this paper provides the first evidence about the relationship between early childhood shocks and these skills, a point of particular interest given the argument put forth by Almlund et al. (2011) and Borghans et al. (2008) that non-cognitive skills are more malleable in children and young adults than cognitive skills.

The remainder of the paper proceeds as follows. Section 2 describes the data. Section 3 describes the empirical strategy and presents the primary results of interest, while Section 4 presents robustness checks. Section 5 explores potential channels for the primary empirical patterns, and Section 6 concludes.

2 Data

The data set used in this paper is the Gansu Survey of Children and Families (GSCF), a panel, multi-level study of rural children conducted in Gansu province, China. Gansu, located in northwest China, is one of the poorest and most rural provinces in China. Summary statistics, drawn from the first wave of the survey, are shown in Table 1.

The first wave, conducted in 2000, surveyed a representative sample of 2000 children aged 9-12 in 20 rural counties, as well as their mothers, household heads, teachers, principals, and village leaders. All but one of these 2000 children have complete information in the first wave. The second wave, implemented in 2004, re-surveyed the first sample of children at age 13-16 and also added a survey of their fathers; 93.6% of the original sample, or 1872 children, were re-interviewed in the second wave, and 1773 completed achievement tests that were administered in their schools.

The third wave, completed in early 2009, re-interviewed the original sample children during Spring Festival, a peak time for familial visits in rural China. If the sampled individual was not available, parents were asked questions about their child's education and employment status; however, skill measures could not be collected from the children who had not returned to their parents' homes. Of the original 2000 children, 1437 (72% of the original sample) were interviewed directly and completed skill tests in this wave. In addition, information was collected for an additional 426 sample children by surveying their parents.

The household survey questionnaires in waves one (2000) and two (2004) were used to collect extensive information about schooling outcomes, household expenditure on education, child time use, time investments in education by parents and teachers, and child and parental attitudes, as well as more standard socioeconomic variables. In addition, a number of tests were administered to the sampled children. In the first wave, a general cognitive ability test developed by the Institute for Psychology of the Chinese Academy of Social Sciences was administered, which tested common knowledge, abstract reasoning and mathematical skills. In both the first and second wave, grade-specific Chinese and mathematics achievement tests developed by the Gansu Educational Bureau were administered to sampled children to test their comprehension of the official primary school curriculum, whether or not they were enrolled in school.

In the second and third waves, a literacy or "life skills" test was administered, modelled after the International Adult Literacy Surveys; the test assessed prose literacy, document literacy and numeracy. This test was not grade-level specific, and the wave two and three assessments, while similar, were not identical. The test was designed to assess individuals' ability to employ literacy and numeracy skills to function successfully in society. For more details about the cognitive assessment tools employed in this paper, see Glewwe, Huang and Park (2013a).

In addition, each wave of data collection included survey questions posed to the sample children that were designed to measure their non-cognitive skills. In the first and second waves, the survey measured both internalizing and externalizing behavioral problems: the former refers to intra-personal problems (depression, anxiety and withdrawal), and the latter to inter-personal problems (destructive behavior, aggression and hyper-activity). These two measures of non-cognitive skills are identical across the two survey waves, and both are constructed by recording the respondent's agreement or disagreement with a series of statements and then applying item response theory (IRT) to generate internalizing and externalizing scores. The scores are then standardized to have a mean of zero and a standard deviation of one.

There are inherent challenges to measuring non-cognitive skills during adolescence, a period where children's behavior may be volatile or rapidly changing. Glewwe, Huang and Park (2013a) found that first wave measures of non-cognitive skills in this sample, collected when the children were 9-12 years old, were more strongly correlated with subsequent labor market outcomes than second wave measures of non-cognitive skills, collected when the children were 13-17 years old. This suggests there may be greater noise from measurement error in the second wave data. In the third wave, two other measures of non-cognitive skills were collected: the Rosenberg Self-Esteem Scale and a depression scale (CES-D). These measures are considered more appropriate than internalizing/externalizing behavioral scores for young adults. Further detail about the construction of the non-cognitive skills measures can be found in Glewwe, Huang and Park (2013a).

These data are linked to rainfall data consisting of monthly reports of climate stations in China, interpolated to the latitude and longitude of the 20 counties in the sample using the inverse-distance weighting method. Only data from stations within 100 kilometers of the county of interest are employed. About 15% of the original sample is missing rainfall data because the village of birth is too distant from a climate station.

3 Empirical Strategy and Results

The primary objective of this paper is to identify the causal impact of early childhood climatic shocks on cognitive and non-cognitive outcomes in childhood and early adulthood. The specification of interest will be the following, where Y_{ivct} is an outcome for student i born in village v in county c in year t:

$$Y_{ivct} = \beta S_{ivct} + \lambda_c + \nu_t + \epsilon_{ivct} \quad (1)$$

λ_c and ν_t denote county and year fixed effects respectively, and S_{ivct} is the climatic shock of interest, in this case rainfall.

The identification strategy postulates that early childhood climatic shocks affect nutritional availability and thus nutritional status in infancy. For each child, rainfall in the first year of life is calculated as total rainfall in the twelve months following the month of birth, with rainfall in years two, three and four calculated analogously. Rainfall in utero is rainfall in the twelve months prior to birth.[2]

[2]Twelve months rather than nine months is employed to allow for a buffer given the imprecision in estimated dates of conception and birth.

3.1 Rainfall and Grain Yield in Gansu

Before analyzing the effect of shocks on child outcomes, it is useful to briefly examine the relationship between rainfall and harvest quality, as proxied by grain yield, in this sample, given that this relationship will prove to be somewhat nonstandard. Grain yield measures for the county of interest are available from Gansu county yearbooks, and are reported only on an annual basis. Thus in order to analyze this relationship, we define $\tilde{S}_{vct}$ equal to rainfall in the calendar year for village v in county c and year t and regress grain yield on rainfall, with and without county and year fixed effects.

$$G_{vct} = \beta\tilde{S}_{vct} + \lambda_c + \nu_t + \epsilon_{vct} \tag{2}$$

In addition, new measures $\tilde{S}^1_{vct}$, $\tilde{S}^2_{vct}$, etc. will be defined to capture rainfall in quarter one through four of the calendar year, respectively. $\tilde{S}^{var}_{vct}$ is defined to be the within-year variation in rainfall.

The results are shown in Table 2. The first three columns regress grain yield on rainfall, rainfall in each period and within-year variation in rainfall without any fixed effects. A generally negative relationship between rainfall and grain yield is evident, and the same pattern is evident with year fixed effects. There is also a negative relationship between variability of rainfall and grain yield, significant only with year fixed effects.

Columns (6) through (9) show the relationship between grain yield and rainfall including both county and year fixed effects. The primary relationship is now small in magnitude and insignificant. Examining the effects by period, a positive relationship is observed during the second quarter, and a negative relationship of almost equal magnitude in the fourth quarter; the coefficients in the first and third quarters are negative but insignificant. There is also a negative relationship between rainfall variation and grain yield, suggesting that areas with particularly large fluctuations may be vulnerable to poor crops.

These results are consistent with the agronomic and climatic literature, which has noted that increased rainfall in Gansu is often associated with lower grain yields due to the concentration of intense rainfall in the harvest period, causing erosion (Li et al., 2002). More specifically, the period in which rainfall is most beneficial for crops is cited as May to early July; high rain in this period is generally correlated with higher yields, consistent with the effects observed here (Cook, Fengrui and Huilan, 2000).

It is crucial to note that on average, rainfall in the second quarter constitutes only around 33% of total rainfall in this sample, suggesting that the negative effect may dominate. In addition, rainfall may have effects on the yield of crops other than grain that are consumed by the household or sold to generate income, leading to a larger effect on nutritional availability. These secondary effects could be positive or negative, but evidence in the next section will suggest they are likely negative.

3.2 Rainfall and Height-for-age

In order to generate some preliminary evidence on whether there is any persistent effect of early childhood shocks on outcomes, the first equation of interest regresses height-for-age, a summary measure of long-term health that has been found in the literature to be highly correlated with early childhood malnutrition (Grantham-McGregor et al., 2007), on rainfall in utero and in each year of life up to age four. We employ a measurement of height captured in the second wave of the survey, when the children were 13 to 16 years old, and normalized to a Z-score using the World Health Organization standards for height-for-age.

Figure 1 shows a histogram of rainfall in the first twelve months of life to illustrate the general patterns of precipitation observed. Given the evidence of a long right tail in rainfall observations, the top 3% of observations (denoted in the figure by the vertical line) are dropped to avoid influence of outliers.[3] The specification is thus as follows,

[3] The relationships between the rainfall shocks of interest and height-for-age as well as other variables in the subsequent analysis are generally robust to the inclusion of outliers in rainfall. However, the relationship between the shock in the first year of life and height-for-age is not significant (though of comparable magnitude) when outliers are included.

where H_{ivct} denotes height-for-age:

$$H_{ivct} = \beta S_{ivct} + \lambda_c + \nu_t + \epsilon_{ivct} \quad (3)$$

The results are shown in Table 3, and standard errors are clustered at the county-year level.

The first thing to note is that the coefficients, when significant, are generally negative, consistent with the prior evidence of a potentially adverse impact of rainfall on grain yield and thus height-for-age.[4] The first five columns in the table show the estimated effects on height-for-age of shocks in utero and in years one through four. We can observe a large and highly significant effect of shocks in utero, following by effects on the first and second year that are relatively large. The estimated effects in years three and four are statistically insignificant, consistent with the intuition that these shocks are after the critical period for early childhood development. Shocks in years three and four of life will be used as placebo tests throughout the analysis.

Column (6) regresses height-for-age on a total shock variable, defined as the mean of rainfall in utero and in years one and two.[5] This is a summary measure of early shocks that may be of interest in the subsequent analysis, and the same negative and significant coefficient is observed. Moreover, the confidence interval on this summary shock measure allows for the rejection of the hypothesis that the average effect in the critical period (i.e., before age two) is equal to the effect observed at ages three and four. Given that the mean of the dependent variable is -1.19 (i.e., the average child in this sample is around one standard deviation below average height for a well-nourished child of his/her age), the estimated coefficient in Column (6) suggests a one standard deviation decrease in rainfall in the so-called "critical period" leads to a roughly 25% increase in height-for-age.

[4]This may also reflect a slight imbalance in birth timing; around 53% of all births are reported in the second half of the year, when rainfall generally has an adverse effect on grain yield, and this could lead to a more negative impact if rainfall in the early months of life is most important. More evidence about birth timing will be presented in the section on robustness checks.

[5]This summary variable, once created, is also normalized to have mean zero and standard deviation one.

This is a mean effect, but the coefficient of interest may vary significantly with month of birth. More specifically, it is possible that for children born late in the calendar year, the most important harvest in fact precedes their birth (or precedes their conception), generating the food stock that feeds the infant (or pregnant mother). This pattern should be evident in a significant interaction between month of birth and the climatic shock. This specification is estimated in Column (7), and no such interaction is observed.[6] This test also suggests that a labor supply response by parents (especially mothers) to climatic shocks is not a plausible channel for the observed effect on height-for-age, as the labor response to rainfall would be expected to vary meaningfully by season, leading to an effect of shocks that varies with the month of birth.

Finally, Column (8) shows the same specification including an interaction effect with gender. There is no evidence that girls are disproportionately vulnerable to early childhood shocks in this sample. It is important to note that gender cannot reasonably be considered to be exogenous in this sample, as 54% of children observed are boys. However, the sex difference does not significantly differ from .5 among the subsample of index children who are also first-born; this is consistent with other anthropological evidence that sex selection on the first birth is rare, and the sex ratio begins to increase significantly primarily following the birth of a first-born daughter. Re-estimating the first stage restricting the sample to only first-born children, for whom gender is plausibly exogenous, also results in an insignificant coefficient on the gender interaction term.

These results suggest that there is a persistent effect of early childhood shocks and particularly shocks in utero on physical health, as measured by height-for-age in adolescence. The objective of the primary empirical analysis is to test whether there is likewise evidence of a persistent effect on cognitive and non-cognitive skills, and whether this effect persists or diminishes over time.

[6]This specification does impose a possibly arbitrary linear structure on the month variable, numbered from one (January) to 12 (December). An alternate specification generates month fixed effects, interacts those month fixed effects with the climatic shock, and tests for the joint specification of the interaction terms. Again, this test fails to reject the null.

3.3 Early Shocks and Cognitive and Schooling Outcomes

In analyzing the effects of early childhood shocks on cognitive and schooling outcomes, the same primary equation (1) will be employed. The explanatory variables of interest will again include shocks in utero, in years one and two, and an average shock measure over the critical period, as well as shocks in years three and four employed as placebo tests. Table 4 shows the result of estimating this specification employing as the dependent variable cognitive and achievement tests in all three waves. All test scores are normalized to have a mean of zero and a standard deviation of one to enable comparison of effect sizes.

Panel A shows the impact of early childhood shocks on tests administered in the first wave when children were 9-12 years old. The coefficients are generally negative, consistent with individuals who were exposed to higher levels of rainfall in childhood, and thus experienced greater nutritional deprivation, showing weaker academic outcomes. The largest effects by far are seen for the shocks in utero, where the effect is also highly statistically significant. The effect of the total shock variable is generally large in magnitude, but noisily estimated.

The magnitude of the estimated coefficients suggests that a one standard deviation increase in rainfall in utero leads to cognitive scores that are around .1 standard deviations lower, and achievement test scores are around .2 standard deviations lower.[7] Examining the coefficients on shocks in year three and year four, there is some weak evidence of the impact of shocks in the third year of life, though diminishing in magnitude, and no significant evidence for year four; some coefficients have in fact reversed in sign.

In the later waves, however, these significant effects of early shocks appear to be significantly attenuated. The results for the wave two outcomes are found in Panel B of Table 4. Comparing the impact of in utero shocks in waves one and two (i.e., the first

[7] For the first wave achievement tests, respondents were randomly assigned to take either the mathematics or the Chinese exam; mean achievement is thus simply equal to the score on the exam administered to that respondent. In the second wave, all respondents participated in both the mathematics and the Chinese exams, and the mean achievement score is the average of the two scores.

rows of Panel A and Panel B), only the coefficient on the literacy/life skills score in Panel B is of comparable magnitude relative to Panel A. The coefficients estimating the impact of in utero shocks on achievement tests in the second wave and the literacy test in the third wave are close to zero, and the confidence intervals allow us to rule out effects of the magnitude observed in earlier waves.

The coefficients on shocks in years one and two for wave two outcomes are uniformly insignificant. Comparing the coefficients on the total shock variable in Panel B to the coefficients in Panel A, a significant attenuation is again observed, and the only significant coefficient in Panel B is for the wave three literacy test. This suggests that children who suffered a loss in academic skills due to weather shocks early in life are catching up relative to their peers who did not experience comparable shocks.

Pnale A of Table 5 shows the estimated coefficients for simple measures of progression through schooling. Examining the coefficients corresponding to the total shock in utero and in years one and two, there is evidence from the first wave that children who experience adverse shocks in early childhood (i.e., higher rainfall) enter kindergarten and primary school at an older age, delaying their entry into schooling.[8] They are in a lower grade level, and they graduate from primary school at an older age (around .4 years later). They remain in a lower grade (around .2 grades lower) in the second wave.

There are two important differences comparing this set of results to the previous results. First, there is no attenuation in the estimated coefficients over time (i.e., no evidence of catch-up).[9] Second, there is some evidence of a significant impact of shocks in years three and four of life, albeit smaller in magnitude.

[8]Note that attendance in kindergarten is not universal, measured at 70% in this sample, and not all children have graduated from primary school at the time of the first wave of data collection. Entry in primary school, by contrast, is nearly universal; only nine children in the sample never entered school.

[9]The coefficient on first wave grade level is notably smaller than the other estimated coefficients, an anomaly that is surprising given the large effect evident latter in the second wave. A larger effect on grade level in wave one is detected in alternate specifications, for example employing a dummy variable for a shock that is above or below the 50th percentile.

3.4 Early Shocks and Non-cognitive Outcomes

Table 5 shows the impact of early-childhood shocks on non-cognitive skills: more specifically, indices of internalizing and externalizing behavioral problems as measured in the first and second wave, and self-esteem and an index of depression as measured in the third wave. The dependent variables are again normalized to have a mean of zero and a standard deviation of one. For the internalizing and externalizing indices and the depressive scale, a higher value indicates more behavioral problems and thus worse non-cognitive skills. For the Rosenberg scale, a higher value indicates improved self-esteem.

Here, there is almost no evidence that early-childhood shocks have a significant impact on non-cognitive skills. There is some weak evidence in wave one that children who have experienced adverse climatic shocks are more likely to have internalizing behavioral problems, with the magnitude of the effect around .08 standard deviations. However, the estimated coefficients are not significant, and the magnitudes decline from the first wave to the second wave. This evidence suggests that impaired non-cognitive skills are not a plausible channel in this context for a persistent effect of early childhood deprivation on adult outcomes.

Measuring non-cognitive skills is, of course, a non-trivial challenge, and it is possible that the failure to detect a significant effect partially or primarily reflects mismeasurement. In order to address this concern, we also compiled a series of more general reports about the child's behavior from his/her mother and teacher. This includes a general behavior index that is the mean of the response (by the mother or teacher) to a series of statements about the child's behavior, and responses by the mother to questions about whether her child is generally naughty and enjoys socializing. These measures also show uniformly insignificant relationships with climatic shocks early in childhood, with the exception of the mother's response about her child's naughty behavior in wave two.[10] This suggests that the null effect on non-cognitive skills is unlikely to be simply an artifact of measurement.

[10] Tabulations available on request.

3.5 Heterogeneous Effects by Gender

Table 6 checks for heterogeneity in the reduced form effects for the in utero shocks by gender for a set of the primary outcomes: test scores in all three waves, and non-cognitive skills in waves one and two.[11] The equation estimated is the following, where G_{ivct} is a dummy variable for child i being female.

$$H_{ivct} = \beta_1 S_{ivct}^{utero} + \beta_2 S_{ivct} \times G_{ivct} + \beta_3 G_{ivct} + \lambda_c + \nu_t + \epsilon_{ivct} \quad (4)$$

Panel A shows the impact of early childhood shocks on cognitive outcomes measured in wave one by gender. There is some weak evidence that the adverse effect of climatic shocks on cognitive skills may be slightly larger for girls, though the estimated coefficient on the interaction effect is insignificant in all cases except for one. For non-cognitive skills, there is some evidence of heterogeneity in the effect of early shocks in Panel C of Table 6. While there are no significant effects for boys or girls in the first wave, in the second wave there is some evidence that adverse shocks lead to worse non-cognitive outcomes for male children (evident in the negative coefficient on rain shock), but not for female children.

3.6 Heterogeneous Effects by Land Endowment

An additional plausible hypothesis about the heterogeneity of the effects of early childhood shocks is linked to familial characteristics. Particularly, households with a greater capacity to self-insure against shocks may demonstrate an attenuated or even zero impact of climatic events in infancy on their children's subsequent human capital outcomes if they are able to partially shield their children from those events.

In order to test this hypothesis, we employ a measure of arguably the most important asset held by rural households: land. Land in rural China is collectively owned, but

[11] Results for the other outcomes and other early childhood shocks are omitted for concision given the lack of any significant pattern, but are available upon request.

households have use rights over plots that are assigned to them for cultivation, and have the rights to all output produced by that plot after fulfilling their mandatory grain quota. Land held is reported by households in both the first and second waves, and the land measure employed in this specification is from the first wave. The equation of interest is parallel to the equation estimated to identify heterogeneous gender effects. L_{ivct} denotes the land cultivated by the household as reported in wave one of the survey, and the climatic shock in utero is employed as the explanatory variable.

$$H_{ivct} = \beta_1 S_{ivct}^{utero} + \beta_2 S_{ivct}^{utero} \times L_{ivct} + \beta_3 L_{ivct} + \lambda_c + \nu_t + \epsilon_{ivct} \tag{5}$$

While households with a greater allocation of land are presumably wealthier and may have a greater ability to self-insure against shocks, it is also possible that they are more vulnerable to weather shocks (unless they produce a crop mix that allows them to diversify their weather risk). The results shown in Table 7 suggest that households with greater land endowments exhibit an attenuated impact of adverse rainfall shocks on their children's cognitive outcomes. A one standard deviation increase in the land endowment of the household would result in an effect of the same rain shock on normalized achievement scores that is attenuated by nearly 50 percent.

This pattern is consistent across the first wave cognitive measures, but has generally disappeared by the second wave, consistent with the prior evidence of catch-up. There is also little evidence of any heterogeneity in the effect for non-cognitive skills, unsurprising given the overall null effect. There is a potential source of bias in these results if the household characteristics that determine the land endowment in the political/administrative process by which land is allocated are also correlated with other characteristics that could be relevant to the human capital formation process for children. For example, households that are politically more influential or better-connected might be more likely to have larger land plots and also independently have access to resources that would render them better able to insure against the effect of weather shocks.

Other work by one of the authors has found that, in a different, nation-wide sample, there was little systematic evidence of political favoritism in the assignment of land plots (Leight, 2013). However, to test for robustness to this potential source of bias, we also re-estimate the same equation using an index of other productive assets as reported in the wave one survey. The results in Panel D of the same table show a parallel pattern, though the implied magnitude is smaller: a one standard deviation increase in the assets endowment of the household would result in an effect of the same rain shock on normalized achievement scores that is attenuated by around 20 percent.

4 Robustness Checks

4.1 Additional channels

Table 8 presents evidence about additional channels through which early childhood shocks might affect cognitive and non-cognitive outcomes in childhood. The specification of interest regresses various socioeconomic characteristics at the household level, measured in the first survey wave, on the climatic shock experienced in utero by the child of interest, analogous to the reduced form equation (1). The characteristics include per-capita income, per-capita income from agriculture, livestock, wage labor and non-agricultural self-employment, assets and fixed capital owned normalized by household size, hours reported worked by the mother and father in a week, land held, square feet of housing owned, and a dummy for the presence of resident grandparents. These regressions are designed to test for an alternate channel through which early childhood shocks could have a persistent effect on outcomes in childhood or young adulthood: namely, a persistent effect on the asset stock or income trajectory of the household.

The results demonstrate that there is no significant correlation between shocks in utero and subsequent economic outcomes, with the exception of an index of fixed productive capital. In this case, households that experience adverse shocks show lower accumulation of fixed capital assets, as expected.[12] It is also relevant to note that in the first wave, net income from wages constitutes a high proportion of total net income, constituting around 45% of total income for the median household. The absence of any significant relationship between prior climatic shocks and household income is thus perhaps unsurprising.

The salience of wage income may seem incongruous given that climatic shocks in the years in which these sampled children were born are observed to have such a large impact on height-for-age, consistent with households that are primarily dependent on agriculture. Like many other interior provinces in China, Gansu experienced rapid growth in outmigration in the 1990s, the decade following the birth of the majority of sample children (Rozelle et al., 1999). Accordingly, households that were once primarily agricultural have rapidly transitioned to a primary dependence on wage income. The lack of correlation between past climatic shocks and later assets and income is consistent with the primary channel of impact in the main specification running through early childhood development, rather than a permanent effect on the trajectory of income or asset accumulation for the household.

One final channel that may mediate the relationship between shocks in the period of birth and later outcomes is birth timing. If parents time births to occur during months or years where climatic conditions are preferable, this may attenuate the relationship between climatic shocks and later outcomes. If some parents are differentially able to time births - a plausible hypothesis - then children born in months or years with adverse shocks may be drawn from households disadvantaged along other dimensions.

In order to test this hypothesis, we construct a dataset at the month-village (and later, year-village level), with the variable B_{vcmt} equal to the number of births observed in village v in county c in month m and year t. We employ months in the five years where 99% of the sample children are born (1987-1991), and B_{vcmt} is set equal to zero for any month-village cell within the specified range in which no births are reported.[13]

[12] Adding a control variable capturing land held to the regressions employing assets and productive capital as the dependent variable does not change the results.

[13] The results are also robust to an alternate specification employing only the month-village cells in which births are reported, restricting B_{vcmt} to be positive.

The specifications of interest are thus the following, for births at the month and year level respectively.

$$\begin{aligned} B_{vcmt} &= S_{vcmt} + \lambda_c + \nu_t + \epsilon_{vcmt} \\ B_{vct} &= S_{vct} + \epsilon_{vct} \end{aligned}$$

County and year fixed effects are included in the month-level specification, and standard errors are clustered at the county-year level. The explanatory variable S is rainfall in the village of interest in the specified month or year.

The results in Panel C of Table 8 show uniformly insignificant coefficients. There is no evidence in the first three columns that the number of births is higher in months or years with preferable climatic shocks. In Columns (4) and (5), the climatic shock is interacted with maternal and paternal education, respectively, as a proxy for parental ability to time births; the interaction effects are again insignificant. Households in the sample do not appear to be timing births to coincide with favorable climatic shocks, and this is consistent across households of varying education levels.

4.2 Measurement Error

Given that some of the primary results of interest in this analysis are null results, this may raise the concern that the failure to detect a statistically significant or economically meaningful effect primarily reflects measurement error in the explanatory variable, rainfall shocks in early childhood. However, given that the rainfall estimates were interpolated from local rainfall stations and data on the distance between rainfall stations and the sampled villages is available, it is possible to test for attenuation bias due to measurement error under the relatively simple assumption that this bias should be larger (and thus the estimated coefficients closer to zero) for localities at a greater distance from weather stations.

In order to implement this test, we create a variable D_{vc}^q for village v in county c that corresponds to the quartile of the average distance from this locality to climatic stations within 100 kilometers. (The 100 kilometer limit is employed to maintain consistency with the primary sample and results, where only weather stations within this limit were employed to generate estimates of rainfall.) We then re-estimate the reduced form equation (1) including the interaction of the rain shock and D^q_{vc}, as well as quartile fixed effects μ_q, resulting in the following specification.

$$Y_{ivct} = \beta_1 S_{ivct} + \beta_2 S_{ivct} \times D^q_{vc} + \lambda_c + \nu_t + \mu_q + \epsilon_{ivct} \qquad (6)$$

If measurement error is a major source of bias, then β_1 and β_2 should be of opposite sign, suggesting greater attenuation in the coefficients of interest for localities that are remote from weather stations.

The results are shown in Table 9. In Panel A, it is evident that the coefficients β_1 and β_2 are generally of the same sign when the dependent variables are height-for-age and cognitive test scores from the first wave. This suggests that if anything, the impact of climatic shocks is larger for localities more remote from weather stations - consistent with the intuition that these may be poorer localities where households are less able to insure against short-term shocks. The bottom row of the table shows the estimated coefficients using this specification for a village in the second quartile of average distance from the weather station; the coefficients are consistent in sign and significance with those estimated in the primary analysis, though generally somewhat larger in magnitude.

In Panel B, the pattern is heterogeneous, with β_1 and β_2 sometimes of the same sign and sometimes of opposite sign. The estimated coefficients for a village in the second quartile are small in magnitude and insignificant, again consistent with the primary results. Both sets of results from the estimation of specification (6) suggests that measurement error is not a major source of bias in these results.

5 Declining Importance of Shocks Over Time

There are at least two important reasons why early childhood shocks may have a diminishing impact on cognitive skills over time. First, there may be an inherent biological process in which children with impaired cognitive skills at an early age experience more rapid growth in those skills. Second, there may be compensatory investments made by parents or teachers that target children who experienced adverse shocks early in life. While we certainly cannot rule out the first channel, a process of innate decay, it cannot be directly substantiated in the data. However, evidence will be presented that the second channel is relevant in this context.

5.1 Household and Teacher Investments

Tables 10 and 11 present evidence about how investments, both non-monetary and monetary, by teachers and parents in children's education responds to differences in the early childhood shocks experienced by different children. Table 10 shows the results of estimating the reduced form specification (1) for measures of non-monetary investments by teachers. The dependent variables in wave one are a dummy variable for the teacher meeting with the child's parents, and a dummy variable for whether the teacher reports a close relationship with the parents; in wave two, the same variables are reported, as well as the number of times the teacher met with the student him/herself.

In general, teachers seem to invest more time in children who were exposed to adverse shocks in infancy, though the evidence is not robust across all shock measures. Examining the evidence for the total shock variable, a one standard deviation increase in rainfall makes it about 3% more likely that teachers report meeting with parents in the first wave (an increase in probability of .024 on a base probability of .697) and 10% more likely they report a close relationship with parents in the first wave; these effects are not significant. It also leads to a 10% increase in the number of meetings reported between the teacher and the student in the second wave.

Table 11 evaluates patterns in the monetary investments made by parents in the child's schooling in the first and second waves. Expenditure is separately reported in a number of categories in each wave, including tuition and a variety of discretionary expenditures, and the effects are also estimated for total expenditure. The evidence here is somewhat heterogeneous: in the first wave results reported in Panel A, some categories of expenditure are negatively correlated with rain shocks, suggesting reinforcing behavior. However, there is more evidence of compensatory behavior, particularly among the subset of households that report positive expenditure.[14]

In the second wave, there is primarily evidence of compensatory behavior. Examining the coefficients on the total shock variable, a one standard deviation increase in rainfall leads to a 20% increase in total expenditure, a 12% increase in expenditure on supplies, a 53% increase in transportation, and a 44% increase in food at school; the latter effect is narrowly insignificant at conventional levels.[15] The estimated effects for households reporting positive expenditure are of comparable magnitude, and are significant across five categories of expenditure. This pattern yields suggestive evidence that parents accurately perceive the effects of early child shocks on their children's cognitive outcomes, and that both parents and teachers make compensatory investments in order to minimize the adverse effects of these shocks.

6 Conclusion

The role of early childhood shocks in shaping long-term economic outcomes has been an increasing focus in both the health and economics literature in recent years. In this paper, we draw on a new and valuable source of evidence - an unusually detailed panel tracking human capital outcomes over time in a poor, rural province in China - to examine how the impact of these shocks evolves over time, and how parental and teacher investments

[14]The specifications estimating the effect of shocks on total expenditure are estimated only if there are more than 50 observations for households reporting positive expenditure in the specified category.

[15]The reported coefficients are changes in expenditure in absolute magnitude; the mean of the dependent variables are reported at the base of the table.

respond to such shocks.

Our evidence suggests that early childhood shocks, measured by rainfall in the county and year of birth, have a robust effect on children's height-for-age, and have a significant impact on cognitive skills in primary school as well as on school progression. While we cannot fully identify the channel for these effects, there is little evidence that these results reflect birth timing on the part of parents, a persistent effect on household income or assets, or a parental labor response to climatic shocks in infancy that would affect children's outcomes. The primary channel seems to be an effect of nutritional deprivation, as proxied by adverse climatic conditions, on nutritional intake and thus on physical and cognitive growth.

However, there is also evidence that children exposed to adverse shocks catch up over time to their less disadvantaged peers. By the second wave of the survey, data collected when the children are between 13 and 16, the effect of shocks on cognitive skills appears to be zero. There is also very little evidence of a relationship between early shocks and non-cognitive skills at any age.

In addition, we present suggestive evidence that the fading cognitive impact of early childhood deprivation reflects at least to some degree compensatory investments made by parents and teachers, who are more likely to invest expenditure and time in the education of children who were exposed to harsher shocks and exhibit a less robust physical endowment as measured by height-for-age. Previous research on the relationship between parental investment and children's endowment has produced conflicting results. Akresh et al. (2012) and Rosenzweig and Zhang (2009) find parents exhibit reinforcing behavior in Burkina Faso and China, respectively. In another paper analyzing the same sample in Gansu, Leight (2014) compares investments across siblings of varying endowment in the same households and again finds evidence of compensating behavior.

In analyzing school-level investments, recent research in Vietnam and Peru has presented evidence that teachers in Vietnam may also target weaker-performing children to encourage them to meet a certain minimum standard level, while straggling students in

Peru are ignored (Glewwe et al., 2013b). Evidence in sub-Saharan Africa and India summarized in Banerjee and Duflo (2011) also suggests that the educational system primarily targets the highest-achieving children and may leave lower-performing children behind.

This cross-country variation in the orientation of household and educational decision-makers towards under-performing children remains an interesting area for future exploration. From a policy perspective, the results in this paper are encouraging, suggesting at least in this context it may be possible to reverse the negative cognitive impacts of early deprivation, and that households and other institutions may already be motivated to make the investments necessary for this catch-up.

7 Figures and Tables

Figure 1: Rainfall in the first year of life

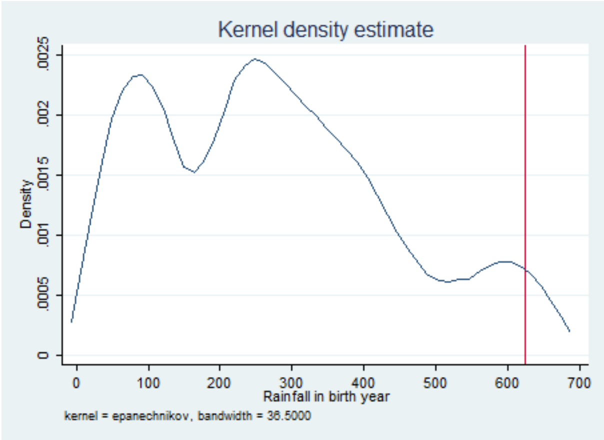

Table 1: Summary statistics

Indicator	Mean	St. dev	Obs.
Income per-capita	468.7	619.6	1435
Net income: cropping	1293.5	2195.1	1435
Net income: livestock	61.4	1604.4	1435
Net income: wages	3694.3	5231.3	1435
Net income: self-employment	882.1	4067.5	1435
Land plot	4.4	5.5	1435
Housing square feet	84.3	65	1435
Household size	4.1	1.2	1435

Table 2: Grain yield and rainfall

	Grain yield								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Precipitation	-1.007***			-1.108***			.055		
	(.192)			(.178)			(.036)		
Quarter 1		.899***			1.035***			-.010	
		(.234)			(.300)			(.057)	
Quarter 2		-.790***			-.673**			.122**	
		(.201)			(.273)			(.048)	
Quarter 3		-.631***			-.662**			-.008	
		(.231)			(.319)			(.051)	
Quarter 4		-.622***			-.916***			-.111**	
		(.152)			(.209)			(.044)	
Rain variation			-.090			-.419***			-.020**
			(.183)			(.111)			(.009)
Fixed effects	None	None	None	Year	Year	Year	County + Year	County + Year	County + Year
Obs.	364	364	364	364	364	364	364	364	364

Notes: The dependent variable is grain yield and the explanatory variable is average precipitation in the same calendar year, or average precipitation in the specified quarter. The sample of villages and years is constituted by the birth villages and years of the individuals in the primary analysis. Fixed effects are included are year, county or county and year as specified. Asterisks indicate significance at the ten, five and one percent level.

Table 3: First stage

	Height-for-age							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Utero shock	-.238***							
	(.055)							
Year 1 shock		-.102*						
		(.059)						
Year 2 shock			-.124**					
			(.056)					
Year 3 shock				-.050				
				(.060)				
Year 4 shock					-.072			
					(.059)			
Precip. variation						-.260***	-.259***	-.250**
						(.068)	(.086)	(.102)
Month int.							-.0001	
							(.007)	
Gender int.								-.006
								(.058)
Obs.	1434	1435	1436	1441	1457	1434	1434	1434

Notes: The dependent variable is height-for-age as measured in wave two of the survey and normalized according to the WHO standards for height by age. The explanatory variable is mean precipitation in the county of birth in the twelve months prior to the month of birth (in utero shock), months 0-11 after birth (year one shock), months 12-23 after birth (year two shock), months 24-35 after birth (year three shock), and months 36-47 after birth (year four shock). Total shock is defined as the sum of the shocks in utero, in year one and in year two. Month int. is the interaction of birth month with the total shock variable, and gender int. is the interaction of gender with the total shock variable. Standard errors are clustered at the county-year level, and all specifications include county and year fixed effects. Asterisks indicate significance at the ten, five and one percent level.

Table 4: Cognitive outcomes

Panel A: Wave one test scores

	Cognitive	Math	Chinese	Mean achievement
	(1)	(2)	(3)	(4)
In utero shock	-.103**	-.161*	-.252***	-.208***
	(.044)	(.088)	(.079)	(.067)
Year 1 shock	-.003	.069	.027	.049
	(.047)	(.068)	(.095)	(.050)
Year 2 shock	-.051	.090	-.215***	-.040
	(.048)	(.066)	(.060)	(.049)
Total rain shock	-.091	-.013	-.277***	-.137*
	(.058)	(.109)	(.096)	(.083)
Year 3 shock	-.068	-.003	-.108	-.042
	(.053)	(.077)	(.075)	(.047)
Year 4 shock	-.052	.055	-.061	.0004
	(.050)	(.067)	(.079)	(.051)
Obs.	1435	707	728	1435
Fixed effects	County+year	County+year	County+year	County+year

Panel B: Wave two and three test scores

	Literacy	Math	Chinese	Mean achievement	Literacy
	(1)	(2)	(3)	(4)	(5)
Utero shock	-.074	-.049	-.038	-.044	-.062
	(.050)	(.082)	(.067)	(.066)	(.052)
Year 1 shock	-.016	-.079	-.007	-.043	-.031
	(.054)	(.079)	(.055)	(.062)	(.059)
Year 2 shock	.006	.095	.004	.050	-.038
	(.043)	(.074)	(.063)	(.060)	(.051)
Total shock	-.057	-.024	-.058	-.041	-.104*
	(.068)	(.129)	(.093)	(.102)	(.060)
Year 3 shock	-.021	-.052	-.005	-.029	-.026
	(.059)	(.090)	(.066)	(.073)	(.065)
Year 4 shock	-.029	-.038	-.011	-.025	-.069*
	(.041)	(.079)	(.064)	(.064)	(.041)
Obs.	1296	1287	1287	1287	1029
Fixed effects	County+year	County+year	County+year	County+year	County+year

Notes: The dependent variables are test results measured in the specified wave, including a cognitive test, achievement tests in mathematics and Chinese, and the sum of the achievement test results. The explanatory variable is precipitation in the village of birth measured in the specified year, where year one of life is defined as the 12 months following birth, the in utero period is defined as the 12 months before birth, and shocks in later years are identified analogously; the total shock variable is the sum of precipitation in utero and in years one and two. Standard errors are clustered at the county-year level, and all specifications include county and year fixed effects. Asterisks indicate significance at the ten, five and one percent level.

Table 5: Academic attainment and non-cognitive outcomes

Panel A: Academic attainment

	Wave one						Wave two		
	Kinder. entry age	Primary entry age	Grade level	Skipped sem.	Repeated grade	Primary graduation age	Grade level	Skipped sem.	Repeated grade
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Utero shock	.224**	.218***	-.067	.006	.017	.216***	-.165**	.008	.012
	(.096)	(.071)	(.043)	(.006)	(.024)	(.064)	(.070)	(.010)	(.040)
Year 1 shock	.148**	.160**	-.010	.004	.014	.159**	.002	.016	-.032
	(.073)	(.076)	(.048)	(.005)	(.023)	(.072)	(.060)	(.012)	(.034)
Year 2 shock	.131*	.169**	-.083*	.003	.023	.196***	-.085	.002	-.040
	(.078)	(.067)	(.050)	(.009)	(.026)	(.063)	(.070)	(.006)	(.032)
Total shock	.400***	.338***	-.123**	.006	.032	.350***	-.198**	.012	-.046
	(.132)	(.092)	(.053)	(.010)	(.034)	(.085)	(.100)	(.014)	(.046)
Year 3 shock	.125	.190***	-.038	.001	.008	.165**	-.081	.020*	-.042
	(.079)	(.069)	(.049)	(.004)	(.026)	(.071)	(.068)	(.011)	(.029)
Year 4 shock	.090	.120*	-.023	.005	.021	.131***	-.045	-.004	-.002
	(.096)	(.062)	(.033)	(.006)	(.027)	(.046)	(.059)	(.014)	(.035)
Obs.	1045	1393	1374	1385	1392	1251	1238	1368	1368

Panel B: Non-cognitive skills

	Wave one			Wave two			Wave three	
	Internal	External	Total	Internal	External	Total	Depression	Rosenberg
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Utero shock	.073	.029	.052	-.010	-.0004	-.006	.002	.049
	(.059)	(.069)	(.065)	(.053)	(.055)	(.057)	(.059)	(.061)
Year 1 shock	.003	.057	.032	.004	.020	.013	-.033	.013
	(.056)	(.054)	(.056)	(.051)	(.052)	(.054)	(.068)	(.072)
Year 2 shock	.008	-.039	-.017	.027	.074	.057	-.045	.107*
	(.057)	(.061)	(.060)	(.056)	(.051)	(.056)	(.061)	(.062)
Total shock	.080	.035	.059	-.009	.030	.012	-.049	.100
	(.078)	(.094)	(.087)	(.065)	(.076)	(.074)	(.072)	(.081)
Year 3 shock	.035	.051	.046	-.083	-.035	-.065	.003	-.035
	(.056)	(.058)	(.058)	(.053)	(.063)	(.062)	(.063)	(.065)
Year 4 shock	.035	.047	.044	-.010	.069	.034	-.017	.002
	(.049)	(.055)	(.052)	(.050)	(.046)	(.050)	(.048)	(.069)
Obs.	1435	1435	1435	1388	1388	1388	1051	1040

Notes: The dependent variables in Panel A are measures of academic attainment, including age of entry in kindergarten and primary school, grade level, dummy variables for having skipped a semester or repeated a grade, and age of primary school graduation as reported in wave one; also included are current grade level and dummy variables for having skipped a semester or repeated a grade as reported in wave two. The dependent variables in Panel B are measures of non-cognitive skills, specifically indices of internalizing and externalizing behavioral problems; a higher value corresponds to more behavioral problems. The explanatory variable is precipitation in the village of birth measured in the specified year, where year one of life is defined as the 12 months following birth, the in utero period is defined as the 12 months before birth, and shocks in later years are identified analogously; the total shock variable is the sum of precipitation in utero and in years one and two. Standard errors are clustered at the county-year level, and all specifications include county and year fixed effects. Asterisks indicate significance at the ten, five and one percent level.

Table 6: Heterogeneous effects by gender

Panel A: Wave one test scores

	Cognitive	Math	Chinese	Total
	(1)	(2)	(3)	(4)
In utero shock	.013	-.053	-.250**	-.179*
	(.079)	(.141)	(.107)	(.094)
Utero shock x Female	-.077*	-.074	-.0007	-.019
	(.044)	(.070)	(.056)	(.039)
Obs.	1435	707	728	1435

Panel B: Wave two and three test scores

	Literacy	Math	Chinese	Total	Literacy
	(1)	(2)	(3)	(4)	(5)
In utero shock	-.053	-.049	-.037	-.043	-.174*
	(.095)	(.131)	(.089)	(.093)	(.098)
Utero shock x Female	-.009	.0009	-.0001	.0004	.078
	(.053)	(.065)	(.053)	(.050)	(.058)
Obs.	1296	1287	1287	1287	1029

Panel C: Non-cognitive skills

	Wave one			**Wave two**		
	Internalizing	Externalizing	Total	Internalizing	Externalizing	Total
	(1)	(2)	(3)	(4)	(5)	(6)
In utero shock	.101	-.066	.014	-.211*	-.218*	-.239**
	(.117)	(.126)	(.123)	(.112)	(.112)	(.121)
Utero shock x Female	-.019	.064	.026	.135**	.149**	.158**
	(.057)	(.053)	(.055)	(.064)	(.061)	(.067)
Obs.	1435	1435	1435	1388	1388	1388

Notes: The dependent variables are measures of cognitive skills as reported in Table 4 and non-cognitive skills as reported in Panel B of Table 5. The explanatory variable is precipitation in utero (12 months prior to birth), and the interaction of the precipitation variable with a gender dummy; the coefficient on the gender dummy is not reported. Standard errors are clustered at the county-year level, and all specifications include county and year fixed effects. Asterisks indicate significance at the ten, five and one percent level.

Table 7: Heterogeneous effects by land and assets endowment

Panel A: Wave one test scores

	Cognitive	Math	Chinese	Total
	(1)	(2)	(3)	(4)
Utero shock	-.123**	-.187**	-.320***	-.251***
	(.049)	(.094)	(.068)	(.068)
Utero shock x Land endowment	.009	.014*	.028***	.020***
	(.007)	(.007)	(.010)	(.006)
Obs.	1435	707	728	1435

Panel B: Wave two and three test scores

	Literacy	Math	Chinese	Total	Literacy
	(1)	(2)	(3)	(4)	(5)
Utero shock	-.101*	-.016	-.048	-.032	-.077
	(.053)	(.087)	(.071)	(.071)	(.056)
Utero shock x Land endowment	.012*	-.014*	.004	-.005	.007
	(.007)	(.008)	(.007)	(.006)	(.006)
Obs.	1296	1287	1287	1287	1029

Panel C: Non-cognitive skills

	Wave one			**Wave two**		
	Internalizing	Externalizing	Total	Internalizing	Externalizing	Total
	(1)	(2)	(3)	(4)	(5)	(6)
Utero shock	.069	.040	.056	-.030	-.016	-.025
	(.060)	(.071)	(.067)	(.057)	(.058)	(.060)
Utero shock x land	.001	-.005	-.002	.009	.007	.009
	(.006)	(.006)	(.006)	(.007)	(.006)	(.007)
Obs.	1435	1435	1435	1388	1388	1388

Panel D: Assets and wave one test scores

	Cognitive	Math	Chinese	Total
	(1)	(2)	(3)	(4)
Utero shock	-.178***	-.284**	-.381***	-.344***
	(.053)	(.115)	(.075)	(.080)
Utero shock x Asset endowment	.005*	.008*	.008**	.008***
	(.002)	(.004)	(.004)	(.003)
Obs.	1435	707	728	1435

Notes: The dependent variables are measures of cognitive skills as reported in Table 4 and non-cognitive skills as reported in Panel B of Table 5. The explanatory variable is precipitation in the county of birth measured in utero (12 months prior to birth) and the interaction of precipitation with land held by the household or an assets index as reported in the first wave of data collection. The coefficients on the land variable and assets index are not reported. Standard errors are clustered at the county-year level, and all specifications include county and year fixed effects. Asterisks indicate significance at the ten, five and one percent level.

Table 8: Additional channels

Panel A: Income and assets

	Per capita income	Agri. income	Livestock income	Wage income	Self empl. income	Assets
	(1)	(2)	(3)	(4)	(5)	(6)
In utero shock	-26.930	14.503	-15.178	-41.584	-61.021	-.290
	(27.074)	(31.576)	(16.832)	(73.973)	(42.171)	(.214)
Obs.	1435	1400	1400	1400	1400	1400

Panel B: Assets and human capital

	Fixed capital	Mother time	Father time	Land	Square feet	Grand-parents
	(1)	(2)	(3)	(4)	(5)	(6)
In utero shock	-.294**	-5.747	8.752	-.048	-4.108	.012
	(.117)	(5.958)	(6.137)	(.127)	(2.701)	(.021)
Obs.	1400	1435	1435	1435	1435	1435

Panel C: Birth timing

	Births per month		Births per year	Births per month	
	(1)	(2)	(3)	(4)	(5)
Monthly rainfall	.004	-.006		-.022	.007
	(.011)	(.010)		(.016)	(.024)
Annual rainfall			.044		
			(.136)		
Rainfall x mother educ.				.002	
				(.004)	
Rainfall x father educ.					-.003
					(.003)
Fixed effects	None	County +	None	None	None
Fixed effects		year			
Obs.	4873	4873	420	1185	1185

Notes: The dependent variables in Panels A and B are measures of household characteristics as reported in wave one: per capita income, net income from four primary sectors (agriculture, livestock, wage earnings and non-agricultural household business), assets and fixed capital, time spent working by the mother and father, land cultivated, square feet of the residence, and whether or not grandparents are co-resident. The explanatory variable is precipitation in the village of birth measured in the year in utero. Standard errors are clustered at the county-year level, and all specifications in Panels A and B include county and year fixed effects. The dependent variable in Panel C is the number of births in a given village in a given month or a year, and the explanatory variables are rainfall in that month or year, and the interaction of rainfall and average maternal and parental education in a village. (The coefficient on education entering linearly is not reported.) Standard errors are clustered at the county-year level, and fixed effects included are as specified. Asterisks indicate significance at the ten, five and one percent level.

Table 9: Measurement error

	Height-for-age (1)	Cognitive (2)	Math (3)	Chinese (4)	Total (5)
Panel A: Height-for-age and wave one cognitive measures					
Utero shock	-.176**	-.134	-.046	-.164	-.102
	(.087)	(.083)	(.117)	(.139)	(.091)
Distance x Utero shock	-.019	-.026	-.074	-.075	-.077**
	(.036)	(.036)	(.045)	(.049)	(.038)
Estimated effect (2nd quartile)	-.213***	-.185***	-.195**	-.313***	-.256***
	(.060)	(.052)	(.095)	(.080)	(.065)
Obs.	1434	1435	707	728	1435
Panel B: Wave two cognitive measures					
Utero shock	-.050	-.040	.073	.016	.124
	(.092)	(.176)	(.115)	(.134)	(.083)
Distance x Utero shock	-.015	.012	-.060	-.024	-.080*
	(.041)	(.058)	(.045)	(.047)	(.043)
Estimated effect (2nd quartile)	-.080	-.016	-.046	.031	-.036
	(.055)	(.099)	(.076)	(.078)	(.068)
Obs.	1296	1287	1287	1287	1029

Notes: The dependent variables are measures of cognitive skills in waves one and two as reported in Table 4. The explanatory variable is precipitation in the village of birth measured in the year in utero and the interaction of precipitation with a variable capturing the quartile of average distance between the village and climatic stations within 100 kilometers. Standard errors are clustered at the county-year level, and all specifications include county and year fixed effects and distance quartile fixed effects. The estimated effect for the second quartile reports the estimated effect of the in utero shock on the outcome of interest for villages in the second quartile of distance from climatic stations. Asterisks indicate significance at the ten, five and one percent level.

Table 10: Teacher investments

	Wave 1		Wave 2		
	Parent meeting (1)	Parent relationship (2)	Parent meeting (3)	Parent relationship (4)	Child meeting (5)
Utero shock	.011	.040	.026	-.033	.075
	(.026)	(.029)	(.033)	(.027)	(.058)
Year 1 shock	.022	.055***	-.007	.005	.091**
	(.014)	(.019)	(.013)	(.093)	(.039)
Year 2 shock	.012	.001	.0005	.042	.013
	(.013)	(.028)	(.019)	(.097)	(.042)
Total rain shock	.022	.031	-.011	.073	.164***
	(.014)	(.035)	(.021)	(.138)	(.058)
Mean	.697	.287	.277	.287	1.545
Obs.	1396	1397	660	1227	1227

Notes: The dependent variables are measures of abstract teacher investment in the child of interest. The explanatory variable is precipitation in the village of birth measured in the specified year, where year one of life is defined as the 12 months following birth, the in utero period is defined as the 12 months before birth, and shocks in later years are identified analogously; the total shock variable is the sum of precipitation in utero and in years one and two. Standard errors are clustered at the county-year level, and all specifications include county and year fixed effects. Asterisks indicate significance at the ten, five and one percent level.

Table 11: Parental investments

Panel A: Wave one parental expenditure

	Total	Tuition	Supplies	Transport.	Tutoring	Uniform
	(1)	(2)	(3)	(4)	(5)	(6)
In utero shock	20.123***	5.611***	-.476	5.353**	.081	.908
	(6.220)	(2.011)	(.703)	(2.201)	(.063)	(.893)
Year 1 shock	2.775	1.855	-1.238**	-.392	.053	.221
	(5.207)	(1.659)	(.599)	(1.778)	(.060)	(.698)
Year 2 shock	6.643	2.235	-1.333**	-.360	-.046	-.189
	(5.360)	(1.887)	(.614)	(1.457)	(.060)	(.851)
Total shock	12.161	4.405*	-2.028**	1.426	.007	.427
	(7.594)	(2.364)	(.861)	(1.203)	(.052)	(1.040)
Total shock (pos. exp.)	12.161	4.941**	-1.669*	183.385		3.626***
	(7.594)	(2.349)	(.881)	(111.854)		(1.057)
Mean	258.864	97.195	20.604	9.884	.373	18.089
Obs.	1403	1403	1403	1403	1403	1403
Mean (pos. exp.)	258.864	97.478	21.03	165.651		53.128
Obs. (pos. exp.)	1403	1399	1374	92		478

Panel B: Wave two parental expenditure

	Total	Tuition	Supplies	Transport.	Food	Tutoring	Other	Uniform
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Utero shock	61.412**	14.623	7.549***	9.312*	24.882*	3.293*	3.223	-.928
	(31.129)	(12.087)	(2.786)	(5.099)	(14.368)	(1.784)	(4.632)	(.900)
Year 1 shock	55.276	7.489	4.517*	8.964	22.840	2.594	8.067	-1.799
	(38.832)	(11.696)	(2.520)	(6.281)	(18.775)	(2.107)	(5.126)	(1.224)
Year 2 shock	44.200	24.647*	3.903*	5.005	15.542	-.192	2.970	.951
	(41.251)	(14.865)	(2.205)	(6.811)	(19.291)	(2.522)	(5.978)	(1.044)
Total shock	82.265*	11.704	6.880***	12.999*	34.615	3.353	7.355	-.631
	(45.086)	(9.475)	(2.207)	(6.797)	(21.645)	(2.628)	(6.588)	(.995)
Total shock (pos. exp.)	82.265*	11.704	8.168***	28.938**	51.540	5.470	32.621***	1.534***
	(45.086)	(9.475)	(2.476)	(11.839)	(33.188)	(5.051)	(6.907)	(.494)
Mean	428.631	238.969	55.81	24.223	78.591	12.21	18.827	35.993
Obs.	1403	1248	1248	1403	1403	1403	1403	1403
Mean (pos. exp.)	428.631	238.969	57.904	93.95	208.627	49.039	53.883	57.172
Obs. (pos. exp.)	1403	1248	1203	475	625	463	594	881

Notes: The dependent variables are household educational expenditure in the specified category on the child of interest. The explanatory variable is precipitation in the village of birth measured in the specified year, where year one of life is defined as the 12 months following birth, the in utero period is defined as the 12 months before birth, and shocks in later years are identified analogously; the total shock variable is the sum of precipitation in utero and in years one and two. Standard errors are clustered at the county-year level, and all specifications include county and year fixed effects. Asterisks indicate significance at the ten, five and one percent level.

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