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EARLY-LIFE HEALTH AND ADULT CIRCUMSTANCE IN DEVELOPING COUNTRIES

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ABSTRACT

A growing literature documents the links between long-term outcomes and health in the fetal period, infancy, and early childhood. Much of this literature focuses on rich countries, but researchers are increasingly taking advantage of new sources of data and identification to study the long reach of childhood health in developing countries. Health in early life may be a more significant determinant of adult outcomes in these countries because health insults are more frequent, the capacity to remediate is more limited, and multiple shocks may interact. However, the underlying relationships may also be more difficult to measure, given significant mortality selection. We survey recent evidence on the adult correlates of early-life health and the long-term effects of shocks due to disease, famine, malnutrition, pollution, and war.

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1. Introduction

A growing body of evidence documents that healthy children tend to become healthy and wealthy adults (Almond and Currie 2010, 2011; Currie 2011). For example, anthropometric markers such as birth weight and child height are related to future schooling, employment, earnings, family formation, and health. Findings from natural experiments suggest that these relationships in large part reflect a pathway running from childhood health to adult outcomes. To the extent that inequalities and shortfalls in adult outcomes are predicted by early-life health, these results may offer additional justification for policies aimed at improving child health.

Much of the existing literature focuses on rich countries, but researchers are increasingly taking advantage of new sources of data and identification to study the long reach of childhood health in developing countries. Far beyond simply extending the work on rich countries, this research on poorer countries has much policy relevance; health shocks in early life are wide-spread in the developing world. The survey papers by Strauss and Thomas (2008) and Bleakley (2010) review some of this work but do not focus on it. In this paper, we review recent research on the long-term effects of health shocks before age 10 in developing countries. To distinguish ourselves from previous authors, we limit our attention to findings since 2004, many of which are not discussed in previous surveys.

We argue that the long-term effects of such shocks are likely to be larger in developing countries for several reasons. First, such shocks are simply more frequent in many developing countries than in the industrialized world, suggesting that the lingering effects of early-life health problems may well be more important in developing countries. Second, child health shocks are likely to interact. For example, a child who is malnourished may be less able to ward off, or to recover from, disease. Similarly, a mother who was malnourished may bear a child who is compromised in her ability to cope with health insults. Moreover, if there are non-linearities in the production function for child health, then the same shock may have quite different effects depending on starting levels of health.

Third, the long-run consequences of early-life health shocks depend on the availability and effectiveness of mitigation strategies. To the extent that parents in rich countries are better able to compensate for shocks, the long-term effects of poor health in childhood may be greater in developing countries. For example, a relatively common congenital anomaly such as cleft palate is easily corrected in rich countries but may lead to a great deal of suffering in poorer settings. On the other hand, if mitigation were universally ineffective across countries, then outcomes might be similar across countries, reflecting a purely biological response.

Early-life health may not only be a more important determinant of adult outcomes in developing countries; its importance may have also increased as childhood mortality rates have declined. Bozzoli et al. (2009) highlight the potential importance of mortality selection: When children die, their long-term outcomes are not measured. Consequently, as infant and child mortality decrease, population average outcomes such as employment and earnings could actually fall, or at least rise more slowly than they would have otherwise, as more unhealthy children live to adulthood. The selection biases introduced by changes in the distribution of survivors are cause for concern in nearly all of the papers we review, and we will revisit them often in our discussion.

Our review is divided in two broad parts. The first deals with associations between measures of early-life health and adult outcomes, while the second describes attempts to disentangle the causal path running from childhood to adulthood. The literature on associations of child health measures with adult outcomes goes back several decades, and in our discussion of it, we concentrate on the retrospective measure that the development literature commonly uses: height. We argue that height captures aspects of the early-life experience similar to those captured by measures more common in the literature on wealthy countries, such as birth weight. Yet height, unlike birth weight, does not require longitudinal data for linkage with other adult outcomes. Nonetheless, despite its broad informational content and ease of data collection, height does not allow researchers to identify which specific aspects of the childhood environment have long-lasting effects.

As a result, we devote the second section of our review to research that traces out the effects of specific changes in the child health environment. To structure the discussion, we separate this work into five thematic categories, each for a separate source of ill health: (chronic) malnutrition, famine, disease, pollution, and war. These health insults affect their childhood victims in diverse ways, and they cause differing degrees of mortality selection. Additionally, as we show below, the long-term effects of the same health condition often vary considerably by setting, by gender, or even by socioeconomic status.

Given that different afflictions may have different effects in the same population, and a single affliction may have varied effects across populations, much remains to be learned about the long-term effects of child health in poorer countries. Similarly, while the concepts of "critical periods" and "catch up growth" have been in the literature for a long time, we still know relatively little either about which periods of childhood are critical for particular types of development, or about how much recovery from health insults is possible. We conclude with some thoughts on fruitful directions for future research. Richer data are becoming available, and the subjects of a recent spate of child health related randomized trials (e.g., Baird et al. 2011) are starting to come of age. These developments are sure to give rise to many useful new insights.

2. Height as a Proxy for the Early-Life Environment

The size and shape of the human body provide a window into the cumulative shocks it has experienced over its lifetime. Researchers have thus used various measures of the body and its growth rate to gauge health.[1] Of the various anthropometric measures studied, the most common are weight, typically a proxy for short-term nutritional status, and height, a marker of health and nutrition during the critical periods of growth in early life (especially from conception to age 3). Absent more direct measures of early-life health, investigations into the effects of early-life conditions have often relied instead on height and birth weight. A large literature explores the later-life correlates of birth weight in industrialized countries, but the literature on poorer countries has focused on height, given the paucity of good longitudinal data following individuals in those settings from birth into adulthood.

In the cases of both height and birth weight, bigger is better. On average, adults who stand taller or were born heavier fare better on a range of social, economic, and cognitive outcomes (see, e.g., Currie 2009; Steckel 2008). Interpretations of these patterns are fairly uniform for birth weight but more variable for height. Perhaps because of the proximity of birth weight to the intra-uterine environment, few have questioned that its relationship with adult outcomes reflects the effects of early-life health, at least after appropriately controlling for family background characteristics.

In contrast, a surfeit of theories aims to explain the link between height and various measures of wellbeing and success. One class of theories, especially popular in the development economics literature, attributes the height premium to the greater strength and health of taller individuals, which increases their productivity (Haddad and Bouis 1991, Thomas and Strauss

[1] The study of the economic, social, and psychological correlates of body size dates at least as far back as the work of eugenicists and biological anthropologists in the nineteenth and early twentieth centuries (Porter 1892; Macdonell 1902, Pearson 1906, Gowin 1915).

1997). A closely related hypothesis stems from the observation that physical growth and cognitive development share inputs in early life. These common inputs induce a correlation between height and cognitive ability, so in addition to being stronger and healthier, taller individuals are smarter (Case and Paxson 2008). But several competing psychosocial theories offer explanations for the height premium that do not rely on the biology of skill formation. Some researchers posit that height affects individual achievement through self-esteem (Wilson 1968; Lechelt 1975; Freedman 1979; Young and French 1996), social dominance (Klein et al. 1972; Hensley 1993), or discrimination (Loh 1993; Magnusson, Rasmussen, and Gyllensten 2006). These theories have attracted far more attention in rich countries than poor, but even in rich countries, nationally representative data strongly support explanations rooted in the biology of skill formation (Case and Paxson 2008, Lundborg et al. 2009). On the other hand, biological mechanisms and psychosocial mechanisms are not necessarily mutually exclusive.

A Statistical Framework

A simple statistical framework illustrates the theories that propose child development as the link between body size and achievement. Let y be an adult outcome (like the log wage), let x be an anthropometric measure (like birth weight or adult height), and let z be an (unobserved) index of the joint determinants y and x. We think of z primarily as an index of the childhood environment. In reality, z may partly reflect genetics, although twin studies suggest that a substantial share of the relationship between anthropometric measures and adult achievement is attributable to non-genetic factors.[2] Moreover, many adult outcomes are likely the product of

[2] Silventoinen et al. (2000) and Sundet et al. (2005), both studying thousands of twin pairs, find that over half of the relationship between height and cognition can be attributed to non-genetic rather than genetic factors. Notably, the studies use data from wealthy, egalitarian, Scandinavian countries, where the variability of childhood conditions is likely much smaller than in developing countries, making genes relatively more important.

epigenetic interactions between genes and the environment, suggesting that the quest to separate nature and nurture is misguided.[3]

Suppose that y and x have the following reduced-form production functions:

$$y = \alpha_y + \beta_y z + \varepsilon_y \tag{1}$$

$$x = \alpha_x + \beta_x z + \varepsilon_x \tag{2}$$

Adult outcomes and body size both increase linearly in z. In the absence of a good measure of z, however, one might run a regression of y on x to learn (imperfectly) about the parameters in equations (1) and (2):

$$y = a_{yx} + b_{yx} x + u \tag{3}$$

The slope coefficient in equation (3) has the following probability limit:

$$\text{plim } b_{yx} = \frac{\beta_y}{\beta_x} \times \frac{1}{1+\frac{\sigma_x^2}{\beta_x^2 \sigma_z^2}} \tag{4}$$

where $\sigma_x^2 = V[\varepsilon_x]$ and $\sigma_z^2 = V[z]$.

Expression (4) has several intuitive implications. The slope coefficient increases in the effect of the early-life environment on y and decreases in the effect of the early-life environment on x. If the residual in equation (2) has zero variance (as assumed, for example, by Weil 2007), then the slope coefficient is equivalent to an instrumental variables estimator in which z is used as an instrument for x to estimate equation (3). But as σ_x^2 increases relative to $\beta_x^2 \sigma_z^2$ (the component of the variance of x explained by z), x becomes a noisier signal of z, which attenuates the slope coefficient. This result provides two reasons to expect b_{yx} to be higher in poor countries.[4] First, early-life conditions are more variable in poor countries, so that $\sigma_x^2/(\beta_x^2 \sigma_z^2)$ is smaller holding β_x constant. Second, early-life conditions are worse on average in poor countries, which

[3] See Jablonka and Lamb (2005) for an accessible discussion of genetics and epigenetics.
[4] Spears (2012) discusses similar reasons for U.S.-India differences in the association between children's height and cognitive test scores.

may increase β_x due to decreasing marginal returns. If a decrease in $\bar{z}$ raises β_y and β_x by the same proportion, the ratio β_y/β_x remains unchanged while $\sigma_x^2/(\beta_x^2\sigma_z^2)$ falls, leading to an increase in b_{yx}. These two reasons for a higher b_{yx} in poor countries rely on cross-national differences in the ratio $\sigma_x^2/(\beta_x^2\sigma_z^2)$. But poor countries may also have higher b_{yx} because they may have higher β_y. For instance, if poor countries had a higher return to skill, then taller workers would receive a higher wage premium, holding other parameters constant.

The Association Between Height and Birth Weight

The framework posits that adult height and birth weight reflect similar underlying variables. Indeed, height and birth weight are highly correlated in settings rich and poor, both across and within families.[5] To give a sense of this empirical regularity, Table 1 examines the association between birth weight and young adult height in two cohorts, one born in 1958 in Great Britain, the other born in 1983-4 in the Philippine 'metro' area of Cebu (which encompasses both urban and rural communities). Towards the bottom of the table, we present the means and standard deviations of birth weight and height in the two samples.[6] As might be expected given the nutritional disparities between the two settings, both measures of body size have significantly lower means in the Philippines than in Britain. Surprisingly, the variances of both variables are higher in Britain than in the Philippines. Based on this result alone, however, one cannot quantify differences in the variances of early-life conditions (σ_z^2) and the variances of the residuals (σ_x^2).

The forward and reverse regressions of the two variables shed some light on this issue. In the first two lines of Table 1, we present the slope coefficients from the regression of height on

[5] For evidence on the relationship between birth weight and height in developing countries, see Haeffner et al. (2002) and Adair (2007). For evidence on developed countries, see the cross-sectional studies by Kuh and Wadsworth (1989), Sørensen et al. (1999), and Pietiläinen et al. (2001), as well as the twin studies by Behrman and Rosenzweig (2005) and Black et al. (2007).

[6] To deal with slight differences in the sex composition of the two samples, we standardize these descriptive statistics to reflect a sex ratio of one.

birth weight and the reverse, in both cases controlling for gender. All of the slope coefficients are highly statistically significant, indicating a strong relationship between height and birth weight. A 1 kilogram increase in birth weight is associated with a 3-4 centimeter increase in height.[7] Consistent with the prediction that $\sigma_x^2/(\beta_x^2\sigma_z^2)$ is smaller in developing countries, both slope coefficients are higher in the Philippines than in Britain. However, the difference in coefficients approaches statistical significance only in the regressions of birth weight on height. For a summary statistic that more clearly describes the combined signal that height and birth weight have for the early-life environment, consider the inverse of the product of the slope coefficients:

$$\text{plim}\ \frac{1}{b_{hw}b_{wh}} = 1 + \frac{\sigma_w^2}{\beta_w^2\sigma_z^2} + \frac{\sigma_h^2}{\beta_h^2\sigma_z^2} + \left(\frac{\sigma_w^2}{\beta_w^2\sigma_z^2}\right)\left(\frac{\sigma_h^2}{\beta_h^2\sigma_z^2}\right) \tag{5}$$

where h refers to height and w refers to birth weight. As Equation (5) shows, this statistic summarizes the importance of residual variation relative to joint input variation in producing height and birth weight. In the third line of Table 1, we report this inverse product for each of our samples. As expected, the relative importance of residual variation is significantly higher in Britain than in the Philippines. This result implies that the higher overall variances of height and birth weight in Britain derive from the residual variance, rather than the variance of joint inputs. Perhaps contemporary Britain has greater genetic diversity than the Philippines. Whatever the case, its greater variance in body size does not reflect a greater variance in childhood conditions.

Apart from the Cebu Longitudinal Study, precisely measured birth weight data are rare in large sample surveys from developing countries, as are longitudinal data following babies into adulthood. In consequence, the development literature—as well as the economic history literature, for similar reasons—has largely relied on height. An important exception to this generalization is a recent paper by Bharadwaj et al. (2010) that links Chilean birth data for all children born

[7] After one controls for gender, the conditional correlation between the two variables is 0.26 in Britain and 0.30 in the Philippines.

between 1992 and 2000 to data on educational attainment up to the 8th grade, and to data on parental time use. Twin fixed effects models show a persistent positive impact of birth weight on educational attainment. Aside from this recent paper, however, most work on developing countries focuses on height.

Changes in Average Height

The literature on height is in part motivated by the remarkable increasing secular trend in heights over the past two centuries. The trend began in Europe, which economic historians attribute to rising living standards (Floud, Wachter, and Gregory 1990; Fogel 2004; Steckel 1995, 2008).[8] Japan followed somewhat later (Shay 1994), as the Japanese economy entered a period of rapid growth in the late nineteenth century. Many countries still classified today as "developing" also saw rising average heights across cohorts born in the twentieth century (Strauss and Thomas 1998). These transformations in the average size of the human body occurred too quickly to be driven by evolution.

Indeed, researchers have now amassed considerable evidence that these secular increases in height have antecedents in early-life health. Many studies show that child and adult height are associated with parental socioeconomic status, nutrition, and access to clean water and sanitation during childhood.[9] Additionally, a number of the quasi-experimental studies reviewed below suggest that these associations represent causal effects of childhood conditions.

Selective mortality presents an obstacle to detecting a relationship between early childhood conditions and future outcomes. This issue arises in the quasi-experimental studies re-

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[8] The United States is a notable exception to the increasing trend in height in Western countries during the 1800s and 1900s. Average heights only began to meaningfully increase around the turn of the twentieth century, after a short period of *declining* heights during the initial phases of industrialization (Costa and Steckel 1997). However, mean height was already far higher in the United States than in Europe in the early days of the republic. European heights caught up with American heights in the twentieth century (Steckel 1995).

[9] See, e.g., Thomas (1994), Adair and Guilkey (1997), and Checkley et al. (2004).

viewed below but is also apparent in the distribution of average heights across countries and birth cohorts. Studying a country-birth cohort panel from the Demographic and Health Surveys, Deaton (2007) demonstrates that higher national income and lower child mortality in the year of birth are associated with increased height outside Africa. But within Africa, where mortality rates are high, declines in child mortality are associated with *decreased* height, and national income bears no relation to height after controlling for mortality. These findings suggest that selective mortality may be an important force in determining the distribution of heights among African adults. In this sense, they offer one explanation for why Africans are much taller than one would expect in light of their incomes.

Height and Other Adult Outcomes

In settings with limited selective mortality, height correlates with skill; the inputs that promote healthy growth in childhood also promote the development of both physical and cognitive skills. Studies in a variety of countries, rich and poor, confirm this correlation. Table 2 provides an overview of three recent studies on developing countries. It shows that height is associated with adult cognitive test scores in China (Huang et al. 2012); in Mexico (Vogl 2012); and in urban areas in Barbados, Mexico, Cuba, Uruguay, Chile, and Brazil (Maurer 2010).[10] Research assessing the relationship between adult height and physical skill is rarer, but Swedish data suggest a robust relationship between height and grip strength, muscular strength, maximum working capacity, and maximum power expended on a stationary bicycle (Lundborg et al. 2011). Height is also associated with non-cognitive skills (Lundborg et al. 2011; Schick and Steckel 2010), but the importance of this correlation in developing countries remains unstudied.

[10] For similar results in industrialized countries see Britain (Richards et al. 2002); Sweden (Tuvemo et al. 1999; Magnusson et al. 2006); and the United States (Case and Paxson 2008). See also Tanner (1979). Abbott et al. (1998) find a similar result in a sample of Japanese-Americans in Hawaii, many of whom were born in Japan in the early twentieth century.

Possibly as a byproduct of the correlation between height and various skills, height is associated with wage gains many developing economies. In the rural Philippines, an extra centimeter of height is associated with 2 percent higher wages (Haddad and Bouis 1991); in Mexico, this semi-elasticity is 2.5 (Vogl 2012). Height and wages are also strongly correlated in Ghana and Brazil (Strauss and Thomas 1998; Schultz 2002), although the estimation strategies used for these settings are not directly comparable with other studies. Consistent with the implications of the statistical framework earlier in this section, the relationship between height and earnings is positive but smaller in wealthy countries (Persico et al. 2004; Case and Paxson 2008; Lundborg et al. 2009). Cognitive and physical skills explain a large share of the earnings premium paid to taller workers in these richer settings.

Evidence on the role of skills in explaining the height premium in developing countries is scarcer. Many authors (e.g., Thomas and Strauss 1997; Schultz 2002) note that height is associated with educational attainment, although they generally reason that this result reflects correlated parental investments in health and education, rather than shared inputs in the production functions for height and skill. In more recent data from Mexico, Vogl (2012) finds mixed evidence on the role of cognitive skill in explaining the relationship between height and earnings. On the one hand, an adult cognitive test score only explains a small share of the height premium.[11] On the other hand, taller workers sort into occupations with higher cognitive skill requirements, consistent with a Roy model in which the return to cognitive (rather than physical) skill drives the height premium, and similar to the occupational sorting observed in industrialized countries (Case and Paxson 2008). In Mexico, the sorting of taller workers into higher-skill occupations almost entirely reflects their greater educational attainment. Collectively, these results suggest either that cognitive ability (and therefore height) increases the productivity of

[11] The cognitive test in Vogl's (2012) data has only 12 questions, making it a noisy measure of intelligence.

schooling, or that parents who invest more in health and nutrition also tend to invest more in other forms of human capital.

Additional evidence on the relative importance of brains and brawn can be found in the literature relating short-term nutritional status to wages. One body of work uses local food prices as instruments for the body mass index (BMI) and nutrient consumption, finding effects of these variables on wages for men but less so for women (Thomas and Strauss 1997; Rosenzweig et al. 2011).[12] These estimated effects suggest that physical strength and robustness remain important in developing economy labor markets, especially for men. Note that instrumental variables methods are more appropriate for estimating the effect of body weight than for estimating the "effect" of height. Several studies, including Schultz (2002) and Behrman et al. (2009), use early-life conditions as instruments in estimating the "effect" of height on wages. However, if height is primarily a proxy for early-life conditions, then we see more justification for studying the reduced-form effects of the "instruments" directly. Height becomes useful as an independent variable precisely when we cannot observe all relevant determinants of childhood development. For much the same reason, we cannot use adult height to distinguish the effects of in utero shocks from those of postnatal shocks. Nonetheless, given the ease of measurement, height provides a useful retrospective proxy for health and nutrition in the early years of life.

3. Evidence Regarding the Longer Term Effects of Early-Life Shocks

In the preceding section, we elaborated on the argument that early-life shocks might have larger effects in developing countries; provided a justification for viewing adult height as an outcome; and emphasized the potential importance of mortality selection. In this section, we

[12] Rosenzweig et al.'s (2011) results also indicate that, among men but not women, increased body weight decreases schooling attainment and increases selection into strength-intensive occupations.

review the recent literature regarding specific types of early-life shocks: malnutrition, famine, disease, pollution, and war.

Nutrition

Table 3 provides an overview of some recent studies examining the longer-term impacts of poor nutrition in childhood. Here we focus on moderate and chronic malnutrition; we discuss famine in the next section. Recent studies have focused on the roles of specific nutrients, and on the question of whether children recover from nutritional shocks during critical periods, such as while they are in utero or in the first year of life.

In one recent study, Malluccio et al. (2009) report on a long-running randomized INCAP (Institute of Nutrition of Central America and Panama) experiment that involved giving Guatemalan children zero to seven years old a high-protein energy drink (the treatment) or a placebo with a similar number of calories. The findings suggest that the treatment increased schooling attainment among women by 1.2 grades, and cognitive ability by .24 standard deviations for both men and women. Hoddinott et al. (2008) study the same intervention and find that nutritional supplements in the first two years of life increased male wages by 46 percent.[13] These large effects suggest that an early diet that is sufficient in calories but not in protein can have severe long-term consequences.

Quasi-experimental studies also provide evidence on the importance of specific nutrients. In one prominent example, Field et al. (2009) examine the effect of fetal exposure to iodine supplementation as part of a large but episodically implemented government program in Tanza-

[13] In absolute terms, Hoddinott et al. (2008) find an effect of US $0.67 per hour, with a 95 percent confidence interval of 0.16-1.17. The point estimate is 46 percent of the average wage, and the confidence interval runs from 11 percent to 80 percent.

nia.[14] Iodine deficiency in pregnant women has been linked to mental retardation in affected fetuses but has been virtually eliminated in developed countries. Field et al. find that children who benefited from the supplements in utero experienced large gains in educational attainment. The effects were larger for girls than for boys, which is consistent with scientific evidence that female fetuses are more vulnerable to damage from iodine deficiency.

A number of recent studies examine the long-term effects of general nutritional deprivation at particular critical periods. Almond and Mazumder (2011) provide evidence on this front in their analysis of the effect of maternal fasting during Ramadan on children in utero. Their study relies on the fact that the timing of Ramadan moves throughout the year, so that the effects can be distinguished from seasonal variation. Using Census data from Uganda and Iraq, they show cohorts affected by maternal fasting are 22 to 23 percent more likely to be disabled in adulthood. In comparison, the estimated effect on disability rates among Arab-named adults in the U.S. is only slightly lower, at 19 percent.

Variation in adult outcomes by season of birth may also shed light on the effects of early-childhood health. In their examination of the age of heart disease onset in Puerto Rico, McEniry and Palloni (2010) focus on whether subjects were in utero during the "hungry season." They find a monotonic relationship between length of exposure and the probability of heart disease. Among those exposed to poor conditions throughout pregnancy, 23 percent had heart disease, compared to 15 to 18 percent among individuals who were partially exposed and 11 percent among those who were not exposed. They note, however, that it is difficult to separate the effects

[14] Another recent analysis of a natural experiment involving nutrient supplementation can be found in the work of Linnemayr and Alderman (2011), who evaluate a nutrition enhancement program in Senegal that was phased in at the village level. The program had multiple components, including Vitamin A and iron supplements for pregnant women. While the results vary somewhat with the estimation method, they find consistent evidence that maternal participation during pregnancy was associated with improvements in child weight-for-age. We do not report this paper in Table 3 because the weight measurements are from childhood as well.

of poor nutrition from the effects of exposure to disease or other seasonal factors in this type of research design. Additionally, the socioeconomic and demographic composition of mothers varies over the year, which presents additional challenges to interpreting this work (Lam and Miron 1994; Buckles and Hungerman 2013).

Research on rainfall shocks provides more convincing evidence on the effects of experiencing hunger in early life. In one such study, Maccini and Yang (2009) link adults in the Indonesia Family Life Survey to data on rainfall in their birth districts during their birth years. They hypothesize that higher rainfall is linked to better nutrition in the first year through its effects on harvests. Indeed, higher early-life rainfall affects height and a range of other adult outcomes for women but not men. For women, a ten percent increase in local rainfall in the year of birth leads to a 0.3-centimeter increase in height, a 0.1-year increase in education attainment, and a 0.12-standard deviation increase in an index of household durable goods ownership. The results for men are statistically insignificant and less consistent, although the (imprecise) estimates of the effect of rainfall on height remain positive. One could interpret the weaker results for men as reflecting mortality selection, since boys are more vulnerable than girls to dying in childhood (Waldron 1983).[15]

Further evidence on the importance of mortality selection can be found in Indian women, among whom early-life rainfall increases average adult height for upper castes but lowers average adult height for lower castes (Pathania 2009). The child mortality rates of the lower castes may be more environmentally sensitive, increasing the likelihood of selective mortality. This reasoning implies that higher early-life rainfall does not diminish the health of children from lower castes but rather keeps unhealthy ones alive. These patterns have diminished in more

[15] As a test for mortality selection, Maccini and Yang (2009) estimate the effect of early-life rainfall on cohort size, finding no effect. However, they run this test either for women only or for both men and women. (The paper is unclear on this issue.) Theory might predict an effect on male cohort size only.

recent cohorts, which have experienced lower rates of child mortality. According to new research by Shah and Millett-Steinberg (2012), exposure to drought in utero reduces test scores among Indian children of school age regardless of parental socioeconomic status.[16] Rocha and Soares (2011) find that exposure to drought reduces both infant health and the subsequent primary schooling performance of cohorts who were exposed in utero.

Famine

Several attributes distinguish famines from the localized rainfall shocks that Maccini and Yang (2009) and Pathania (2009) study. First, in general equilibrium, famines affect both food prices and farmers' incomes, while localized rainfall shortfalls affect only incomes. Second, perhaps due in part to price adjustments, famines are typically more severe than localized shocks, with massive effects on mortality. As a result, concerns about selective mortality are likely to be more relevant in studies of famine. Third, unlike localized weather shocks, famines arguably have as much to do with politics as with food output (Drèze and Sen 1991). Thus, research strategies designed to measure the effects of localized rainfall shocks may fail to generate plausible estimates of the effects of famine.

Table 4 summarizes a growing literature aimed at detecting the long-term health effects of famine in developing countries. As Table 4 makes clear, most of this literature has focused on the effect of exposure in utero, with relatively little information available about the effect of exposure in early childhood. This focus on the in utero period is inspired by the literature on the "Barker hypothesis" (Barker, 2001) which suggests that events during pregnancy can have long-term effects by "programming" the development of the fetus. See Almond and Currie (2011) for a review of this fetal effects literature.

[16] Interestingly, Shah and Millett-Steinberg (2012) also find that current exposure to drought improves test scores in school-aged children, which they interpret as a substitution effect due to drought-related reductions in parents' and children's opportunity costs of time.

Most studies of the in utero effects of famine identify cohorts of affected children and follow them over time. One potential difficulty is that children who were already born at the time of the famine are also subject to nutritional deprivation, though at a later stage. This partial exposure of pre-famine cohorts suggests that the in utero cohort must be compared to cohorts in utero after the famine only. However, individuals in utero after the famine were conceived during or after the famine, which raises concerns about fertility responses to the famine, which may change the composition of parents having children. Post-famine cohorts may thus have different background characteristics from the in utero cohort.

The cohort-based approaches provide some evidence of the effects of famine on long-term outcomes. Meng and Qian (2009) and Umana-Aponte (2011) evaluate the effect of famine exposure in utero on years of schooling in China (1959) and Uganda (1980), respectively. Relative to pre- and post-famine cohorts, cohorts exposed to famine in utero attained approximately 0.58 fewer years of schooling in China and 0.364 fewer years of schooling in Uganda. In results from Ethiopia, Dercon and Porter (2010) estimate that a 1984 famine reduced the probability of completing primary school by 2 percent for cohort exposed at two to three years of age, but had no effect on education for the cohort exposed in utero. They do, however, find effects on height in both cohorts.

The Chinese famine has received particular attention, and several papers provide evidence complementary to Meng and Qian's. As with the studies described in the previous paragraph, analyses of the Chinese famine use both pre- and post-famine cohorts as control groups. Chen and Zhou (2007) examine the effects of the Chinese famine on height, finding a decrease of 3 cm for those born or conceived during the famine. Gørgens et al. (2012) report a similar stunting effect of the famine on the rural Chinese population for whom the famine was most severe. In further analyses of socioeconomic outcomes, Almond et al. (2010) estimate that women (men) exposed to the Chinese famine in utero were 3 percent (5.9 percent) less likely to work and 13 percent (12 percent) more likely to be disabled, and that men were 6.5 percent less likely to be married. Finally, building on earlier research examining the effects of the Dutch "hunger winter" of 1944 on a wide range of outcomes (see for example, Lumey et al. 2011), two papers investigate the effects of the 1959 Chinese famine on other health outcomes. Fung (2009) demonstrates that in utero exposure to famine predicts obesity for women, but not for men, while St. Clair et al. (2005) find that prenatal and infant exposure to famine doubles the likelihood of developing schizophrenia.

Since famine often involves substantial mortality, it can be difficult to interpret the magnitudes of the effects. Indeed, the data suggest that mortality selection may severely dampen the estimated effects of early-life shocks on the average height of adult survivors. For example, data on Chinese adults show little sign of a decline in average heights among cohorts exposed to the Great Famine in early life unless one accounts for selection (Gørgens et al. 2012). In Meng and Qian's study (2009) stunting effects are most noticeable at the upper quantiles of the height distribution, as would be expected if mortality culled individuals from the bottom tail of the height distribution.

Disease

Historical studies in developed countries suggest that the introduction of effective treatments for childhood disease had profound effects on future outcomes and population health. For example, Bhalotra and Venkataramani (2011) examine the introduction of sulfa drugs in the U.S. in the 1930s, which were highly efficacious for pneumonia. Pneumonia was a leading killer of children in the U.S., much as it is in the developing world today. They compare areas with initially high death rates due to pneumonia to areas with initially lower rates, arguing that sulfa drugs ought to have had a greater impact in the former than in the latter. They find that sulfa drug availability in utero and in early childhood increased years of schooling by 0.09 years, increased income by 2.3 percent, and increased employment by 1.2 percent for men. The results for women are small and insignificant, which they interpret as evidence that the gains to men arose primarily because better health led to increased returns in the labor market. Using a somewhat similar research design, Bleakley (2007) compares school enrollment, attendance, literacy, and years of schooling of individuals born in areas with high and low hookworm endemicity, before and after the eradication of hookworm in the United States. He finds that a one-standard deviation reduction in the hookworm rate increased school enrollment by 0.25-standard deviations, increased literacy, and fulltime attendance, but had no effect on years of schooling.

Table 5 summarizes several recent papers examining the effect of early-life disease exposure on future outcomes in developing countries. The papers deal with both endemic and epidemic diseases, taking advantage of both increases and decreases in incidence. In particular, several studies exploit variation in the incidence of endemic disease—such as helminth infection and malaria—that was induced by large-scale eradication campaigns.

One set of papers (Nelson (2010) on Brazil and Lin and Liu (2011) on Taiwan) investigates the long-term effects of in utero exposure to influenza using a cohort comparison methodology similar to that in Almond (2006). They examine the impact of exposure to the 1919 influenza epidemic by focusing on the affected cohort's break from trend relative to cohorts born just before and after the outbreak. Following Almond (2006), Lin (2011) also incorporates geographic variation in mortality as an indicator for the intensity of prenatal influenza exposure. The 1919 Brazilian cohort that was exposed to the pandemic in utero finished 0.2 fewer years of schooling, had 20 percent lower wages, and members were 20 percent less likely to be employed. In Taiwan, each 1 percent increase in the birth year maternal mortality rate (a proxy for influenza incidence) led to a reduction of 0.343 years of schooling. Those affected were also 3.6 percent, 2.1 percent, 1.6 percent, and 0.06 percent less likely to complete elementary school, junior high school, high school, and college, respectively relative to cohorts born just before or just after.

It is somewhat difficult to compare effect sizes when baseline levels of outcomes like education were so different across countries. Almond (2006) reports that the U.S. cohort affected by the 1919 epidemic had 0.125 fewer years of schooling, earned 5 percent lower wages, and were 20 percent more likely to be disabled. This comparison suggests that perhaps flu exposure had a larger effect on future wages in Brazil than in the U.S. Kelly (2009) finds small effects of the 1957 Asian flu pandemic on British children's test scores at ages 7 and 11. Just as we have speculated that the effects of early health shocks might be smaller in developed countries than in developing ones, it is possible that the effects of the 1957 flu were smaller than those of the 1919 flu pandemic because of improvements in medical care or in the underlying health of those affected. Note that if the extent of mortality selection had fallen between 1919 and 1957, then we would expect the estimated effect of the later epidemic to be larger than that of the earlier epidemic.

Several studies estimate the effect of specific diseases by examining eradication campaigns in a difference-in-differences framework, much as in the papers by Bhalotra and Venkataramani (2011) and Bleakley (2007) described above. This research strategy compares cross-cohort changes in areas with high initial disease prevalence to cross-cohort changes in areas that have lower initial disease prevalence because the former are more likely to be affected by the eradication campaigns.

Three papers apply this method in asking whether early-life malaria exposure affects socioeconomic outcomes in adulthood. Using data from the U.S. South and Latin America, Bleakley (2010) estimates that 100 percent eradication of malarial infections increased subsequent adult income by 47 percent in the US, 45 percent in Brazil, 45 percent in Colombia, and 41 percent in Mexico. Bleakley also finds positive effects on literacy, but mixed results for years of schooling. Cutler et al. (2010), studying India's malaria eradication campaign of the 1950s, also detect no effect on educational attainment. However, consistent with Bleakley (2010), they find that malaria eradication increased household consumption, perhaps implying that the eradication of malaria increases incomes by allowing people to work more, or at higher productivity jobs. These results highlight the fact that reductions in disease can work through multiple channels and can well have effects on income through improved health or labor force participation even if they have no effects on schooling or cognition. Indeed, in some circumstances, improvements in health may have positive effects on earnings even if they decrease educational attainment. Even so, not all studies of malaria eradication fail to find effects on educational attainment. In her study of eradication in Paraguay and Sri Lanka, Lucas (2010) estimates that a 10-percentage point reduction in malaria incidence increases female schooling by 0.1 years and female literacy by 1 percentage point.

Complementing Bleakley's (2007) work on the historical United States, several studies examine the effect of deworming on medium and long-term outcomes in developing countries. In a well-known paper, Miguel and Kremer (2004) analyze the experimental introduction of deworming treatments in Kenyan schools. The deworming intervention increased school attendance by 7 percent but had no effect on test scores. In a follow-up study, however, Baird et al. (2011) find that self-reported health, years of schooling, and test scores all increased for the treated group. Hours worked rose 12 percent in the full sample and 20 percent among those who were working for wages. Moreover, Ozier (2011) shows that deworming school-aged children had positive externalities on very young children in the same community, fitting for a communicable disease like helminth infection. Children less than one year old during the treatment experienced IQ gains on the order of 0.2-standard deviations, which translated into an additional 0.5-0.8 years of schooling.

Pollution

The literature on determinants of child health in developing countries has traditionally focused on disease and nutrition.[17] However, children are more vulnerable than adults to the effects of many types of pollutants, both because they are still developing and because their small size means that they may end up with relatively high doses per unit body mass. For example, children are more susceptible to lead poisoning because the blood-brain barrier that protects adults is not fully formed. These considerations suggest that the alarmingly high levels of contamination of air, water, and soil in many developing countries could have extremely harmful long-term consequences for child development.

In many cases, the pollution levels in developing countries are outside the range that has been studied in the developed world, and may be outside the range of pollution levels that existed historically. For example, in Chay and Greenstone's (2003a,b) path-breaking work examining reductions in Total Suspended Particles (TSPs) in the 1970s and early 1980s U.S., "low" TSP implies concentrations of 44 ug/m3 and "high" TSP concentrations were 92 ug/m3. Wang et al. (1997) study pollution in residential areas of Beijing from 1988-1991 and consider TSP levels ranging from 150 to 700 ug/m3. Similarly, roughly 70 percent of the river water in

[17] In many settings these killers remain the greatest threats. For example, Field et al. (2011) show that when households in Bangladesh abandoned tube wells that were contaminated with arsenic, mortality from diarrheal disease doubled.

China is unsafe for human consumption, although many people in rural areas rely on these sources for drinking water (World Bank, 2006). Brainerd and Menon (2011) find that a 10 percent increase in chemical runoff from fertilizers in the water increases infant mortality by 11.26 percent and decreases height for age by 0.14 standard deviations.

There is now considerable evidence from developed countries that air pollution has harmful effects on birth weight and infant mortality (see Currie, 2011 for a recent summary of this literature) and a growing literature showing that this is also true in the developed world. Foster et al. (2009) study air pollution in Mexico using satellite measures of aerosol optical depth. Variation in pollution comes from a voluntary certification program, and regional variation in the supply of auditors available to implement the program. They find that a 3.6 percent improvement in aerosol optical depth resulted in a 16 percent decline in infant mortality due to respiratory illness, but no decline from deaths due to external causes (a control cause). Jayachandran (2009) estimates OLS models where an average aerosol index (TOMS) captures the variation in pollution levels that resulted from the 1997 Indonesian wildfires. Her results indicate that areas affected by the smoke suffered a 1.2 percent reduction in birth cohort size with the largest effects among the poor, a result that highlights the importance of selection once again. Despite these concerns about selection bias, the Wang et al. study mentioned above found that each 100-ug/m3 increase in SO2 (TSP) exposure in the third trimester reduces birth weight by 7.3 (6.9) grams and increased the probability of low birth weight by 11 percent (10 percent).

The question of precisely which pollutants are most harmful is important for policy and is difficult to address, given that many pollutants come from the same sources and are highly correlated. Moreover, mechanisms are not well understood. For example, particulates do not cross the placenta (as carbon monoxide does) but may cause an inflammatory response in the mother. Additionally, while a good deal of information has accumulated about the "criterion air pollutants" that are routinely tracked in the United States because of the Clean Air Acts, much less information is available about thousands of other toxic chemicals that are in use.

Very little research in any country has tracked the long-term impacts of pollution in any setting, rich or poor. A few notable exceptions are Nilsson (2009), who finds that in Sweden, reductions in ambient lead concentrations have positive long-term effects on children's eventual educational and labor market outcomes;[18] Ferrie et al. (2011), who show that higher exposure in childhood to water-borne lead reduced test scores for male World War II enlistees; and Almond et al. (2009), who study the effects of radiation exposure in utero on educational outcomes for children affected by the Chernobyl nuclear disaster in Sweden. In the Chernobyl study, children exposed to radiation at 8-25 weeks gestation in the most affected municipalities were 4 percent less likely to qualify for high school.

A final caveat is that even in cases where there is a clearly defined pollution problem, such as smoke from primitive cooking stoves, the most obvious solutions are not always the most effective. Hanna et al. (2012) evaluate a large-scale randomized trial in which clean cooking stoves were introduced to Indian villages. The stoves apparently had little effect on health mainly because households did not use them. Clearly, much work remains to be done on this topic.

War

Like malnutrition, disease, and pollution, war and exposure to violence threaten health in the short term. Several studies examine effects on birth and early childhood outcomes. For example, Mansour and Rees (2012) study the 2000-2005 al-Aqsa Intifada in Palestine using mother fixed effects models and find that each additional conflict fatality in the first trimester

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[18] The lead levels Nilsson studies were already less than the U.S. "thresholds for concern" at the beginning of his sample period, suggesting that even declines from already low levels had positive effects.

increases low birth weight by 0.003 percentage points. Camacho (2008) examines data from Columbia between 1998 and 2003, and also uses mother fixed effects. She finds that exposure to land mine explosions during the first trimester reduces birth weight by 2.8 grams.

Bundervoet et al. (2009), Akresh et al. (2007), and Akresh et al. (2013) estimate the effect of early childhood exposure to violence on children's height-for-age z-scores using a difference-in-difference methodology. For example, Bundervoet et al. (2009) exploit variation in civil war timing across cohorts and provinces in Burundi. They estimate that among children 6 to 60 months, the height-for-age z-score decreased by .047 for each month of exposure to civil war.

A growing literature, reviewed in Table 6, suggests that exposure in early childhood may also have significant long-term scarring effects. Aguero and Deolalikar (2012) estimate the effect of childhood exposure to the Rwandan genocide on women's height-for-age z-scores. Using difference-in-differences for exposed cohorts with Zimbabwean women as the control group, they find that Rwandan women exposed to the conflict have 0.2-standard deviations lower height-for-age z-scores. Taking Akresh and Verwimp (2006) and Aguero and Deolalikar (2012) together, it appears that the Rwandan civil war greatly affected the height of girls in Rwanda, and that even exposure late in adolescence affected adult female height.

Several papers evaluate the effects of conflict on years of schooling. Alderman et al. (2006) combine maternal fixed effects and IV estimation to show that exposure to civil war and drought shocks in early childhood in Zimbabwe reduced children's height-for-age z-scores, which subsequently had negative effects on years of schooling and adult height. Akresh and de Walque (2008) estimate a difference-in-difference model and find that children exposed to the Rwandan genocide earned 0.4 fewer years of schooling. In Peru, León (2010) estimates that for each additional year of civil war exposure in early childhood, children acquired 0.07 fewer years of schooling. Therefore, a child exposed for the first three years of life attains, on average, 0.21 fewer years of schooling. Some of this effect on education may work through the destruction of school buildings.

Since the exposure occurred in childhood, rather than in utero, the authors posit that the channel through which the violent event affects height is economic or nutritional. Some authors also emphasize the possible effects of extreme stress or of being physically unable to attend school. These types of explanations may also apply to other papers about the effects of exposure to disaster, such as Sotomayor (2012), who compares Puerto Rican cohorts in utero during the hurricane years of 1929 and 1933 to surrounding cohorts, finding them more likely to have been diagnosed with high blood pressure, high cholesterol, or diabetes as adults.

War has long been regarded as one of the "four horseman of the apocalypse" suggesting that people are well aware of its unique capacity for destruction. This new literature does not help us to distinguish the mechanisms underlying the long-term effects on children, though it does confirm the long reach of such disastrous events.

4. Discussion and Conclusions

A growing literature shows that events in early life have long-term consequences for adult health, cognition and labor market success, both in developed and in developing countries. Still, many basic questions remain unanswered. We still know relatively little about mechanisms. And it is difficult to say much about the relative magnitudes of the effects of different types of shocks, nor about possible interactions between them, given data limitations and differences in methodology across studies.

Moreover, while many suggest that critical periods—times in the life of the child when negative health insults are most harmful—exist, it is generally unclear when these periods are and to what extent they differ across insults. Much of the recent literature has focused on shocks sustained in utero. This focus is partly because of the belief that gestation is a critical period, but also because it is a well-defined period with a distinct beginning and end—unlike, for example, "early childhood." The sharp definition facilitates measurement of exposure.

Similarly little evidence is available about possible intergenerational effects, though these effects represent one of the most intriguing explanations for how the consequences of health shocks can persist over long periods. Along these lines, Bhalotra and Rawlings (2011) link mothers in 38 developing countries to infant health and height-for-age z-scores in early childhood. They show that a one-standard deviation decrease in mother's height is associated with a 7.4 percent increase in the probability that her child is low birth weight and a 9.3 percent higher neonatal mortality rate. The effects were largest for mothers at the bottom of the income distribution. In a companion paper, (Bhalotra and Rawlings, 2013) they argue that improvements in the health and educational environment were associated with reductions in these inter-generational correlations. Although these associations are compelling, they are not obviously causal. Even so, a follow-up of the INCAP nutritional intervention discussed above provides additional evidence on intergenerational links. Behrman et al. (2009) show that children born to mothers who received the protein supplement in childhood had babies who were 116 grams heavier and 0.26 z-scores taller on average. Furthermore, Fung and Ha (2010) find evidence that the Chinese Great Famine reduced the heights and weights of survivors' children.

The fact that events in early childhood have long-term consequences says little about the extent to which the actions of parents, schools, or other institutions can ameliorate these consequences. The extent to which parents reinforce or compensate for early-life shocks is an active area of research: Rosenzweig and Zhang (2009) find evidence of reinforcement in China, while Liu et al. (2009) and Bharadwaj et al. (2010) find evidence of compensation in the Philippines and Chile, respectively. Parents' decision to compensate or reinforce may depend not only on beliefs and values but also on the practical supports available to them.

Finally, to our own surprise and chagrin, we find that little research on the impact of HIV/AIDS on children falls under the scope of our review. Perhaps this omission is due to the fact that the epidemic so obviously appears to be a catastrophe with long-term impacts for many children's lives. It is estimated that more than a quarter-million children under age 15 die of AIDS-related causes each year, while more than 3 million are currently living with HIV/AIDS, 90 percent of them in sub-Saharan Africa (WHO 2011). Beyond the direct health impacts, HIV/AIDS may also have indirect effects through the devastation of families. As of 2003, an estimated 15 million children had lost at least one parent to AIDS, 80 percent of them in sub-Saharan Africa (UNAIDS 2004), where research suggests that parental death reduces school enrollment (Case et al. 2002; Case and Ardington 2006; Evans and Miguel 2007). Many others have sick caretakers as a result of the virus.

Case and Paxson (2011) make the further important point that the societal response to disease can impact long-term child outcomes through its effects on health infrastructure. Using data from fourteen sub-Saharan African countries, they find that in countries heavily impacted by HIV, skilled birth attendance, antenatal care, and immunization rates declined between 1988 and 2005. Countries with a minimal burden from HIV experienced no such declines. This deterioration, which presumably occurred because of a diversion of health resources to fight the AIDS epidemic, may have lasting effects on children even if neither they nor their parents are HIV-positive.

In sum, research in the past decade has shown that health shocks in early-life have long-term effects on adults in both the developed and developing world. But the literature still has little understanding of heterogeneity in these effects. Future research should focus on identifying pathways and mechanisms; measuring the relative magnitudes of the effects of different health shocks; examining interactions between shocks; and revisiting the question of critical periods. Beyond these issues, policy-makers have much to learn from new findings on the efficacy of interventions designed to help children reach their full potential.

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Table 1: Young Adult Height and Birth Weight in Britain and the Philippines

	Britain	Philippines	p-value of diff.
	(1)	(2)	(3)
Coef. (S.E.) from regression of...			
Height on birth weight	3.47 (0.12)	3.93 (0.29)	0.143
Birth weight on height	0.020 (0.0007)	0.023 (0.0018)	0.051
Inverse of the product of the coefs.	14.53 (0.98)	10.84 (1.48)	0.038
Mean [S.D.] of…			
Birth weight (kg)	3.33 [0.52]	3.00 [0.44]	< 0.001
Height (cm)	169.82 [6.83]	157.11 [5.64]	< 0.001
Age at height measurement	23	20-22	
Sample size	11,423	1,904	

Note: All regressions control for gender; the means and standard deviations are standardized for a sex ratio of one. All standard errors are robust to heteroskedasticity; the standard error for the inverse of the product of the coefficients is computed using the delta method. The British data are from the National Child Development Study, which followed all British children born in a single week of 1958. The Philippine data are from the Cebu Longitudinal Health and Nutrition Survey, which followed a representative sample of children born in Metropolitan Cebu in 1983-4. In the Filipino data, birth weight was actually measured at the age of three days; 88 percent of height measurements occurred at age 21.

Table 2: Associations of Height and Other Adult Outcomes

Study	Methods	Data/Size	Outcomes
Author: Behrman et al. (2009) **Country:** Guatemala **Shock:** Randomly assigned high protein-energy drink and placebo, two small and two large villages, 1969-1977. Earthquake, 1976.	Look at relationship between cognitive and health human capital and labor market outcomes. OLS and IV: instrument adult human capital with variables reflecting prices and policies, and individual and family endowments.	INCAP longitudinal data on children born from 1962- 1977 from a nutritional supplementation trial. Children were followed up in 2002-04. 962 obs.	In OLS, find a stat. sig. effect of adult height and fat-free body mass on wages, but this disappears in the IV specifications. Similar results for annual hours and total income. Only adult cognitive skills are stat. sig. when both health and cognitive human capital measures are treated as endogenous; years of schooling and adult reading comprehension z-scores are stat. sig. in both OLS and IV.
Author: Huang et al. (2012) **Country:** China **Shock:** No shock; associations between height shrinkage and SES variables are explored.	Use upper arm and lower leg length measurements to estimate a pre-shrinkage height function and predict pre-shrinkage heights for an older population. Use estimated pre-shrinkage height and shrinkage as covariates in OLS regressions.	China Health and Retirement Longitudinal Study. Sample is 2,609 people 45-49 (the "young" sample) and 5,868 people 60+ (the "old" sample) in 2011.	Shrinkage and socio-economic variables such as schooling and household per capita expenditure are negatively correlated. Measured height is positively and significantly associated with all of the cognition measures. Height shrinkage is strongly negatively correlated with these measures, suggesting that part of the association between measured height and cognition occurs through height shrinkage.
Author: Maurer (2010) **Country:** Barbados, Mexico, Cuba, Uruguay, Chile and Brazil **Shock:** No shock; relationship between cognitive function in later life and height, early-life conditions and education.	Sex specific OLS/Tobit or 2SLS/IV-Tobit, depending on whether height is instrumented with knee height. Tobit for potential ceiling effects (scores only measure cognitive function if below the maximum, otherwise are a lower bound).	Survey on Health, Well-being and Aging in Latin America and the Caribbean in 2000, representative urban samples of persons aged 60+, 7894 obs.	Find a stat. sig. positive association between height and later-life cognitive function; larger for women than men. Significance is lost for men when height is instrumented, suggesting that for men this association is partly due to mid- and later-life circumstances. Adding controls for childhood conditions doesn't affect the height coefficients, but including education does weaken the association.
Author: Vogl (2012) **Country:** Mexico **Shock:** No shock; looks at the skill returns underlying the labor market height premium.	OLS/logit of hourly earnings and occupation on height, look at mechanisms by adding health and childhood covariates, education and cognitive test scores.	Mexican Family Life Survey, a nationally representative household survey with waves in 2002 and 2005. Use individuals 25-65.	An 1 cm increase in height leads to wage gains of 2.1% (2.9%) for men (women). Adding cognitive test scores leads to a 17% decrease in the earnings premium to taller workers, but about half of the premium can be attributed to these workers being more educated or having higher paying jobs (with greater intelligence and lower strength requirements).

Table 3: Effects of Childhood Nutrition on Adult Outcomes

Study	Methods	Data/Size	Outcomes
Author: Almond and Mazumder (2011) **Country:** US, Iraq, Uganda **Shock:** Days of Ramadan exposure *in utero*	OLS: percent of pregnancy overlapping with Ramadan on future disability status, home ownership, years of schooling, employment and earnings.	Michigan Natality Files 1989-06, Uganda 2002 census (80,000 obs., aged 20-80), Iraq 1997 census (250,000 people born from 1958-77 who were 20-39 in 1997)	In Uganda, Muslims *in utero* during Ramadan are 22% more likely to be disabled and 2.6% less likely to own a home. There is no effect on schooling. In Iraq, Muslims *in utero* during Ramadan are 23% more likely to be disabled, 1.4% less likely to own their own home, and less likely to be employed.
Author: Field et al. (2009) **Country:** Tanzania **Shock:** Iodized oil capsule distribution program, 1986-95.	Examine impact of prenatal iodine supplementation on schooling. District-level fixed effects regression, exploiting variation in program activity (gaps and delays).	2000 Tanzanian Household Budget Survey, children aged 10-13; 1395 obs.	Distribution of iodine supplements results in large and stat. sig. increase in progression through school; children treated *in utero* attain 0.35-0.56 years of additional schooling relative to siblings and older and younger peers. Girls consistently benefit more than boys; consistent with the greater cognitive sensitivity of female fetuses to maternal thyroid deprivation.
Author: Hoddinott et al. (2008) **Country:** Guatemala **Shock:** Randomly assigned high protein-energy drink (*atole*) and placebo (*fresco*), two small villages and two large villages, 1969-1977.	OLS; look at the relationship between exposure to *atole* or *fresco* at specific ages between 0-7 years and economic variables.	Data from 60% of the children (0-7 years) in the original nutrition intervention program, followed up between 2002 and 2004. 1424 people, aged 25–42.	Exposure to *atole* before, but not after, age 3 was associated with higher hourly wages, but only for men. If exposed to *atole* from 0-2 years, wages went up by US$0.67 per hour (a 46% increase). Hours worked were less and annual incomes were greater for those exposed to *atole* from 0-2, but not stat. sig.
Author: Linnemayr and Alderman (2011) **Country:** Senegal **Shock:** Nutrition Enhancement Program; vitamin A and deworming for children 6-59 months, iron for pregnant women, bednets, breastfeeding promotion, cooking workshops; 2004-2006.	Estimate the effect of the package of services on weight-for-age z-scores by OLS, 2SLS (instrument actual receipt with planned treatment status), and a combination of diff-in-diff and propensity score matching.	Data from the program's two survey rounds, 2004 and 2006; children under 5 years old. 10,127 obs.	The impact of planned treatment status on z-scores is insignificant, as is the impact of the instrumented intervention; both show a positive, stat. sig. impact on weight-for-age z-scores for children who benefited from the program *in utero*. The TOT estimates show z-scores improved by 0.1, while the propensity score matching estimate shows a larger impact of 0.27.

Author: Maccini and Yang (2009) **Country:** Indonesia **Shock:** Rainfall during year of birth, 1953-74	Impact of early life rainfall on health, schooling and SES. IV regression: instrument is rainfall measured at the 2nd-5th closest rainfall stations.	Global Historical Climatology Network; Indonesian Family Life Survey from 2000, 8883 obs.	Higher early life rainfall has a positive effect on girls, but not boys. For adult women, 20% higher rainfall in year of birth leads to 0.57 cm of greater height, 3.8 pct points less likely to self report poor health, 0.22 more yrs of schooling and 0.12 sds higher on an asset index.
Author: Maluccio et al. (2009) **Country:** Guatemala **Shock:** Randomly assigned high protein-energy drink (*atole*) and placebo (*fresco*), two small villages and two large villages, 1969-1977.	Diff-in-diff: study impact on educational outcomes of nutrition by contrasting individuals exposed at different periods of their lives in *atole* versus *fresco* villages. 2SLS; instrument supplement intake with exposure to intervention.	Longitudinal data; children of 0-7 years at any point during intervention. Follow up rounds in 1988-9 and 2002-4, end up with 1,471 obs. Institute of Nutrition of Central America and Panama.	Find impact of exposure to the nutritional intervention from 0-36 months 25 years after it ended. *Atole* intervention at 0-36 months increases schooling for women by 1.2 grades (.33 sd), reading comprehension by 0.28 sd for men and women (with a stronger effect for women), cognitive ability by 0.24 sd for men and women. The 2SLS point estimates are approximately 2x the OLS.
Author: McEniry and Palloni (2010) **Country:** Puerto Rico **Shock:** Rural population's exposure to poor nutrition / disease during pregnancy from seasonality in sugar cane harvests; late 1920s to early 1940s	Kaplan-Meier hazard estimates, age of onset of heart disease by level of exposure during late gestation; Cox and log logistic regression models to estimate the effect of exposure on heart disease timing.	Puerto Rican Elderly: Health Conditions; survey of rural population 60+ and their spouses, in 2003 and 2006-7, 1438 obs.	Those fully exposed (born in 4^{th} quarter) to poor nutrition and infectious diseases during late gestation had the highest prevalence of heart disease (23%). Those with partial exposure had a lower prevalence (18%, 15%), and unexposed individuals (2^{nd} quarter birth) had the lowest (11%). The risk of developing heart disease if fully exposed was twice as high as for the unexposed at later ages. No impact on timing of onset or for the urban population.
Author: Pathania (2007) **Country:** India **Shock:** Effects of drought shocks at birth on height of rural women in India, 1950-1999	OLS of effect of various drought measures on height, with various fixed effects and linear time trends, depending on the specification.	Historical rainfall data and height of ever-married women 15-49 (National Fertility and Health Survey-2, 1998-2000). 60,641 obs.	Drought at birth associated with a 0.3 cm drop in the height of upper caste women but a 0.4 cm gain in the height of the Scheduled Tribes, a low caste group. The effects are mostly driven by *in utero* drought exposure and are consistent with with stronger selection effects for lower castes. Don't find a caste gradient in height outcomes for more recent birth cohorts.

Table 4: Effects of Childhood Famine Exposure on Adult Outcomes

Study	Methods	Data/Size	Outcomes
Author: Almond et al. (2010) **Country:** China **Shock:** 1959–1961 famine	Impact of famine *in utero* on outcomes. Aggregate weighted death rate in year/month proxy for famine intensity. Also compare mainland born (exposed to famine) and Hong Kong born (control) mothers.	1% sample of the 2000 Chinese Census and Hong Kong natality micro data from 1984-2004.	Women (men) in most exposed famine cohorts 7.5% (9%) more likely to be illiterate, 3% (5.9%) more likely not to work, and 13% (12%) more likely to be disabled. Men were 6.5% less likely to be married and 8.2% more likely to have never married. Comparison group is three years pre- and post-famine (1956-1978 and 1962-1964); also between mainland China and Hong Kong born women.
Author: Chen and Zhou (2007) **Country:** China **Shock:** 1959-61 famine	Diff-in-Diff of famine's impact on height, labor supply and income. Interact year of birth with excess death rate in region (as proxy for severity), quantile regressions.	China Health and Nutrition Survey, 1991. Sample is rural population born 1954-67, 1953 obs.	Statistically significant decrease in height of 3.03 cm for those born/conceived in famine. Some evidence for decr. in hours worked and income. The comparison group is made up of people born after the famine (1963-1969), and those born before (1954-1958).
Author: Dercon and Porter (2010) **Country:** Ethiopia **Shock:** 1984 famine	Exposure to famine *in utero* and in early childhood on height and primary school completion. OLS: Household FE.	479 young adults (17–25) from the sixth round of the Ethiopian Rural Household Survey in 2004, with data from previous rounds.	Compare four cohorts: "born before" (oldest cohort, aged 37-72 mo. in famine), "just before" (aged 12-36 mo. in famine), "born during" (born and in-utero during famine), and "born after" (youngest cohort; born Sept. 1985 to Sept. 1987). People exposed to famine in utero or within the first 36 months of life are 3.9 cm shorter. Children exposed at 2-3 years of age are 2% less likely to finish primary school. No effects on schooling for cohort exposed in utero.
Author: Fung (2009) **Country:** China **Shock:** 1959–1961 famine	Effect of being exposed to the famine as infants on adult BMI and obesity. GLS with RE; excess mortality in province/year as a proxy for famine intensity.	China Health and Nutrition Survey (in 1989, 91, 93, 97, 00, 04, and 06), rural households with births within 5 years of 1959, 11,098 obs.	Early childhood famine exposure leads women to be 14.6% more likely to be overweight and 5.3% more likely to be obese. No effects for men. Comparison group is pre-famine (those born in 1954-58) and post-famine (born 1962-66) cohorts.

Author: Gorgens et al. (2012) **Country:** China **Shock:** 1959–1961 famine; use the fact that children inherit their parents' genotype (selection) but not phenotype (stunting)	If famine survivors have greater average potential height, their children will be taller than non-famine cohorts. Create an econometric model of the relationship between the height of parents and children; use children of famine and control cohorts to sort out stunting from selection. OLS/family FE.	First four waves of the China Health and Nutrition Survey, 2115 families in the rural sample and 1080 families in the urban sample.	In the rural population, for those that were under age 5 during the famine, find large and stat. sig. stunting. For mothers (fathers), the estimated effects are 1.49-2.22 cm (1.47-1.80 cm). Estimates of selection (the famine coefficient in the OLS regression minus the estimated stunting) for mothers (fathers) are 1.92-2.64 cm (0.85-1.18 cm). Results for the older famine cohort (born 1948-1956) and the urban sample are weaker, but also show stunting and positive height selection. The control group is defined as those born up to 10 years immediately before (1938 to 1947) and after (1962 to 1971) the famine cohorts.
Author: Meng and Qian (2006) **Country:** China **Shock:** 1959-61 famine	Quantile analysis using cross sectional and cohort variation in famine exposure, measured as the average county-level cohort size of survivors born during the famine. Estimate the effect of exposure on the 90th percentile of the outcome distributions. 2SLS: instrument exposure with the interaction of non-famine grain production and birth year.	1990 Population Census, 1989 China Health and Nutritional Survey, 1997 China Agricultural Census, the FAO's GAEZ data on crop suitability. Sample is county-birth year cells for cohorts born 1943-1966.	Exposure to famine had a larger adverse impact at higher percentiles; when comparing individuals exposed and not exposed to famine, those in the 90th percentile are relatively worse off than those in the 10th percentile. For the early childhood cohort, exposure on average decreased height by 1.6% (2.7 cm), weight by 5% (3.03 kg), weight for height by 1.2%, (0.004 kg/cm), and labor supply by 13.9% (12.7 hours per week). Compare those born during or just before the famine with those born after or who were too old to be affected.
Author: St.Clair et al. (2005) **Country:** China **Shock:** 1959–1961 famine	Effect of famine *in utero* and in early childhood on schizophrenia. Adjusted relative risk ratios across cohorts.	All psychiatric case records (1971-2001) from the Wuhu region of Anhui. From 191-779 cases per year for people born from 1956-65.	Prenatal and infant exposure to famine leads to a 2-fold increase in the likelihood of developing adult schizophrenia. Compare rates among those born before, during, and after the famine; 1956-1958 and 1963-1965 were defined as unexposed years. Findings replicate the results from Dutch data.

Author: Umana-Aponte (2011) **Country:** Uganda **Shock:** 1980 famine	OLS/probit of effect of famine *in utero*, in early childhood and famine intensity on years of schooling and literacy. Different combinations of FE across specifications.	1991 and 2002 Uganda Population and Housing Censuses from IPUMS-I, 702,233 and 302,833 obs., Ugandan 2006 DHS, 10,743 obs.	Cohort exposed to famine in utero earned 0.364 fewer years of schooling, was 4.2% less likely to complete primary school, and was 3.1% less likely to be literate. With family FE children exposed to famine in utero were 7-10% less likely to ever attend school. The control group are the cohorts surrounding the those exposed to the famine, or who were born outside the a□ected region.

Table 5: Effects of Childhood Disease Exposure on Adult Outcomes

Study	Methods	Data/Size	Outcomes
Author: Baird et al. (2011) **Country:** Kenya **Shock:** Primary Schooling Deworming Project; 1998-2009	Calibrate a version of the Grossman (1972) model, where investments in health increase future endowments of healthy time.	Data from Miguel and Kremer 2004, follow up with participants a decade later.	Deworming increased schooling by 0.3 years and test scores by 0.112 sd, but had no effect on grade completion; those treated also report being in better health. In the full sample, hours worked increased by 12%; for those working for wages, hours worked increased by 20%
Author: Bleakley (2010) **Country:** US, Brazil, Colombia, and Mexico **Shock:** DDT spraying in the 1950s (1920s for the US)	Compare labor market outcomes of children born well before and just after eradication campaigns in regions with different pre-treatment malaria rates. OLS and 2SLS with temperature and altitude as instruments.	For US, Mexico and Brazil (Colombia), IPUMS censuses, 1960-00 (1973-93), males 25-55, born 1905-75 (1918-68); various sources for malaria data.	The effect on adult income per probability of childhood infection (the reduced-form difference divided by the pre-eradication malaria infection rate): for the US, 0.47 and 0.60 (occupational income score and Ducan Index); for Brazil, 0.59 and 0.45 (log total income and log earned income); for Colombia, 0.45 (industrial income score); and for Mexico, 0.41 (log earned income).
Author: Cutler et al. (2010) **Country:** India **Shock:** DDT spraying campaigns, 1950s and 60s	Compare log household monthly per capita expenditure for those born before and after the eradication campaign, in areas with different pre-treatment malaria prevalence. District and cohort FE.	National Sample Survey in 1987, men (111,218 obs.) and women (107,551 obs.) aged 20- 60; government information on 1948 malaria endemicity.	No robust evidence of an effect of malaria eradication on human capital attainment. Assuming malaria levels were reduced to zero after the campaign, a 40 percentage point reduction in the spleen rate (as in the most malarious states) is associated with a 2 percent increase in per capita household expenditure for treated men. No impact on women.
Author: Miguel and Kremer (2004) **Country:** Kenya **Shock:** Primary Schooling Deworming Project; school-based mass treatment with deworming drugs that were randomly phased into schools, 1998-99	Look at effect of program on health and education outcomes. Estimate cross-school treatment externalities by including the number of pupils in primary schools within 3 km from each school each year, how many of them were treated. Also try to back out within-school externalities.	International Christelijk Steunfonds Africa gave pupil / school questionnaires in 1998 and 1999. Parasitological survey by the Kenya Ministry of Health. 75 schools with total enrollment of 30,000 children, ages 6-18.	School participation increased by 7 pct. pts. in treatment schools. The proportion of pupils with moderate/heavy infection is 25 pct. pts. lower in treated schools, strongly stat. sig. This is decomposed into a 12 pct. pt. reduction from within-school externalities and a 14 pct. pt. reduction from direct effects of deworming. Cross school externalities: each additional 1000 attending a treated school within 3 (3-6) km is associated with 26 (14) pct. pts. fewer infections.

Author: Lin and Liu (2011) **Country:** Taiwan **Shock:** 1918 influenza pandemic	Impact of influenza *in utero* on later life outcomes. Use maternal mortality rate as a proxy for the degree of exposure; regress outcomes on maternal mortality rate, infant mortality rate, region dummies, and linear trend.	Dynamic Census of the Taiwanese Population; 1980 Population and Housing Census; 1989 Survey of Health and Living Status of the Elderly; 1927 Health Statistics for School Students	A one pct. pt. increase in the maternal mortality rate is associated with: a decrease in the probability of being literate, finishing elementary school, junior high school, senior high school, and college by respectively 2.9%, 3.6%, 2.1%, 1.6% and 0.6%; a decrease in cohort size of 1%; an increase in the probability of having kidney disease, vertigo, tennitus, circulatory disease, thyroid problems, and respiratory disease by 29%, 45%, 23%, 27%, 53%, and 23%; a decrease in average weight and height of students by 0.5 kg and 0.5 cm.
Author: Lucas (2010) **Country:** Paraguay and Sri Lanka **Shock:** DDT interior residual spraying malaria eradication campaigns, initiated in 1945 in Sri Lanka, 1967 in Paraguay	Compare education outcomes of women born before/after eradication campaigns in regions with different pre-eradication malaria intensity; also use percentage of years less than 18 before eradication. Region and cohort FE.	Sri Lanka: 1987 DHS, ever married women 18-49, 5,822 obs.; Paraguay: 1990 DHS, ever married women 18-49, born 1958 or later, 2,931 obs.	Large and stat. sig. increase in schooling from malaria eradication, of 2-3 years for worst off regions. A 10 percentage point decrease in the incidence rate in Sri Lanka (Paraguay) leads to a stat. sig. increase in schooling by 0.114 (0.118) years, in primary schooling by 0.051 (0.056) years, in high literacy by 0.924 (2.083) pct. pts., and in minimal literacy by 0.846 (0.631) pct. pts.
Author: Nelson (2010) **Country:** Brazil **Shock:** 1918 Influenza Pandemic	Regress education and labor market outcomes on an indicator for being born in 1919 (or quarter of birth), $year\ of\ birth$ and $year\ of\ birth^2$; logit for binary and OLS for continuous variables.	Pesquisa Mensal de Emprego, 1986-1998; people born from 1912-1922 in the six largest metro areas. 379,930 obs., 41,315 with wage data	Those born in 1919 were 13% less likely to graduate from college, 5% less likely to be employed, 8.6% less likely to have formal employment, and had 0.046 less years of schooling than those born in other years from 1912-1922. For each outcome, the coefficient on the 1^{st} or 2^{nd} quarter birth dummy (or both) is stat. sig. and in the direction that would support the Fetal Origins Hypothesis.

Author: Ozier (2011) **Country:** Kenya **Shock:** Primary Schooling Deworming Project; 1998- 2010	Look for long-term effects of deworming; estimate the impact on younger children who did not receive treatment directly. Regress various cognitive outcomes on indicators for age at deworming.	Height, weight, migration and cognitive data on 20,000+ children (from 8-14 in 2009 or 9-15 in 2010) at the 73 deworming project schools.	The deworming had large cognitive effects on children who were less than one when their communities received mass deworming treatment; equivalent to 0.5-0.8 years of schooling. Effects were also estimated among children who were likely to have older siblings in school to receive the treatment directly; in this subpopulation, effects are nearly 2x as large.

Table 6: Effects of Childhood War Exposure on Adult Outcomes

Study	Methods	Data/Size	Outcomes
Author: Akresh and de Walque (2008) **Country:** Rwanda **Shock:** Rwandan genocide, 1994	Diff-in-diff; look at whether children aged 6-15 in 2000 (exposed to the genocide) have lower educational attainment than similar children in 1992, relative to older cohorts (16-35) with completed schooling.	DHS for Rwanda, 1992 and 2000; 27,114 and 18,528 individuals respectively, aged 6 to 35	Children exposed to the Rwandan genocide earned 0.421 fewer years of schooling, and the effect was stronger for males and those from non-poor households. The authors interpret the genocide as a negative shock that brought all children to low levels of schooling, disproportionately affecting boys and non-poor children, who previously had an advantage.
Author: Akresh et al. (2011) **Country:** Nigeria **Shock:** Nigerian civil war of 1967-1970	Diff-in-diff across war exposure and ethnicities; impact of "war" (months of war exposure interacted with exposed ethnicity) on height; control for war exposure and ethnicity-specific linear trends, and ethnicity, birth year, state and survey year FE.	Nigerian DHS, 2003 and 2008; 13,407 women born from 1954-1974.	The effect of war on height is stat. sig. for each age band; war-exposed girls aged 0-3 during the conflict had an average exposure of 17.5 mo. and, for average exposure, experienced a decrease in adult height of 0.75 cm relative to unexposed girls in the same cohort. Girls aged 4-12 during the war showed similar effects. Effects were larger for girls aged 13-16, who suffered a height deficit of 4.53 cm ($\frac{2}{3}$ the sample sd) from a mean exposure of 20.6 mo.
Author: Aguero and Deolalikar (2012) **Country:** Rwanda **Shock:** Rwandan genocide, 1994	Diff-in-diff across cohorts and country of birth; compare heights in the treated group (Rwandan women, under 21 in 1994) to various controls (mainly older Rwandan women and women in Zimbabwe)	DHS of Rwanda (2001 and 2005), all women aged 6-40 in 1994. Zimbabwe (1999 and 2005-06); Kenya, Tanzania, Mozambique, and Zambia DHS data. 27,910 obs.	The genocide is associated with a decrease in height-for-age z-scores of 0.16-0.2, and an increase in the probability of being stunted by 6.9-7.3 pct. pts. The effect of the shock decreases with age but is not zero for older ages; stat. sig. impacts found even for those aged 13-18 at the time of the genocide.

Author: Alderman et al. (2006) **Country:** Zimbabwe **Shock:** Civil war (log of the number of days a child was alive before 8/18/1980), two year drought (1982-84).	Look at impact of child height on grade attainment and age starting school. IV-Maternal fixed effects regression using civil war and drought shocks as an instrumental variable for early childhood nutritional status across siblings.	Longitudinal surveys in 3 resettlement areas. Surveyed 400 households in 1983-4, again in 1987 and annually from 1992-2001. Data on 680 children 6 mo - 6 yrs. at baseline, with 19 yrs. of follow-up.	Exposure to civil war (drought) decreases child height-for-age z-score by -0.035 to -0.049 (-0.576 to -0.729), statistically significant. Maternal FE-IV regressions: larger pre-school height associated with greater attained height in adolescence, number of grades attained, and (more weakly) starting school younger.
Author: Blattman and Annan (2010) **Country:** Uganda **Shock:** Indiscriminate abduction of children (as young as 5, mostly 10-15) to be soldiers for the Lord's Resistance Army, late 1990s	Look at impact of abduction on education, labor market and health outcomes. OLS, weighted least squares, treatment effect bounding for selective attrition (Lee 2005)	Survey of War Affected Youth, 741 boys born between 1975 and 1991 in Northern Uganda, 462 were once with the LRA. Conducted in 2005-2006.	Abduction leads to a substantial loss of education (0.78 years, an 11% decrease) and literacy (17% less likely to be literate). No impact on probability of employment, but abductees are half as likely to be in skilled work. Wages are 22-36% lower. Psychological distress in those that experienced the most violence (abducted or not).
Author: Leon (2009) **Country:** Peru **Shock:** Peruvian civil conflict, 1980s and 1990s	Look at effect of the number of years of exposure to violence in each period of life (-2-3, 4-6, 7-12, 13-17) on educational attainment. District and year of birth FE, and a province specific cubic time trend.	2007 and 1993 censuses, and data on human rights violations from the Peruvian Truth and Reconciliation Commission	The average person exposed to violence attained 0.12-0.19 fewer years of education; for each additional year of civil war exposure in early childhood, children acquired 0.07 fewer years of schooling. The results showed that children can catch up if they experience violence after starting their schooling, but if they are exposed earlier, the effect persists.