# Inside the Black Box of Early-life Shocks on Later-Life Outcomes - Evidence from Indonesia

Laura Zimmermann *

University of Georgia

Preliminary

October 2017

**Abstract**

A large existing literature documents that early-life shocks like famines, wars or rainfall shocks have negative long-term consequences for adult health and human capital accumulation. But how exactly these adverse shocks translate into adult outcomes and to what extent they are reversible remains largely unclear. This paper uses panel survey data from Indonesia to analyze how rainfall shocks in utero and in the first two years after birth affect the health and education outcomes of the same individuals at various ages from young children to young adults. The results show that the negative consequences of an early-life rainfall shock in terms of height and education already start to materialize during childhood, but that children born under negative conditions have caught up to others by the time they are young adults. Women are more affected than men, especially in rural areas. There is little evidence to suggest that early-life shocks have similar impacts on more short-term health measures or cause a permanent income shock.

Keywords: early-life shocks, rainfall shocks, children, Indonesia, gender

*Department of Economics, Amos Hall, 310 Herty Drive, Athens, GA 30602. email: lvzimmer@uga.edu.

# 1 Introduction

Households in developing countries have to cope with a variety of potential health shocks, including famines, droughts, war, and a wide range of natural disasters. While these shocks are likely to have adverse effects on all household members in some form, the negative consequences of such shocks are potentially especially severe for individuals who are exposed to them early in life. Health shocks during the time in utero or in the first two years of life have been found to have large long-term consequences for adult health, and can also lead to lower human capital accumulation and lower earnings.[1]

Since it is impossible to completely prevent most of these types of shocks, three questions are of particular interest to researchers and policymakers: First, how large are the long-term impacts of early-life shocks, do they differ by the type of shock, and which outcomes are affected? Second, what, if anything, can be done either while the shock occurs or later in life to minimize the adverse long-run consequences of the shocks? And third, which individuals are particularly heavily affected, for example due to their location, gender or socio-economic group? Answers to all of these questions are important for parents and policymakers to behave optimally after a shock has occurred.

While a large and growing literature focuses on the analysis of early-life shocks and their later-life impacts, the answers to many of these questions remain unclear. A number of papers document that early-life health shocks have large negative long-term health consequences for affected individuals (Almond, 2006; Almond et al., 2006; Chen and Zhou, 2007; Hoddinott et al., 2008; Jayachandran, 2009; Maccini and Yang, 2009; Pathania, 2009; Rocha and Soares, 2011). Data limitations ensure that most of the existing literature only observes outcomes of individuals in adulthood, however, and typically does not have any information on physical and cognitive development during childhood. This makes it impossible to analyze whether the impacts of early-life shocks are already present among primary school-aged children and further accumulate as those children grow up, or whether the negative consequences of early-life conditions only manifest themselves in adulthood. Observing individuals as they are growing up is therefore important to

[1] For an overview of the recent early-life health shock literature in developing countries see Currie and Vogl (2013).

better understand the mechanisms through which early-life conditions translate into worse health outcomes in adulthood.

Additionally, a few recent papers that have some data on outcomes as children have found that children born under adverse shocks may be able to at least partially catch up to others born under more favorable circumstances. This includes a partial catch-up on height, which is typically considered to be a long-term proxy for health since it is difficult to reverse the negative height trajectory caused by early-life shocks (Crookston et al., 2010; Deolalikar, 1996; Leight et al., 2015; L.S., 1999; Lundeen et al., 2013; Mani, 2012; Schott et al., 2013; Singh et al., 2014). It remains largely unclear why and under which conditions such a catch-up is possible, however, and what role individual characteristics like location or gender play in the process. Most existing papers are also unable to follow children into adulthood to see whether the initial narrowing of the gap that they document among younger children continues into adulthood and eventually leads to a complete catching up over time.

This paper focuses on the pathways through which early-life rainfall shocks translate into longer-run outcomes. Many developing countries are still heavily dependent on agriculture, which makes households vulnerable to unexpected variations in rainfall through the effect on agricultural output, food prices or the availability of employment. These impacts lower the availability of household resources to invest in young children after adverse shocks. Rainfall shocks may also directly have health consequences if they influence the prevalence rate of waterborne diseases. To carry out the analysis, the paper exploits detailed Indonesian household panel survey data from 1993 to 2014. Children who were born within a window of a few years around the first survey are observed multiple times in later waves as they grow up. This provides information on the impact of early-life rainfall shocks on outcomes like height and education at various stages of children's physical and cognitive development, and can be used to test whether the negative impacts of adverse rainfall shocks in early childhood become visible early as the children grow up and if there is a narrowing of the health gap as children get older. Information on household income and short-term measures of health like weight for height can be used to disentangle whether early-life shocks have long-term consequences because they occur during a critical time period in children's development, or because rainfall shocks that occur in early childhood make it more likely that the child or household is hit by subsequent health or income shocks.

The results show that both in-utero and post-birth rainfall shocks affect the years of schooling and height of children in Indonesia as they become older, but that children born under adverse early-life conditions are able to catch up substantially by the time the children have become young adults. Women are more heavily affected by rainfall shocks than men, and the effect is especially pronounced for completed years of schooling. In many cases, the impacts of early-life rainfall shocks for people born in rural and urban areas are relatively similar to one another. There is no strong evidence that early-life shocks affect household income and on short-term health measures, however. This suggests that rainfall shocks are likely to affect adult health through a one-time shock occurring during a critical time period of the child's life rather than through a series of negative shocks that continue at older ages.

## 2 Hypotheses

Based on the existing literature, a couple of potential pathways could explain why early-life shocks have long-term impacts on adult outcomes since most existing papers do not observe those outcomes while individuals are growing up. Figure 17 shows those pathways in a diagram, working backwards from the adult impacts. The short-fall of adult outcomes could only manifest itself in adulthood, for example because the impact of early-life shocks has been latent and only becomes visible after a certain stage of physical and cognitive development. Alternatively, the negative impacts from early-life shocks could be due to the accumulation of negative impacts since early childhood.

Most of the existing literature is unable to disentangle these two different channels due to lack of data on outcomes of the same individuals over time. Implicitly, however, many paper argue for a version of the second channel.[2] The first step of the empirical analysis therefore tests whether early-life rainfall shocks only influence adult outcomes or whether they already affect outcomes as

[2] One of the main arguments for using height as a measure of health in the existing literature is that it is thought to be a cumulative measure that is more susceptible to early life conditions than other measures like weight, which measure more short-term investments in health.

the children are growing up.

If the impacts of early-life shocks only have important consequences in adulthood, this could either be driven by our inability to measure more subtle impacts earlier in life, or be due to the nature of the biological process, which then needs to be further explored. On the other hand, if the adult effects are the cumulative impacts since early childhood, or if they get attenuated over time, the next step is to analyze whether those impacts come from a one-time shock or repeated shocks. In the first case, a one-time shock occurring during a critical time period in physical or cognitive development could cause permanent setbacks that are irreversible later in life. Alternatively, if the impact of the shock wears off over time, the negative impacts of a one-time shock may not be as irreversible as often assumed in the literature.

In the second case, it is possible that having experienced a negative early-life shock makes children or the households that they live in more susceptible to other shocks in the future and therefore leads to negative long-run consequences. Alternatively, if the impact disappears over time, more resources could flow into a household to help the household cope with the consequences of the original shock, or children with a bad early-life shock could become less susceptible to future shocks. This hypothesis is usually refereed to as the Thrifty Genes hypothesis.

In both cases, the underlying mechanism by which early-life rainfall shocks affect later-life outcomes could either work directly through a health channel, or affect outcomes indirectly through its impact on household income. Some papers like Maccini and Yang (2009) find empirical patterns that are consistent with a direct health channel in the form of water-borne diseases. This entails that more rainfall would lead to negative outcomes. A household income channel predicts the opposite pattern: Negative impacts should occur during times with less rainfall than usual, for example because of lower household income from agriculture due to a worse harvest or due to higher food prices.

# 3 Data and Empirical Estimation Strategy

The primary dataset used in the empirical analysis is the Indonesian Family Life Survey (IFLS). The IFLS household survey is representative of 83 percent of the Indonesian population and is a panel dataset consisting of five waves. Detailed questions about a wide range of socio-economic and health outcomes were collected from the same households in 1993, 1997, 2000, 2007 and 2014 (Frankenberg and Karoly, 1995; Frankenberg and Thomas, 2000; Strauss et al., 2004, 2016, 2009). Importantly, individuals are followed even if the household moves or if an individual leaves the original household. The same individuals can therefore be followed over a time span of about 20 years.

This setup makes it possible to analyze how early-life rainfall shocks affect long-run outcomes and when those effects manifest themselves, which is typically very difficult in a developing country context due to data unavailability. Of particular interest for the empirical analysis are therefore household members who were very young at the time of the first survey in 1993, since the follow-up surveys provide a wealth of information on their household and personal outcomes at various points while growing up. My analysis will therefore focus on children born between 1990 and 1994. Those children are 19-24 years old by the time of the last survey in 2014. At this age, it is possible to study the long-run impacts of early-life shocks on physical health measures like height since individuals will have stopped growing. Many people will also have completed their schooling in this age group, although this is not true for individuals choosing to pursue higher education.

To construct early-year rainfall shocks, the birth location needs to be known. The IFLS collects information on respondents' province, *kabupaten* (district) and *kecamatan* (sub-district) of birth, but this question is not asked for young children in the household. In those cases, the birth location of children can be inferred through the parents' migration history and their location around the time of the child's birth. Since many Indonesian households in the sample have not moved over time, in most cases the birth location is also the current location of the household.

Administrative boundaries in Indonesia have changed dramatically over time and especially after the end of the Suharto regime in the late 1990s. A large decentralization of power to districts has incentivized the creation of a many new districts[3]. This means that birthplace information collected from earlier surveys in general will be less precise than that collected in more recent surveys since names have changed and districts have split into smaller areas. Depending on the survey wave, *kecamatan* codes and/or names are provided, and newer surveys provide a partial

[3] For an analysis of the political economy impacts of the decentralization see Burgess et al. (2012)

mapping of birth locations over time. Birth location information is not collected from every individual in every survey, however. To achieve the most complete birth location information possible while also relying more heavily on more reliable and up to date information, information available in the IFLS was combined with information on administrative splits from the Indonesian Statistical Service and a crosswalk of *kecamatan* codes developed by Olken (2009). Where available, the most recent birthplace information is used. Birth locations are then geocoded and matched to the closest grid point of the rainfall data.[4]

Rainfall data on a 0.5 grid on longitude and latitude coordinates comes from the University of Delaware, and contains monthly rainfall data from 1900 to 2008. Rainfall shocks are constructed by standardizing rainfall in the time period of interest around an individual's birth by subtracting long-term average rainfall from rainfall in the specific time window before or after birth, and dividing that value by the standard deviation. This implies that rainfall shocks can be interpreted in terms of standard deviations. Three rainfall shock variables are constructed: An in utero variable that captures the rainfall shock in the 12 months prior to birth, and two post-birth variables that capture rainfall shocks in the first and second year of a person's life, respectively.

The regression equation takes the following form:

$$y_{ijkl}= \beta_0 + \beta_1 rainfall_{jkl} + \theta_j + \eta_k + \epsilon_{ij}$$

$y_{ijkl}$ is an outcome variable of interest for individual $i$ born in location $j$ in year $k$ and month $l$. The coefficient of interest is $\beta_1$, which measures the impact of an early-life rainfall shock on later-life outcomes. $\theta_j$ are birth location fixed effects and $\eta_k$ age fixed effects. The empirical results are robust to including month fixed effects. Standard errors are clustered at the rainfall grid point level. In some regressions, I use the change in a variable between the survey year and 1997 as my outcome of interest. This has the advantage that it directly incorporates information on an individual's physical or cognitive development over time into the analysis.

The main analysis focuses on completed years of schooling and height (measured in centimeters) as outcome variables, as well as on two other outcome variables: stunting and cognition test scores.

[4]Especially because of frequent splits and other changes in administrative boundaries, contradictions emerge between recorded information at different administrative levels. Where possible, these discrepancies are resolved based on other information in the survey or manually.

A person is stunted if he or she is more than two standard deviations shorter than expected. To construct this variable, a person's height is standardized based on WHO information on the typical height distribution expected at this age (measured in months and reported separately for men and women).

From the 2000 survey round onwards, the IFLS tests respondents' cognitive abilities by administering the Raven's Standard Progressive Matrices test. In this non-verbal test, respondents are asked to complete a series of visual problems: They are shown a pattern that contains a missing piece, and are then given a choice of a number of potential patterns to complete the pattern. The test is widely accepted as a useful test of systematic method of reasoning and is recommended by the World Health Organization for worldwide use (Kaplan and Saccuzzo 1997). The IFLS uses the standard version of the test, which includes 12 colored matrices, and adds on five math problems. There are slight variations in the exact number of problems given to respondents in each wave. As is common in the literature, I use the percent of correctly answered questions in this test as my outcome variable.

Height and cognition measures are among the most commonly used variables in the literature on the long-term consequences of early-life shocks. Height is often used as a proxy for overall health because it is easy to measure and because health is determined relatively early in life based not only on genetic factors, but also based on diet and illnesses experienced in childhood. This is typically thought to make adverse conditions early in life only partially reversible at older ages. Lower height is associated with increased mortality and increased risk of cardiovascular diseases (Gunnell et al. 2003). Lower educational attainment could be a consequence of a combination of lower physical health and decreased cognitive development: Less healthy children may be physically unable to attend school, for example, whereas deficits in cognitive development may make it harder for a child to do well in school. Analyzing the impact of early-life shocks on schooling, height and cognition test scores therefore makes it easier to disentangle potential mechanisms through which the shocks translate into differences in school attainment.

# 4 Results

## 4.1 Descriptive Figures

To get a first sense of the impact of early-life rainfall shocks on later-life outcomes and of the adjustment processes that occur while the children are growing up, Figures 1 to 16 show scatterplots for the four main outcome variables. The outcome variables include two height measures, height measured in centimeters and an indicator variable equal to one if a child is stunted, as well as the completed years of schooling and the percent of correct answers given to the Raven test. These last two variables proxy for cognitive abilities. The figures plot the correlation between an in-utero rainfall shock of individuals born between 1990 and 1994 and each of these outcome variables without any further controls. Odd figure numbers show the relationship between early-life rainfall and a given outcome variable in each of four surveys waves in 1997, 2000, 2007 and 2014. Even figure numbers, on the other hand, plot the relationship of the change in the outcome variable in 2000, 2007 or 2014 relative to the 1997 outcome value.

Figure 1 shows the effect of an in-utero rainfall shock on height in centimeters for the same sample of women. The first sub-figure reveals that in 1997, there is a positive relationship between rainfall and height among girls who are 3 to 7 years old at this point: Positive rainfall shocks, which mean higher than expected rainfall, are associated with taller children on average. This positive relationship persists in 2000, when the women are between 6 and 10 years old, although the estimated linear regression line is slightly less steep. By the time the women are 13 to 17 years old in 2007, the positive relationship has become substantially weaker, and in 2014, when the women are 20 to 24 years old the regression line is horizontal. This disappearance of the impact of an in-utero rainfall shock on height as the girls become adults suggests that women with very negative rainfall shocks are able to catch up to women who had much more favorable conditions in-utero over time.

Figure 2 uses the same data, but reports changes rather than levels. In the first sub-figure, a woman's height in 1997 is subtracted from her own height in 2000, and analogous variables are constructed for 2007 and 2014. As the graphs show, the change variables mirror the relationship of the rainfall shock and height measured in levels: Between 2000 and 1997, girls who experienced a very negative rainfall shock have grown slightly more than girls with a positive rainfall shock, and this effect becomes substantially greater in the later waves. Figure 2 therefore supports the idea that individuals with worse early-life conditions are able to catch up to women born with better rainfall over time.

Figures 3 and 4 show similar scatterplots for stunting. Stunted individuals are more than two standard deviations shorter than they should be when compared to the WHO reference population based on age in months and gender. The outcome variable stunted is therefore an indicator variable that is equal to one if a woman is stunted at a certain age, and zero otherwise. Figure 3 shows a similar dynamic pattern to the one in Figure 1: In 1997, women born after a highly negative in-utero rainfall shock have a substantially higher likelihood of being stunted than women born after a positive shock. Over time, however, the likelihood of being stunted drops among women with negative rainfall shocks, while it remains more stable for women with positive shocks. Together with the mirrored patterns in Figure 4, this again suggests that a number of women born after adverse early-life shocks are able to catch up over time.

Figures 5 to 8 focus on the dynamic patterns of two measures of cognitive abilities, completed years of schooling and the percent of correct answers in the Raven test. Figures 5 and 6 show that a similar catching-up process seems to occur for years of schooling as for height, but that the advantage women born with positive rainfall shocks have relative to women born under negative shocks appears to be more persistent over time. By 2014, convergence in the completed years of schooling has occurred, however. Qualitatively similar empirical patterns emerge in Figures 7 to 8. Since the Raven test was only administered from the 2000 wave onwards, this cognition variable is missing a 1997 graph.

Figures 9 to 16 show the same graphs for men. The empirical patterns for men are similar to those for women for height in centimeters, years of schooling and cognition, although the catching-up process is not as consistent and pronounced for height in the male sample as it is for the female sample. The stunting results show a very different pattern: Across all waves, men with a positive rainfall shock in utero have a slightly higher probability of being stunted than those with a negative rainfall shock. This contradicts the typical finding that a negative rainfall shock, a drought, should lead to higher malnutrition rates for which stunting is typically used as a measure.

Overall, the simple descriptive figures therefore suggest three main takeaways: First, in contrast to most of the existing literature on the long-run impacts of adverse early life shocks, the long-run effects on both physical health and cognitive ability have usually disappeared by the time the Indonesian men and women are in their teens and are mostly non-existent when the individuals are between 20 and 24 years old. Second, as predicted by much of the existing literature, younger children born under more favorable rainfall conditions have an advantage relative to children born under unfavorable conditions. But a catching-up process over time leads to a convergence of outcomes later in life. Lastly, these effects are much more pronounced and more consistent for women than for men.

## 4.2 Main Results

While the figures are suggestive, they do not include any fixed effects and do not take into account that individuals born in the same location at around the same time will have highly correlated rainfall shocks. Tables 1 to 4 therefore show the regression result analogues of the figures with a few changes: To capture early-life shocks that occur in the first couple of months after birth as well as in-utero shocks, the regressions simultaneously include three standardized rainfall shock variables: the in-utero shock as well as the rainfall shock in the first 12 months and in months 13 to 24. The regression also include age and birth location fixed effects, and standard errors are clustered at the birth location level. As before, the regressions condition on observing the same individuals over time.[5]

Tables 1 and 2 show the main results for women. Panel A of Table 1 shows that the impact of early-life rainfall shocks on height for women is very similar to the figures: In 1997, a one standard deviation higher rainfall in-utero than expected leads to an increase in height of about one centimeter, which is also statistically significant at the one percent level. In 2000, this effect is still statistically significant but has decreased in size, while the coefficient becomes much smaller

[5] In the very large majority of cases, the empirical results are robust to dropping this condition.

and statistically insignificant in 2007 and 2014. The height difference regressions in the last three columns show that as in the graphs the change in height relative to a woman's height in 1997 moves in the opposite direction: Women who experienced a positive rainfall shock in utero grow more slowly, and this effect increases in absolute magnitude and statistical significance in later waves.

Panel A also shows that similar impacts occur for rainfall shocks in the first and second year after birth: Women have a height advantage in younger years when they experienced a positive rainfall shock in early life, but they lose this advantage in their teens and early adulthood. There is no consistent pattern between the different early life rainfall shocks with respect to magnitudes, however. All three shocks seem to be of similar importance.

Panel B reports the stunting results. Relative to Panel A, the sample in Panel B is smaller because the World Health Organization (WHO) reference tables for height used to determine stunting among children based on age in months and gender does not extend the calculations to far into adulthood, so the older women in 2014 are dropped from the analysis due to missing comparison values.[6] The results show that the probability of being stunted is lower among women with positive rainfall shocks in utero, but this health advantage persists into adulthood and we see no similar catching-up process as in Panel A. Post-birth shocks in general have no statistically significant impact on stunting rates and the magnitudes of the estimated coefficients are typically much smaller, with the exception of a shock in the first 12 months after birth, which leads to an increase in the probability in being stunted between 2007 and 1997. In contrast to the graphs, children in the extreme left tail of the height distribution are therefore unlikely to catch up after a negative in-utero shock, but women seem to be insulated from negative long-run consequences due to post-birth shocks.

Panel A of Table 2 shows that catching-up is also harder for completed years of schooling. A woman born after a positive one-standard deviation rainfall shock in utero has about 0.04 more years of schooling in 1997, and this effect wides in 2000 before becoming smaller and statistically

[6]WHO reference population values are provided up to age 19 for every month. To construct the stunting variable, I calculated a person's age in months on the interview date since the survey includes information on the birth month. Depending on birth date and interview date, individuals can still be 19 in the 2014 survey when they were born in 1990. The individuals in Panel A and Panel B are therefore not directly comparable.

insignificant in later waves. But for both types of post-birth shocks, the educational advantage of a good early-life rainfall shock persists even into adulthood, although the effect is imprecisely estimated for the shock in the second year of life.

The cognition results measured by the percent of correctly answered questions in the Raven test are more imprecisely estimated. Women with a favorable rainfall shock after birth answer about two to three percentage points more questions correctly. This advantage seems to disappear in later waves, also some of the estimated coefficients are relatively large, if imprecisely estimated. Since the Raven test was administered for the first time in the 2000 survey, it is impossible to study whether there is a cognition advantage in 1997.

Overall, Tables 1 and 2 show that many of the takeaways from the graphs remain: the long-run effects of early life rainfall shocks are lower in general than may be expected based on large parts of the existing literature, and a catching-up process seems to at least partially explain this. Convergence of outcomes over time is more difficult to achieve for women in years of schooling than it is in terms of height, although the catching-up process is also more limited for stunted women.

Tables 3 and 4 show the analogous results for men. As for women, men have a height advantage after positive rainfall shocks in younger years that disappear as they grow up, although the in-utero effects are imprecisely estimated. As in the graphs, if anything men actually have a higher likelihood of being stunted after a positive rainfall shock than after a negative shock, although this effect only shows up in the change specifications that compare a man's stunting status in 1997 to that in later years. Table 4 finds no statistically significant impact of early-life rainfall shocks on cognition test scores, and much smaller effects on completed years of schooling for men than for women. A positive rainfall shock in the second year of life actually leads to a reduction in the completed years of schooling of about 0.6 years in 2014. Overall, as in the graphs, the long-term impacts of early life shocks are therefore typically lower and less persistent for men than for women.

### 4.3 Extensions

To better understand the dynamic patterns in Tables 1 to 4, it is useful to test whether they are likely caused by a one-time shock during a critical phase of physical and cognitive development or whether the initial shock in early life caused multiple other shocks later in life. Tables 5 and 6 focus on other health outcomes and on household expenditures, respectively. In the existing literature, the typical explanation for why early-life shocks lead to long-term consequences is that the shocks disturb physical and cognitive development during a critical time, making it difficult to reverse these negative impacts later in life. If this is true, some of the results above suggest that the negative consequences may not be as irreversible, or the critical time period not as narrow, as often thought. Alternatively, it is possible that having experienced a shock early in childhood makes children more likely to experience further shocks later in life, which could partially balance out the negative early childhood shocks and lead to the narrowing of the health gap. The Thrifty Genes Hypothesis, for example, suggests that individuals who have experienced an early-life shock may become more efficient at handling shocks later in life. This could make them less susceptible to diseases than children without this experience. It is also possible that an early-life rainfall shock, which may proxy for a household income shock, could lead to positive income shocks in the future as a reaction to the shock, for example because relatives or the government provide additional resources to affected households to alleviate the negative impacts of the rainfall shock.

Table 5 reports the results using the body mass index (BMI) and lung capacity as outcome variables. While the BMI can be constructed from height and weight data across all the surveys between 1997 and 2014, lung capacity for the sample was only measured in 2000 and 2014. Both of these measures are widely used as health indicators. The BMI measures weight for height and thereby captures malnutrition, which in turn directly correlates with overall health. Lung capacity is used to measure lung disease like asthma, but has also been found to be correlated with mortality, cardiovascular diseases and cognitive decline (Albert et al., 1995; Cook et al., 1991). In contrast to height, both weight for height and lung capacity can be more easily influenced later in life, however, and therefore capture short-term investments in health to a larger extent than height. If the long-term consequences of early-life shocks stem primarily from a one-time shock early in life rather than a series of shocks, we would therefore not expect to see similar empirical results to those in the earlier results.

As Table 5 shows, the impacts of early-life rainfall shocks experienced before and after birth on these more short-term health measures are much less pronounced than for height. There is no evidence of large and consistent effects on the BMI or on lung capacity for men or women. Since these measures have an important short-run component and since there is no evidence of large impacts even in 1997 when the children are young, these results are much more consistent with a one-time shock during a critical period of physical health development that is captured in height rather than with a series of shocks experienced during childhood.

Table 6 reports the results for per-capita household expenditures over time. Even around the time of birth as measured by expenditures in 1993, the results only find a positive impact of higher rainfall on per-capita household expenditures for women in the second year after birth, but not for earlier shocks. Those positive impacts persist in 1997, but become smaller and statistically significant in later waves. There are no similar effects for men. These results suggest that rainfall shocks have temporary effects on household income, but that for the most part they are not associated with more permanent income changes. They also do not support the idea that households that experienced a negative shock later receive more resources, which in turn would allow them to invest more resources into the catching-up process of their child.

A different way of getting at the likely underlying channels is to focus on the location of a household in early childhood. Rural households are typically believed to be more affected by rainfall shocks than urban households due to their involvement in agriculture. If households are more likely to have a better harvest and an increased household income after good rainfall shocks, then rural households may be able to invest more resources in their children after a positive rainfall shock. Urban incomes, which are less dependent on agriculture, should be less affected by the weather. On the other hand, papers like Maccini and Yang (2009) find results consistent with larger health impacts for men from rainfall shocks in urban settings, which they hypothesize could be due to a higher prevalence of water-borne diseases in urban areas after higher rainfall. This is a potential explanation for the negative education impacts from higher rainfall observed in some specifications in Table 4 if higher rainfall has negative impacts on cognitive development for men.

Tables 7 to 14 estimate the main results separately for rural and urban areas. Tables 7 to 7 show that women in rural and urban areas experience similar impacts on years of schooling and height as well as a similar catching-up process over time, which contradicts the typical story that rainfall shocks predominantly affect children in rural areas. Tables 11 to 14 find again that men in general are less impacted by negative early-life rainfall shocks than women. They also show, however, that men in urban areas have a stronger and more persistent positive impact of rainfall shocks in the first 12 months after birth on completed years of schooling, whereas favorable rainfall in the second year after birth leads to lower schooling in rural areas while growing up.

Overall, these tables suggest that children born in urban environments face broadly similar long-term consequences as children born in rural areas. These results would be consistent with urban households being affected by rainfall through food prices.

# 5 Conclusion

This paper has estimated the impact of early-life rainfall shocks on education, health and cognition outcomes at different points in time. The results suggest that both in-utero and post-birth shocks have longer term impacts because they occur during a critical time period in the children's physical and cognitive development.

There is little evidence that rainfall shocks around the time of birth have persistent income effects of households over time, and there is no consistent evidence that more short-term measures of health, measured by the body-mass index and lung capacity, are permanently affected. The impacts are larger for height, which is a more long-term measure of health that heavily depends on childhood conditions, but children adversely affected in early childhood manage to catch up to others born under more favorable conditions by the time they reach adulthood. Education impacts for women are more persistent, although the gap narrows over time as well. Women are more heavily affected by rainfall shocks than men on both health and education outcomes. While most of the effects are consistent with a transitory income shock leading to a shortfall in household resources which cause negative consequences since it occurs during a critical child development phase, the negative impact of higher rainfall shocks for men in some specifications support similar evidence in the literature that men could be more susceptible to water-borne diseases. The results are quite similar across rural and urban areas.

These results suggest that children experiencing adverse rainfall shocks in urban areas should not be neglected in favor of a sole focus on children born in rural areas. The evidence showing that catch-up is possible for children even for a measure like height, which has traditionally been seen as more permanent and its trajectory very difficult to change for older children, suggests that with the right kind of interventions it may be possible to insulate children from negative long-term consequences.

# References


Albert, M., Jones, K., Savage, C., Berkman, L., Seeman, T., Blazer, D., Rowe, J., 1995. Predictors of cognitive change in older persons: Macarthur studies of successful aging. Psychological Aging 10 (4), 578–89.

Almond, D., 2006. Is the 1918 influenza pandemic over? long-term effects of in-utero influenza exposure in the post-1940 u.s. population. Journal of Political Economy 114, 612–712.

Almond, D., Chay, K., Li, H., Zhang, J., 2006. Long-term effects of the 1959-1961 china famine: Mainland china and hong kong.

Burgess, R., Hansen, M., Olken, B. A., Potapov, P., Sieber, S., 2012. The political economy of deforestation in the tropics. The Quarterly Journal of Economics 127 (4), 1707–1754.

Chen, Y., Zhou, L.-A., 2007. The long-term health and economic consequences of the 1959-1961 famine in china. Journal of Health Economics 26, 659–681.

Cook, N. R., Evans, D. A., Scherr, P. A., Speizer, F. E., Taylor, J. O., Hennekens, C. H., 1991. Peak expiratory flow rate and 5-year mortality in an elderly population. American Journal of Epidemiology 133 (8), 784–794.

Crookston, B., Penny, M., Alder, S., Dickerson, T., Merrill, R., Stanford, J., Porucsznik, C., Dearden, K., 2010. Children who recover from early stunting and children who are not stunted demonstrate similar levels of cognition. Journal of Nutrition 140 (11), 1996–2001.

Currie, J., Vogl, T., 2013. Early-life health and adult circumstance in developing countries. Annual Review of Economics 5 (1), 1–36.

Deolalikar, A. B., 1996. Child nutritional status and child growth in kenya: Socioeconomic determinants. Journal of International Development 8 (3), 375–393.

Frankenberg, E., Karoly, L., 1995. The 1993 indonesian family life survey: Overview and field report. Tech. rep., RAND, Santa Monica, CA.

Frankenberg, E., Thomas, D., 2000. The indonesia family life survey (ifls): Study design and results from waves 1 and 2. Tech. rep., RAND, Santa Monica, CA. DRU-2238/1-NIA/NICHD.

Hoddinott, J., Maluccio, J., Behrman, J., Flores, R., Martorell, R., 2008. Effect of a nutrition intervention during early childhood on economic productivity in guatemalan adults. Lancet 371, 411–416.

Jayachandran, S., 2009. Air quality and early-life mortality evidence from indonesias wildfires. Journal of Human Resources 44, 916–925.

Leight, J., Glewwe, P., Park, A., 2015. The impact of early childhood rainfall shocks on the evolution of cognitive and non-cognitive skills, working Paper.

L.S., A., 1999. Filipino children exhibit catch-up growth from age 2 to 12 years. Journal of Nutrition 129, 1140–1148.

Lundeen, E., Behrman, J., Crookston, B., Dearden, K. A., Engle, P., Georgiadis, A., Penny, M., Stein, A., 2013. Growth faltering and recovery in children aged 1-8 years in four low- and middle-income countries: Young lives. Public Health Nutrition 371, 1–7.

Maccini, S., Yang, D., June 2009. Under the weather: Health, schooling, and economic consequences of early-life rainfall. American Economic Review 99 (3), 1006–26.

Mani, S., 2012. Is there complete, partial or no recovery from childhood malnutrition? empirical evidence from indonesia. Oxford Bulletin of Economics and Statistics 74 (5), 691–715.

Olken, B. A., 2009. Merged indonesian kecamatan codes. Tech. rep., National Bureau of Economic Research.

Pathania, V., 2009. The long run impact of drought at birth on height of womenin rural india. Working Paper.

Rocha, R., Soares, R., 2011. Early life health and educational performance: evidence from rainfall fluctuations in the brazilian northeast. Working Paper.

Schott, W., Crookston, B., Lundeen, E., Stein, A., Behrman, J., 2013. Child growth from ages 1 to 8 years in ethiopia, india, peru and vietnam: Key distal household and community factors. Social Science and Medicine 97, 278–287.

Singh, A., Park, A., Dercon, S., 2014. School meals as a safety net: An evaluation of the midday meal scheme in india. Economic Development and Cultural Change 6 (2).

Strauss, J., Beegle, K., Sikoki, B.and Dwiyanto, A., Herawati, Y., Witoelar, F., 2004. The third wave of the indonesia family life survey (ifls): Overview and field report. Tech. rep., WR-144/1-NIA/NICHD.

Strauss, J., Witoelar, F., Sikoki, B., 2016. The fifth wave of the indonesia family life survey (ifls5): Overview and field report. Tech. rep., WR-1143/1-NIA/NICHD.

Strauss, J., Witoelar, F., Sikoki, B., Wattie, A., 2009. The fourth wave of the indonesian family life survey (ifls4): Overview and field report. Tech. rep., WR-675/1-NIA/NICHD.

Table 1: Impact of Rainfall Shocks on Height (Women)

| | **Panel A: Height in cm (1990-1994)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **height** | | | | **height difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.9364*** | 0.6932*** | 0.0423 | -0.0891 | -0.2432 | -0.8941* | -1.0256*** |
| | (0.2743) | (0.2351) | (0.3888) | (0.2455) | (0.1999) | (0.5001) | (0.3109) |
| post (0-12 months) | 0.8946*** | 0.8857*** | -0.4752 | 0.2755 | -0.0089 | -1.3698*** | -0.6192** |
| | (0.2783) | (0.2310) | (0.4441) | (0.2996) | (0.2074) | (0.4636) | (0.2967) |
| post (13-24 months) | 0.5158* | 0.6191* | -0.7910* | -0.4302 | 0.1032 | -1.3068*** | -0.9461*** |
| | (0.2805) | (0.3139) | (0.4589) | (0.3096) | (0.2122) | (0.4701) | (0.3052) |
| N | 858 | 858 | 858 | 858 | 858 | 858 | 858 |
| R squared | 0.7321 | 0.6776 | 0.1352 | 0.1412 | 0.1452 | 0.3793 | 0.7076 |
| | **Panel B: Stunting (1990-1994)** | | | | | | |
| | **stunted** | | | | **stunting difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | -0.0486 | -0.0762* | -0.1219*** | -0.0962*** | -0.0276 | -0.0733 | -0.0476 |
| | (0.0407) | (0.0381) | (0.0337) | (0.0321) | (0.0311) | (0.0503) | (0.0396) |
| post (0-12 months) | -0.0310 | -0.0222 | 0.0255 | 0.0250 | 0.0088 | 0.0565* | 0.0560 |
| | (0.0323) | (0.0251) | (0.0191) | (0.0259) | (0.0287) | (0.0304) | (0.0421) |
| post (13-24 months) | -0.0016 | -0.0322 | -0.0101 | -0.0130 | -0.0306 | -0.0086 | -0.0114 |
| | (0.0282) | (0.0285) | (0.0241) | (0.0270) | (0.0196) | (0.0354) | (0.0328) |
| N | 490 | 490 | 490 | 490 | 490 | 490 | 490 |
| R squared | 0.1946 | 0.1730 | 0.1903 | 0.1765 | 0.1478 | 0.1996 | 0.1773 |

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

Table 2: Impact of Rainfall Shocks on Schooling and Cognition (Women)

| | Panel A: Years of Schooling (1990-1994) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **schooling** | | | | **schooling difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.0352*** | 0.1165*** | 0.0503 | -0.1546 | 0.0812** | 0.0150 | -0.1899 |
| | (0.0133) | (0.0321) | (0.0657) | (0.1311) | (0.0310) | (0.0641) | (0.1293) |
| post (0-12 months) | 0.0439*** | 0.1193*** | 0.1929** | 0.2792* | 0.0754** | 0.1489* | 0.2352 |
| | (0.0160) | (0.0295) | (0.0804) | (0.1488) | (0.0315) | (0.0783) | (0.1504) |
| post (13-24 months) | 0.0704*** | 0.0997** | 0.2052** | 0.2166 | 0.0293 | 0.1347 | 0.1461 |
| | (0.0220) | (0.0414) | (0.0852) | (0.1674) | (0.0398) | (0.0891) | (0.1713) |
| N | 925 | 925 | 925 | 925 | 925 | 925 | 925 |
| R squared | 0.4600 | 0.7456 | 0.4533 | 0.2382 | 0.6789 | 0.3947 | 0.2385 |

| | Panel B: Cognition (Raven Test Percent) (1990-1994) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **cognition** | | | | **cognition difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | | 0.9372 | 1.4662* | -0.7056 | | 0.5290 | -1.6428 |
| | | (0.9938) | (0.8104) | (1.1937) | | (01.2854) | (1.8033) |
| post (0-12 months) | | 2.2747** | 0.9270 | 0.8523 | | -1.3478 | -1.4224 |
| | | (1.1322) | (0.7819) | (0.9818) | | (1.0484) | (1.2610) |
| post (13-24 months) | | 2.8818** | 1.2048 | 0.3199 | | -1.6771 | -2.5619 |
| | | (1.1699) | (0.8178) | (1.2021) | | (1.3369) | (1.5592) |
| N | | 738 | 738 | 738 | | 738 | 738 |
| R squared | | 0.2443 | 0.2054 | 0.1651 | | 0.1814 | 0.1939 |

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

Table 3: Impact of Rainfall Shocks on Height (Men)

| | **Panel A: Height in cm (1990-1994)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **height** | | | | **height difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.5199 | 0.4370 | -0.0463 | 0.1234 | -0.0829 | -0.5661 | -0.3965 |
| | (0.4205) | (0.3443) | (0.5718) | (0.3513) | (0.3342) | (0.5311) | (0.3707) |
| post (0-12 months) | 0.7088** | 0.9167*** | -0.0043 | 0.3867 | 0.2079 | -0.7131 | -0.3220 |
| | (0.3164) | (0.3374) | (0.4849) | (0.3330) | (0.3312) | (0.5501) | (0.3486) |
| post (13-24 months) | 0.5186** | 0.6811** | 0.1245 | -0.0479 | 0.1625 | -0.3941 | -0.5666 |
| | (0.2546) | (0.3109) | (0.6253) | (0.3540) | (0.2648) | (0.5983) | (0.3497) |
| N | 837 | 837 | 837 | 837 | 837 | 837 | 837 |
| R squared | 0.6813 | 0.5446 | 0.2521 | 0.1215 | 0.2080 | 0.2255 | 0.6805 |

| | **Panel B: Stunting (1990-1994)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **stunted** | | | | **stunting difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | -0.0810 | 0.0084 | 0.0406 | 0.0252 | 0.0893* | 0.1216** | 0.1062* |
| | (0.0606) | (0.0587) | (0.0584) | (0.0660) | (0.0481) | (0.0559) | (0.0619) |
| post (0-12 months) | -0.0039 | -0.0154 | -0.0130 | -0.0259 | -0.0114 | -0.0090 | -0.0220 |
| | (0.0302) | (0.0307) | (0.0265) | (0.0289) | (0.0297) | (0.0301) | (0.0342) |
| post (13-24 months) | 0.0237 | 0.0206 | 0.0447* | -0.0001 | -0.0031 | 0.0210 | -0.0238 |
| | (0.0230) | (0.0285) | (0.0256) | (0.0343) | (0.0286) | (0.0319) | (0.0429) |
| N | 470 | 470 | 470 | 470 | 470 | 470 | 470 |
| R squared | 0.1760 | 0.1936 | 0.1670 | 0.1410 | 0.1859 | 0.2042 | 0.1431 |

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

Table 4: Impact of Rainfall Shocks on Schooling and Cognition (Men)

| | **Panel A: Years of Schooling (1990-1994)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **schooling** | | | | **schooling difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.0107 | 0.0601 | 0.0782 | 0.0512 | 0.0493 | 0.0674 | 0.0405 |
| | (0.0189) | (0.0430) | (0.0744) | (0.1287) | (0.0503) | (0.0741) | (0.1269) |
| post (0-12 months) | 0.0426*** | 0.0682 | 0.1014 | 0.0137 | 0.0256 | 0.0588 | -0.0289 |
| | (0.0137) | (0.0457) | (0.0777) | (0.1575) | (0.0459) | (0.0775) | (0.1576) |
| post (13-24 months) | 0.0279 | 0.0233 | -0.2004** | -0.6044*** | -0.0046 | -0.2283** | -0.6323*** |
| | (0.0284) | (0.0487) | (0.0905) | (0.1862) | (0.0540) | (0.1029) | (0.1989) |
| N | 962 | 962 | 962 | 962 | 962 | 962 | 962 |
| R squared | 0.3751 | 0.6391 | 0.3601 | 0.2005 | 0.5650 | 0.3154 | 0.2070 |

| | **Panel B: Cognition (Raven Test Percent) (1990-1994)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **cognition** | | | | **cognition difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | | -0.5382 | -0.1626 | -1.4920 | | 0.3756 | -0.9538 |
| | | (1.0573) | (0.6472) | (1.0935) | | (1.2467) | (1.3856) |
| post (0-12 months) | | 1.4175 | -0.0894 | 0.0653 | | -1.5069 | -1.3522 |
| | | (1.3376) | (0.6937) | (1.2962) | | (1.4462) | (1.5735) |
| post (13-24 months) | | 0.4106 | 0.5284 | -0.9686 | | 0.1178 | -1.3792 |
| | | (1.1511) | (0.8619) | (1.2482) | | (1.2595) | (1.1306) |
| N | | 755 | 755 | 755 | | 755 | 755 |
| R squared | | 0.2932 | 0.2069 | 0.1556 | | 0.1970 | 0.2353 |

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

Table 5: Impact of Rainfall Shocks on Other Health Outcomes

| | Panel A: Women (1990-1994) | | | | | |
|---|---|---|---|---|---|---|
| | body mass index (bmi) | | | | lung capacity | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2014 |
| in-utero | -0.0881 | -0.0405 | 1.739 | 0.207 | -3.139 | 0.0985 |
| | (0.0950) | (0.128) | (1.400) | (0.189) | (4.415) | (1.967) |
| post (0-12 months) | -0.0234 | 0.0832 | 3.974 | 0.0895 | 4.626 | 1.774 |
| | (0.0957) | (0.117) | (3.621) | (0.184) | (3.657) | (2.937) |
| post (13-24 months) | 0.173 | -0.0351 | -2.628* | -0.0466 | 4.730* | -1.491 |
| | (0.117) | (0.0763) | (1.391) | (0.161) | (2.778) | (2.061) |
| N | 1464 | 1807 | 1919 | 1830 | 473 | 1826 |

| | Panel B: Men (1990-1994) | | | | | |
|---|---|---|---|---|---|---|
| | body mass index (bmi) | | | | lung capacity | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2014 |
| in-utero | -0.170* | 0.0108 | 0.361 | -0.200 | 5.545 | 2.277 |
| | (0.0931) | (0.0792) | (0.563) | (0.178) | (4.700) | (3.134) |
| post (0-12 months) | 0.0800 | 0.0886 | -1.372 | 0.119 | 1.872 | -1.855 |
| | (0.142) | (0.122) | (1.283) | (0.114) | (4.739) | (3.299) |
| post (13-24 months) | -0.0293 | -0.178 | -1.923 | -0.168 | 2.943 | 0.442 |
| | (0.0754) | (0.140) | (1.850) | (0.115) | (2.156) | (3.325) |
| N | 1480 | 1830 | 1884 | 1676 | 522 | 1677 |

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 6: Impact of Rainfall Shocks on Per-Capita Household Expenditures

| | **Panel A: Women (1990-1994) per-capita household expenditures** | | | |
|---|---|---|---|---|
| **Specification** | 1993 | 1997 | 2000 | 2007 |
| in-utero | -0.0316 | -0.0255 | -0.0298 | -0.0539 |
| | (0.0376) | (0.0294) | (0.0258) | (0.0667) |
| post (0-12 months) | -0.00278 | 0.0142 | 0.0119 | -0.0319 |
| | (0.0485) | (0.0281) | (0.0338) | (0.0435) |
| post (13-24 months) | 0.0594* | 0.0650** | 0.0277 | 0.0239 |
| | (0.0303) | (0.0273) | (0.0261) | (0.0359) |
| N | 993 | 1670 | 1907 | 2051 |
| | **Panel B: Men (1990-1994) per-capita household expenditures** | | | |
| **Specification** | 1993 | 1997 | 2000 | 2007 |
| in-utero (0-12 months) | -0.0267 | -0.0449 | -0.0103 | -0.0561* |
| | (0.0404) | (0.0384) | (0.0320) | (0.0319) |
| post (0-12 months) | 0.0316 | 0.0227 | 0.0418 | -0.0212 |
| | (0.0381) | (0.0293) | (0.0381) | (0.0430) |
| post (13-24 months) | -0.0462 | 0.0264 | -0.0186 | 0.0740** |
| | (0.0501) | (0.0304) | (0.0286) | (0.0284) |
| N | 1074 | 1696 | 1911 | 2007 |

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

Table 7: Impact of Rainfall Shocks on Height (Women, Rural)

| | **Panel A: Height in cm (1990-1994)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **height** | | | | **height difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.7730** | 0.5946* | -0.0904 | -0.4420 | -0.1784 | -0.8634* | -1.2150*** |
| | (0.3152) | (0.3283) | (0.4704) | (0.4082) | (0.2236) | (0.4869) | (0.4289) |
| post (0-12 months) | 1.0633** | 0.9592** | -1.0183 | 0.2398 | -0.1041 | -2.0816*** | -0.8234* |
| | (0.4075) | (0.3990) | (0.6550) | (0.5944) | (0.2412) | (0.6625) | (0.4166) |
| post (13-24 months) | 0.0259 | 0.2547 | -0.8636 | -0.4222 | 0.2288 | -0.8895* | -0.4480 |
| | (0.3184) | (0.3992) | (0.5423) | (0.4091) | (0.3475) | (0.5083) | (0.3968) |
| N | 496 | 496 | 496 | 496 | 496 | 496 | 496 |
| R squared | 0.7593 | 0.7168 | 0.1677 | 0.1587 | 0.1436 | 0.3539 | 0.6972 |
| | **Panel B: Stunting (1990-1994)** | | | | | | |
| | **stunted** | | | | **stunting difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | -0.0695 | -0.0883 | -0.1022** | -0.0551 | -0.0188 | -0.0327 | 0.0143 |
| | (0.0573) | (0.0527) | (0.0486) | (0.0455) | (0.0431) | (0.0673) | (0.0578) |
| post (0-12 months) | -0.0157 | -0.0386 | 0.0615* | 0.0587 | -0.0229 | 0.0772 | 0.0744 |
| | (0.0366) | (0.0359) | (0.0365) | (0.0574) | (0.0380) | (0.0524) | (0.0598) |
| post (13-24 months) | 0.0329 | 0.0013 | -0.0053 | 0.0057 | -0.0317 | -0.0382 | -0.0272 |
| | (0.0440) | (0.0429) | (0.0376) | (0.0409) | (0.0286) | (0.0524) | (0.0477) |
| N | 282 | 282 | 282 | 282 | 282 | 282 | 282 |
| R squared | 0.2267 | 0.2009 | 0.2031 | 0.1766 | 0.1735 | 0.2197 | 0.1975 |

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

Table 8: Impact of Rainfall Shocks on Schooling and Cognition (Women, Rural)

| | **Panel A: Years of Schooling (1990-1994)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **schooling** | | | | **schooling difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.0558* | 0.1358*** | -0.0215 | -0.4693** | 0.0800* | -0.0773 | -0.5250** |
| | (0.0281) | (0.0481) | (0.0935) | (0.2016) | (0.0435) | (0.0949) | (0.2039) |
| post (0-12 months) | 0.0731*** | 0.1060** | 0.1774* | 0.1503 | 0.0329 | 0.1043 | 0.0772 |
| | (0.0270) | (0.0484) | (0.0943) | (0.2061) | (0.0597) | (0.0907) | (0.2099) |
| post (13-24 months) | 0.0521 | 0.1106* | 0.2397** | 0.2385 | 0.0585 | 0.1877 | 0.1864 |
| | (0.0400) | (0.0589) | (0.1125) | (0.2344) | (0.0502) | (0.1230) | (0.2421) |
| N | 530 | 530 | 530 | 530 | 530 | 530 | 530 |
| R squared | 0.4707 | 0.7601 | 0.4512 | 0.3184 | 0.6825 | 0.3938 | 0.3197 |
| | **Panel B: Cognition (Raven Test Percent) (1990-1994)** | | | | | | |
| | **cognition** | | | | **cognition difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | | 1.5495 | 2.9403** | 0.5382 | | 1.3908 | -1.0113 |
| | | (1.7157) | (1.3525) | (1.3986) | | (2.3011) | (2.3469) |
| post (0-12 months) | | 1.3192 | 0.6809 | 1.4223 | | -0.6384 | 0.1030 |
| | | (1.4732) | (1.1369) | (1.2263) | | (1.6065) | (1.5537) |
| post (13-24 months) | | 2.1235 | 2.2556** | 1.7605 | | 0.1321 | -0.3630 |
| | | (1.4320) | (1.0993) | (1.2194) | | (1.9115) | (1.8865) |
| N | | 412 | 412 | 412 | | 412 | 412 |
| R squared | | 0.2947 | 0.2610 | 0.3011 | | 0.2282 | 0.2561 |

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

Table 9: Impact of Rainfall Shocks on Height (Women, Urban)

| | Panel A: Height in cm (1990-1994) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **height** | | | | **height difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 1.1911*** | 0.8390** | 0.0736 | 0.3894 | -0.3521 | -1.1176 | -0.8017** |
| | (0.3748) | (0.3776) | (0.6875) | (0.2749) | (0.3159) | (0.7837) | (0.3625) |
| post (0-12 months) | 0.7556 | 0.9514* | 0.5506 | 0.6112 | 0.1959 | -0.2050 | -0.1444 |
| | (0.5186) | (0.5067) | (0.6461) | (0.4390) | (0.4576) | (0.5710) | (0.4720) |
| post (13-24 months) | 1.2069** | 1.1182** | -0.8771 | -0.3991 | -0.0887 | -2.0840** | -1.6060*** |
| | (0.4489) | (0.4484) | (0.8818) | (0.4300) | (0.4842) | (0.9343) | (0.4830) |
| N | 349 | 349 | 349 | 349 | 349 | 349 | 349 |
| R squared | 0.7359 | 0.6716 | 0.1471 | 0.2480 | 0.2102 | 0.5034 | 0.7547 |
| | **Panel B: Stunting (1990-1994)** | | | | | | |
| | **stunted** | | | | **stunting difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | -0.0519 | -0.0652 | -0.1801** | -0.2116*** | -0.0133 | -0.1282 | -0.1597* |
| | (0.0593) | (0.0590) | (0.0658) | (0.0626) | (0.0626) | (0.0805) | (0.0818) |
| post (0-12 months) | -0.0498 | -0.0221 | -0.0190 | -0.0017 | 0.0277 | 0.0309 | 0.0482 |
| | (0.0548) | (0.0378) | (0.0574) | (0.0308) | (0.0415) | (0.0425) | (0.0465) |
| post (13-24 months) | -0.0865** | -0.0948** | -0.0323 | -0.0513 | -0.0083 | 0.0542 | 0.0351 |
| | (0.0345) | (0.0393) | (0.0433) | (0.0439) | (0.0352) | (0.0462) | (0.0517) |
| N | 187 | 187 | 187 | 187 | 187 | 187 | 187 |
| R squared | 0.2267 | 0.2009 | 0.2031 | 0.1766 | 0.2226 | 0.1751 | 0.1982 |

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

Table 10: Impact of Rainfall Shocks on Schooling and Cognition (Women, Urban)

| | Panel A: Years of Schooling (1990-1994) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **schooling** | | | | **schooling difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.0201 | 0.1119** | 0.1553* | 0.1097 | 0.0918** | 0.1352 | 0.0896 |
| | (0.0200) | (0.0504) | (0.0901) | (0.1611) | (0.0439) | (0.0822) | (0.1653) |
| post (0-12 months) | -0.0137 | 0.1028* | 0.1542 | 0.3149 | 0.1165** | 0.1679* | 0.3285* |
| | (0.0190) | (0.0562) | (0.0999) | (0.1883) | (0.0315) | (0.0956) | (0.1883) |
| post (13-24 months) | 0.1176*** | 0.1059 | 0.2117** | 0.2027 | -0.0117 | 0.0941 | 0.0851 |
| | (0.0337) | (0.0670) | (0.1003) | (0.2615) | (0.0570) | (0.1014) | (0.2700) |
| N | 384 | 384 | 384 | 384 | 384 | 384 | 384 |
| R squared | 0.5197 | 0.7806 | 0.6335 | 0.3122 | 0.7246 | 0.5762 | 0.3006 |

| | Panel B: Cognition (Raven Test Percent) (1990-1994) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **cognition** | | | | **cognition difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | | 0.5212 | 0.1659 | -1.6222 | | -0.3553 | -2.1434 |
| | | (1.6627) | (0.8866) | (1.8374) | | (1.6563) | (2.5541) |
| post (0-12 months) | | 4.1049** | 0.9213 | -0.6348 | | -3.1836* | -4.7397** |
| | | (1.8557) | (1.2812) | (1.6860) | | (1.8473) | (2.2853) |
| post (13-24 months) | | 2.6368 | -0.2217 | -1.2660 | | -2.8586* | -3.9028 |
| | | (1.6593) | (0.9253) | (2.4078) | | (1.6048) | ( 2.5966) |
| N | | 314 | 314 | 314 | | 314 | 314 |
| R squared | | 0.2799 | 0.2619 | 0.1598 | | 0.2613 | 0.2324 |

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

Table 11: Impact of Rainfall Shocks on Height (Men, Rural)

| | Panel A: Height in cm (1990-1994) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **height** | | | | **height difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.5196 | 0.4509 | 0.2705 | -0.0130 | -0.0687 | -0.2491 | -0.5326 |
| | (0.5803) | (0.3914) | (0.6866) | (0.4313) | (0.3929) | (0.6623) | (0.4686) |
| post (0-12 months) | 0.8473** | 0.9409* | 0.0776 | 0.2217 | 0.0936 | -0.7697 | -0.6256 |
| | (0.4235) | (0.4781) | (0.8021) | (0.4413) | (0.4540) | (0.7887) | (0.4135) |
| post (13-24 months) | 0.4821 | 0.7769* | 0.3313 | -0.2364 | 0.2948 | -0.1508 | -0.7185 |
| | (0.4120) | (0.4137) | (0.6838) | (0.4451) | (0.3650) | (0.6564) | (0.4712) |
| N | 506 | 506 | 506 | 506 | 506 | 506 | 506 |
| R squared | 0.6895 | 0.5526 | 0.2875 | 0.1430 | 0.2244 | 0.2429 | 0.6772 |

| | Panel B: Stunting (1990-1994) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **stunted** | | | | **stunting difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | -0.1141 | -0.0405 | 0.0368 | 0.0261 | 0.0736 | 0.1508** | 0.1402* |
| | (0.0844) | (0.0697) | (0.0627) | (0.0707) | (0.0528) | (0.0713) | (0.0772) |
| post (0-12 months) | -0.0039 | 0.0254 | -0.0116 | -0.0112 | 0.0293 | -0.0077 | -0.0073 |
| | (0.0390) | (0.0366) | (0.0375) | (0.0390) | (0.0345) | (0.0414) | (0.0434) |
| post (13-24 months) | 0.0387 | 0.0643 | 0.0690* | 0.0431 | 0.0256 | 0.0303 | 0.0044 |
| | (0.0520) | (0.0446) | (0.0369) | (0.0451) | (0.0373) | (0.0464) | (0.0652) |
| N | 274 | 274 | 274 | 274 | 274 | 274 | 274 |
| R squared | 0.1824 | 0.2293 | 0.1826 | 0.1727 | 0.1857 | 0.1768 | 0.1628 |

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

Table 12: Impact of Rainfall Shocks on Schooling and Cognition (Men, Rural)

| | **Panel A: Years of Schooling (1990-1994)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **schooling** | | | | **schooling difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.0463* | 0.1599** | 0.0863 | -0.0904 | 0.1136 | 0.0400 | -0.1367 |
| | (0.0254) | (0.0635) | (0.1079) | (0.1988) | (0.0745) | (0.1053) | (0.1926) |
| post (0-12 months) | 0.0237 | -0.0049 | -0.0021 | 0.1147 | -0.0286 | -0.0259 | 0.0910 |
| | (0.0226) | (0.0547) | (0.1009) | (0.1928) | (0.0538) | (0.1016) | (0.1945) |
| post (13-24 months) | 0.0380 | 0.0031 | -0.3437*** | -0.8362*** | -0.0350 | -0.3818*** | -0.8743*** |
| | (0.0393) | (0.0691) | (0.1246) | (0.2250) | (0.0639) | (0.1226) | (0.2227) |
| N | 574 | 574 | 574 | 574 | 574 | 574 | 574 |
| R squared | 0.3707 | 0.6364 | 0.3820 | 0.2959 | 0.5590 | 0.3468 | 0.3051 |

| | **Panel B: Cognition (Raven Test Percent) (1990-1994)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **cognition** | | | | **cognition difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | | -0.5745 | 0.2820 | -3.3341** | | 0.8565 | -2.7596 |
| | | (1.6861) | (1.0479) | (1.3802) | | (1.9032) | (1.9468) |
| post (0-12 months) | | 1.8892 | 0.3655 | -0.8779 | | -1.5237 | -2.7671 |
| | | (2.0955) | (1.2409) | (1.7081) | | (2.4725) | (2.0841) |
| post (13-24 months) | | -1.3694 | 1.7130 | -3.2829* | | 3.0824* | -1.9134 |
| | | (1.7355) | (1.2738) | (1.6856) | | (1.6513) | (1.9927) |
| N | | 438 | 438 | 438 | | 438 | 438 |
| R squared | | 0.3417 | 0.2871 | 0.2197 | | 0.2396 | 0.2637 |

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

Table 13: Impact of Rainfall Shocks on Height (Men, Urban)

| | Panel A: Height in cm (1990-1994) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **height** | | | | **height difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.3004 | 0.3493 | -0.6929 | 0.0112 | 0.0489 | -0.9933 | -0.2893 |
| | (0.5476) | (0.5193) | (0.8818) | (0.5438) | (0.3143) | (0.8801) | (0.4638) |
| post (0-12 months) | 0.5464 | 0.8104 | 0.3066 | 0.8102 | 0.2641 | -0.2397 | 0.2638 |
| | (0.3948) | (0.5517) | (0.6771) | (0.7051) | (0.4782) | (0.7309) | (0.6778) |
| post (13-24 months) | 0.8020** | 0.9622* | -0.7175 | 0.2302 | 0.1602 | -1.5195 | -0.5718 |
| | (0.3203) | (0.5332) | (1.0770) | (0.4456) | (0.4154) | (1.0870) | (0.3932) |
| N | 320 | 320 | 320 | 320 | 320 | 320 | 320 |
| R squared | 0.7366 | 0.5911 | 0.2987 | 0.2028 | 0.3408 | 0.3047 | 0.7505 |
| | **Panel B: Stunting (1990-1994)** | | | | | | |
| | **stunted** | | | | **stunting difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | 0.0164 | 0.1470** | 0.0468 | 0.0438 | 0.1307* | 0.0304 | 0.0274 |
| | (0.0751) | (0.0694) | (0.0996) | (0.0942) | (0.0753) | (0.0928) | (0.0865) |
| post (0-12 months) | 0.0027 | -0.0814 | -0.0297 | -0.0811* | -0.0841 | -0.0324 | -0.0838 |
| | (0.0394) | (0.0486) | (0.0365) | (0.0434) | (0.0615) | (0.0524) | (0.0609) |
| post (13-24 months) | 0.0411 | -0.0187 | -0.0098 | -0.0529 | -0.0598 | -0.0508 | -0.0939 |
| | (0.0438) | (0.0466) | (0.0354) | (0.0349) | (0.0597) | (0.0584) | (0.0573) |
| N | 178 | 178 | 178 | 178 | 178 | 178 | 178 |
| R squared | 0.2962 | 0.3184 | 0.2657 | 0.2204 | 0.3339 | 0.3839 | 0.2795 |

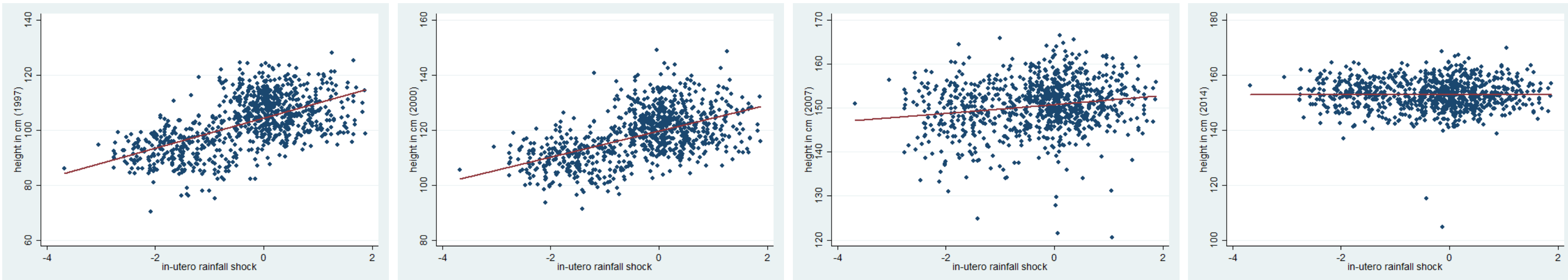
Note: *** p<0.01, ** p<0.05, * p<0.1

Table 14: Impact of Rainfall Shocks on Schooling and Cognition (Men, Urban)

| | **Panel A: Years of Schooling (1990-1994)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **schooling** | | | | **schooling difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | -0.0298 | -0.0674 | 0.0284 | 0.1011 | -0.0377 | 0.0581 | 0.1309 |
| | (0.0265) | (0.0704) | (0.1216) | (0.2059) | (0.0677) | (0.1151) | (0.1992) |
| post (0-12 months) | 0.0578*** | 0.2088** | 0.2430** | -0.0412 | 0.1510* | 0.1851* | -0.0990 |
| | (0.0185) | (0.0802) | (0.0974) | (0.1892) | (0.0772) | (0.0973) | (0.1919) |
| post (13-24 months) | 0.0252 | 0.0314 | -0.0557 | -0.4011* | 0.0062 | -0.0809 | -0.4263* |
| | (0.0384) | (0.0751) | (0.1082) | (0.2367) | (0.0835) | (0.1136) | (0.2471) |
| N | 379 | 379 | 379 | 379 | 379 | 379 | 379 |
| R squared | 0.4682 | 0.7030 | 0.4796 | 0.2339 | 0.6393 | 0.4215 | 0.2294 |
| | **Panel B: Cognition (Raven Test Percent) (1990-1994)** | | | | | | |
| | **cognition** | | | | **cognition difference to 1997** | | |
| **Specification** | 1997 | 2000 | 2007 | 2014 | 2000 | 2007 | 2014 |
| in-utero | | -0.9114 | -0.6672 | 0.5192 | | 0.2441 | 1.4306 |
| | | (1.6847) | (0.8705) | (1.6116) | | (1.6301) | (2.3709) |
| post (0-12 months) | | 0.3276 | -0.0902 | 1.2093 | | -0.4177 | 0.8817 |
| | | (1.9061) | (1.0403) | (2.1005) | | (1.9598) | (2.7139) |
| post (13-24 months) | | 2.6295* | -1.4944* | 2.0909 | | -4.1238*** | -0.5385 |
| | | (1.4215) | (0.8097) | (2.3923) | | (1.5108) | (2.0877) |
| N | | 306 | 306 | 306 | | 306 | 306 |
| R squared | | 0.3297 | 0.1622 | 0.2022 | | 0.2629 | 0.2683 |

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

Figure 1: The Impact of In-Utero Shocks on Height (Women)




Note: Height measured in centimeters. This figure as well as all the following figures plot the correlation between in-utero rainfall shocks and a given outcome variable. The rainfall shock is standardized by subtracting expected rainfall in the birth location from actual rainfall in utero, and dividing by the standard deviation of rainfall in that area. Odd numbered graphs show the impact of rainfall on the level of an outcome variable, whereas even numbered graphs plot the change of the outcome variable in a survey year relative to the same person's outcome value in 1997.



Figure 2: The Impact of In-Utero Shocks on Height Difference (Women)

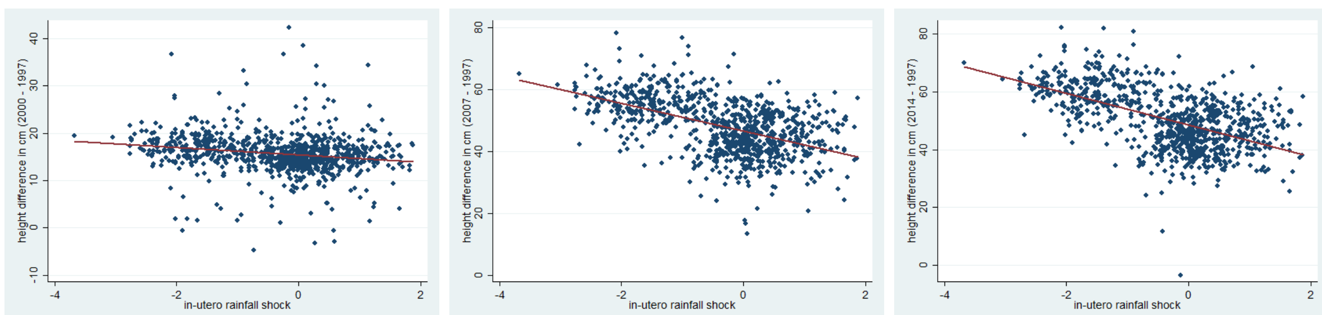
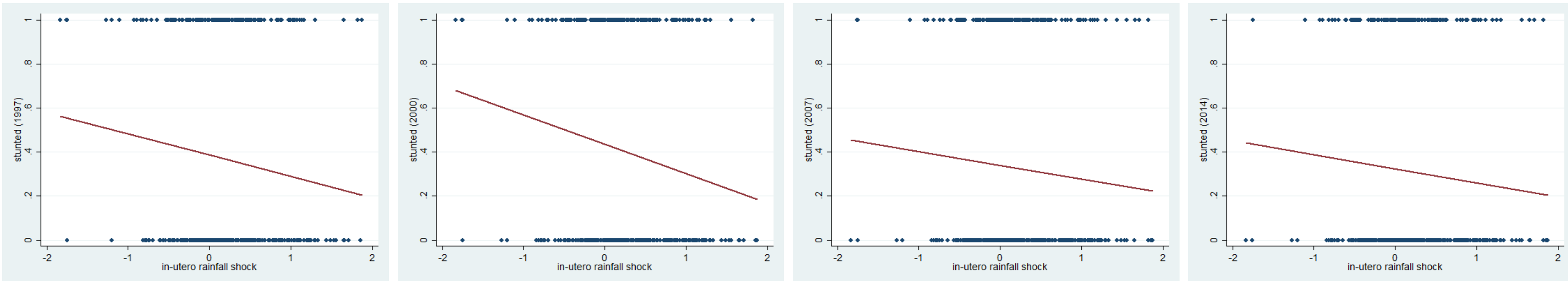


Figure 3: The Impact of In-Utero Shocks on Stunting (Women)




Note: A person is defined as stunted if he or she is more than two standard deviations shorter than expected based on a WHO reference population that takes into account a person's age in months and gender.

Figure 4: The Impact of In-Utero Shocks on Stunting Difference (Women)

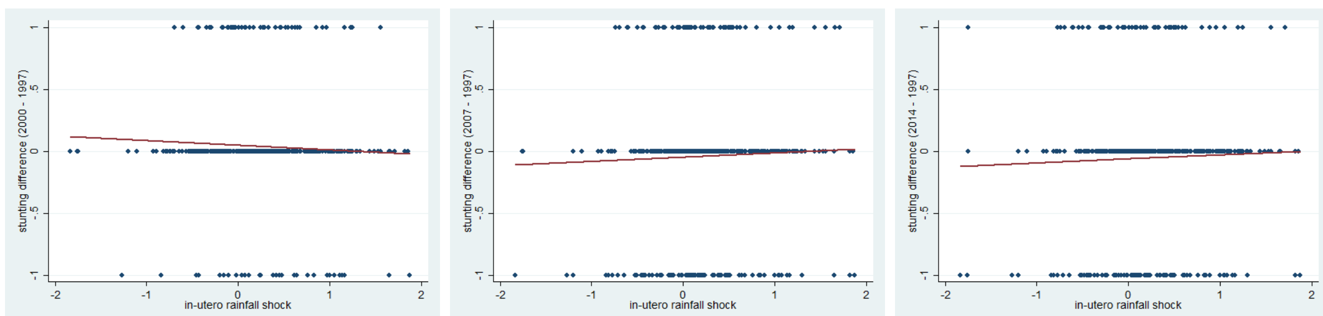


Figure 5: The Impact of In-Utero Shocks on Completed Years of Schooling (Women)

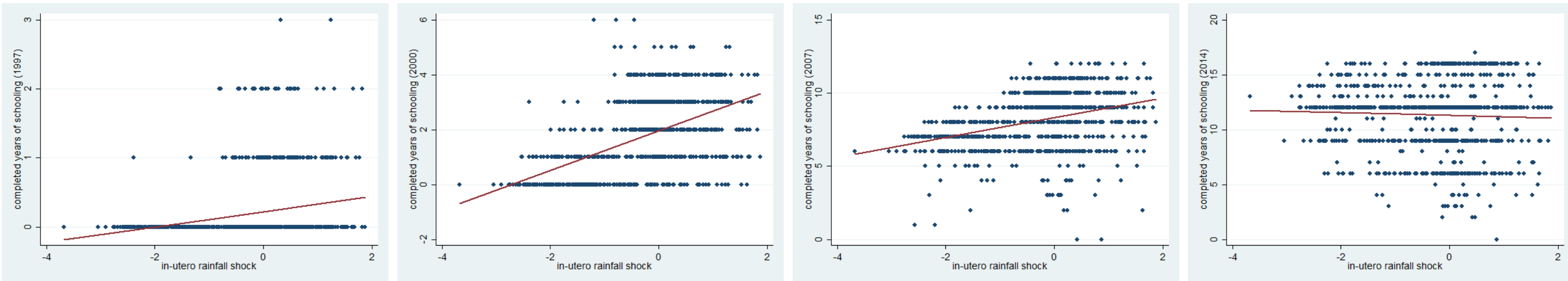



Figure 6: The Impact of In-Utero Shocks on Completed Years of Schooling Difference (Women)

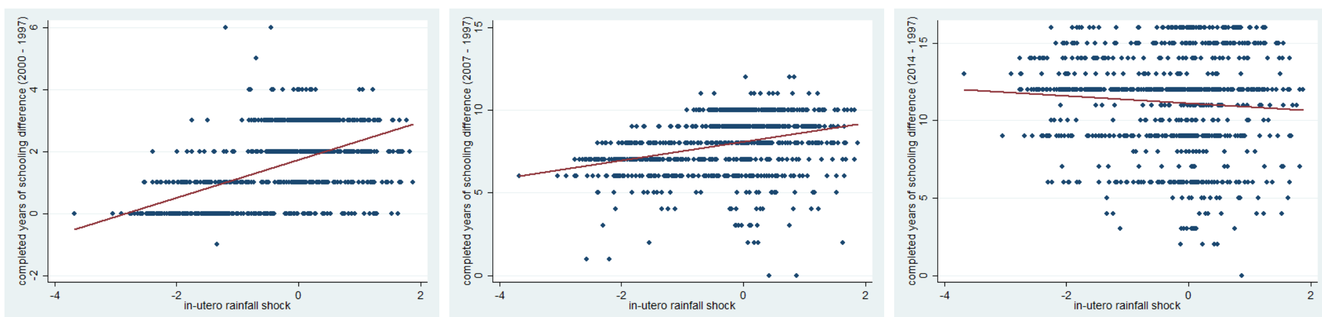
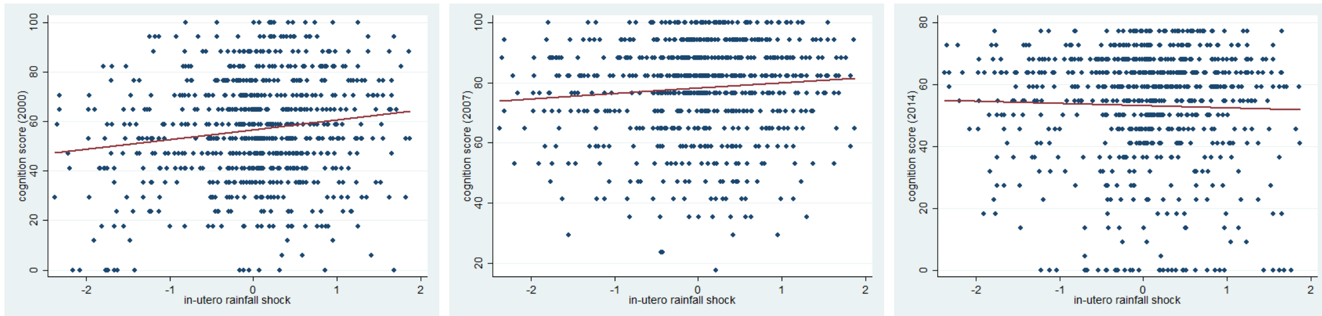


Figure 7: The Impact of In-Utero Shocks on Cognition Test Score (Women)




Note: Cognition test scores come from responses to the Raven's Matrices Test. Test scores are calculated as the percent of questions answered correctly.

Figure 8: The Impact of In-Utero Shocks on Cognition Test Score Difference (Women)

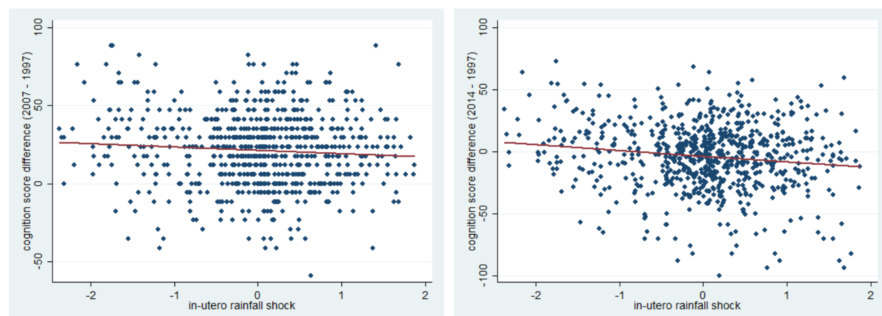


Figure 9: The Impact of In-Utero Shocks on Height (Men)

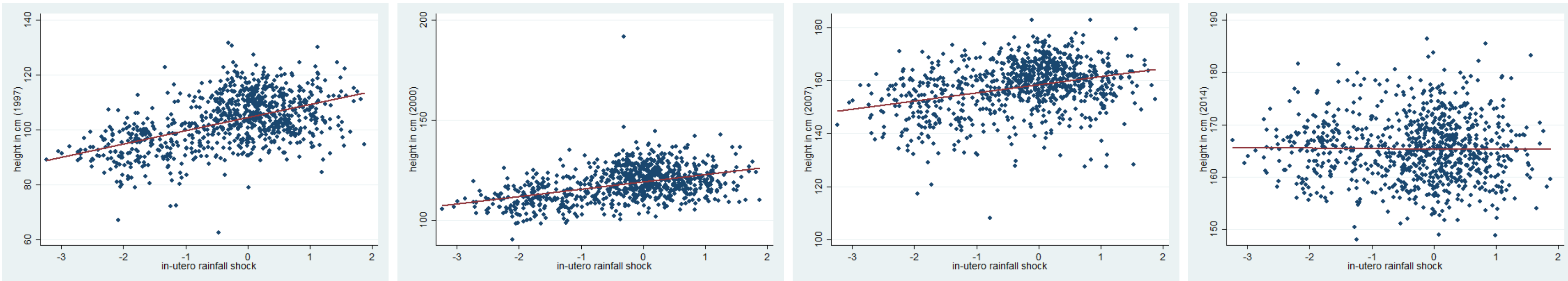



Figure 10: The Impact of In-Utero Shocks on Height Difference (Men)

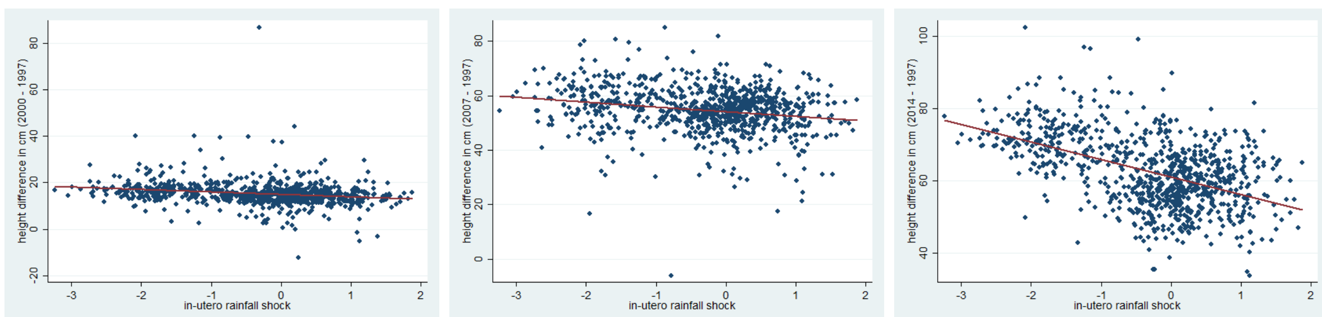


Figure 11: The Impact of In-Utero Shocks on Stunting (Men)

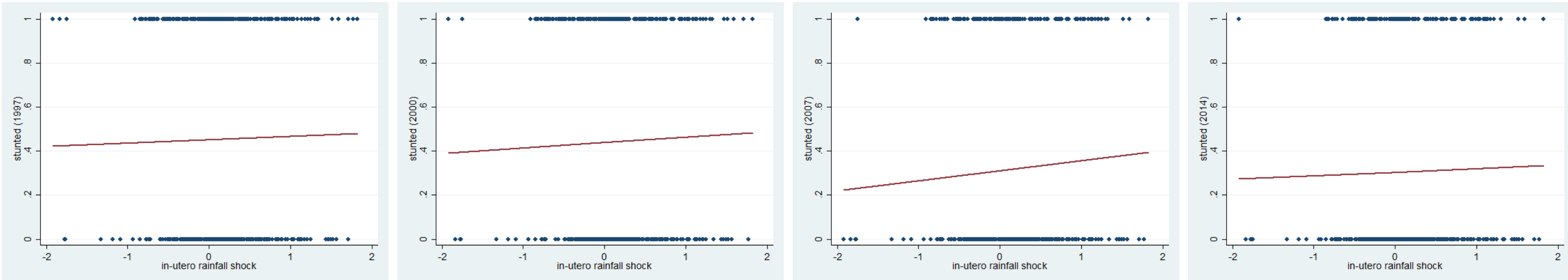



Figure 12: The Impact of In-Utero Shocks on Stunting Difference (Men)

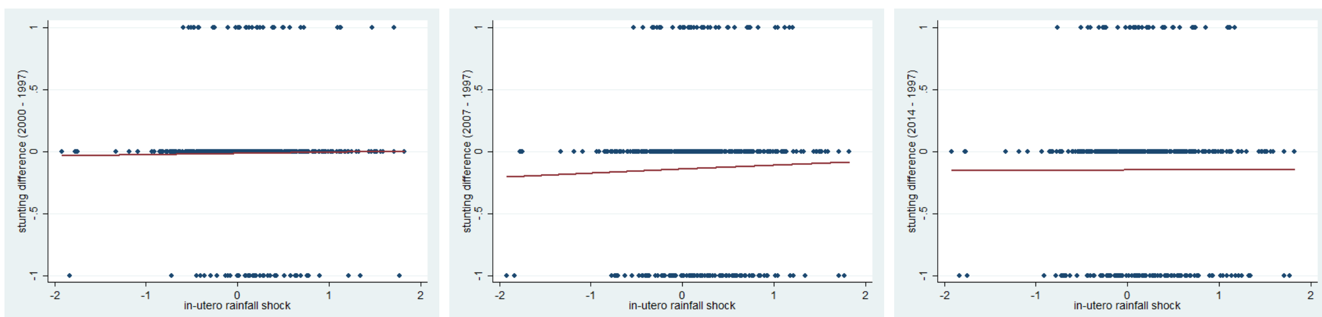


Figure 13: The Impact of In-Utero Shocks on Completed Years of Schooling (Men)

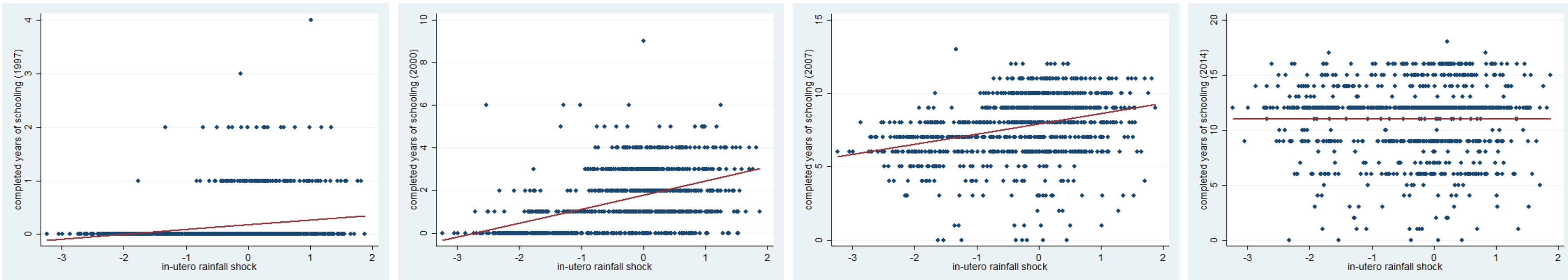



Figure 14: The Impact of In-Utero Shocks on Completed Years of Schooling Difference (Men)

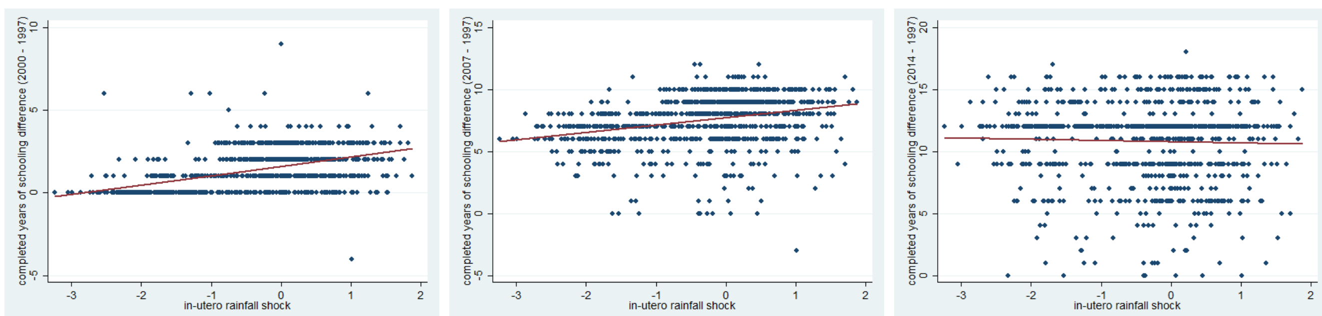


Figure 15: The Impact of In-Utero Shocks on Cognition Test Score (Men)

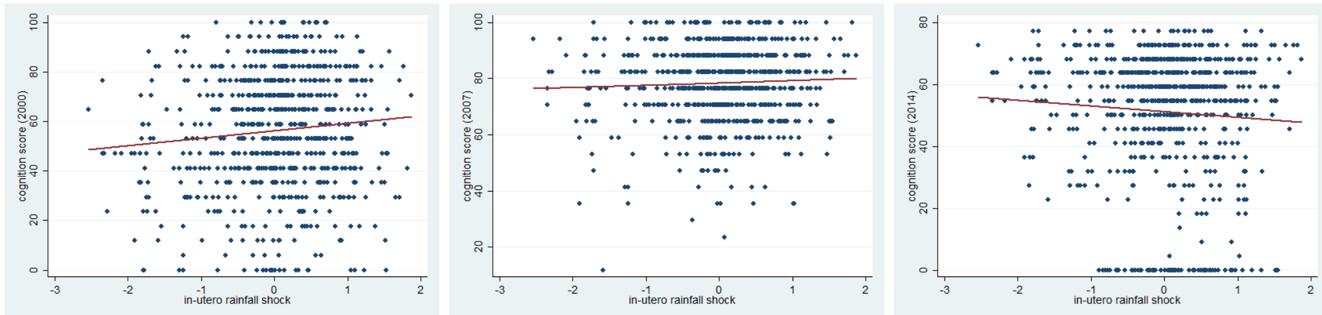



Figure 16: The Impact of In-Utero Shocks on Cognition Test Score Difference (Men)

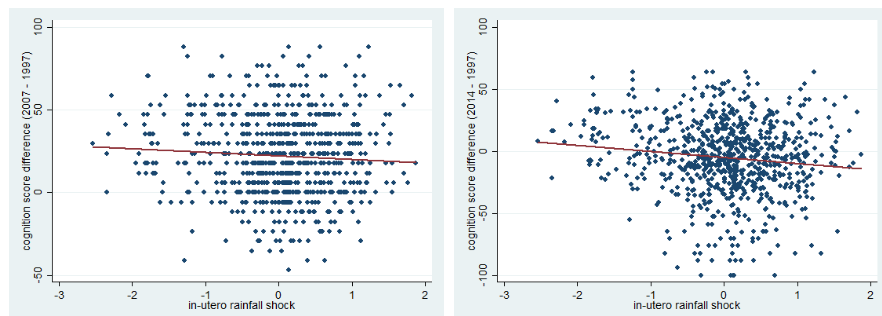


Figure 17: Potential Pathways from Early-Life Rainfall Shocks to Later-Life Outcomes