The Effects of Negative Economic Shocks at Birth on Adolescents' Cognitive Health and Educational Attainment in Malawi

Fabrice Kämpfen[a,b*] Fatima Zahra[c] Hans-Peter Kohler[b]
Rachel Kidman[d]

[a]School of Economics, University College Dublin. Ireland
[b]Population Studies Center, University of Pennsylvania, Philadelphia, PA, USA
[c]GIRL Center, Population Council, Washington, D.C., USA
[d]Department of Family, Population and Preventive Medicine, Stony Brook, NY, USA

October 30, 2021

Abstract

We provide new evidence of the association between moderate negative economic shocks in utero or shortly after birth and adolescents' cognitive outcomes and educational attainment in Malawi. This is one of the first studies to analyze the effect of not one, but multiple moderate negative economic shocks in a sub-Saharan African (SSA) low-income country (LIC). This focus is important as multiple economic shocks in early life are more representative of the experiences of adolescents in LICs. Combining data on adolescents aged 10-16 from the Adverse Childhood Experiences (ACE) project with the Malawi Longitudinal Study on Families and Health (MLSFH) ($N = 1,559$), we use linear and probit regression models to show that girls whose households experienced two or more economic shocks in their year of birth have lower cognitive skills as measured by working memory, reading and mathematical skills. Girls also have lower educational attainment, conditional on age. These effects are gendered, as we do not observe similar effects among boys. Overall, our results point to lasting effects of early-life adversity on adolescents, and they highlight that, even in a LIC context where early-life adversity is common, policymakers need to intervene early to alleviate the potential long-term educational impacts of in utero or early life shocks among girls.

Keywords: *Economic shock, Early life adversity, Cognitive health, Schooling, Investments in education, Adolescents, Malawi*
JEL: *I15, I25, J13, C21*

*E-mail address: kampfenf@sas.upenn.edu, Tel.: +1215-898-6441. Please do not circulate without permission of the authors.

1 Introduction

Prenatal and early childhood conditions are critical for long-term human capital development (Almond and Currie 2011; Georgiadis *et al.* 2017). Prior studies have identified the human capital effects of these conditions, showing that both extreme and subtle shocks in utero and during early childhood can have lasting effects on later educational attainment, test scores, and child health (Almond *et al.* 2018; Brown 2018; Cook *et al.* 2019; Lee 2014). These negative shocks can affect children through both biological and social pathways that determine educational and cognitive outcomes. For instance, prenatal and postnatal malnutrition can damage brain development (Levitsky and Strupp 1995). In addition, it may lower parental investments in maternal or child nutrition and thus affect children's long-term cognitive outcomes (Almond *et al.* 2018; Wolf and McCoy 2019). Together, these pathways help form the environment within which the cognitive development of the fetus and young children takes place, and set a foundation for later educational achievement.

Most research from low-income countries (LICs) has examined extreme climate shocks, famine, and violence, showing detrimental effects on test scores and educational attainment (Ampaabeng and Tan 2013; Millett and Shah 2012; Rosales 2013). There is scarce evidence on how multiple, relatively frequently occurring negative shocks—which are more common to households in these contexts—affect these outcomes. Few studies in sub-Saharan Africa have shown how such shocks in utero and early childhood influence adolescents' educational outcomes (Beshir and Maystadt 2020), despite the fact that repeated exposure to moderate shocks is a much more common early-life experience in LICs than exposure to severe shocks.

Using a rare LIC dataset that links shocks and household conditions in the year of birth with Malawian adolescents' cognitive and educational outcomes, we contribute to literature on the relationship between shocks in the year of birth and adolescent educational outcomes by focusing on four research questions that, to date, have received scant attention in LICs: 1. Do multiple negative shocks experienced in the year of birth impact adolescent educational attainment; age for grade progression; and reading, math, and working memory test scores? 2. Do we observe differences in coefficient size for adolescents' educational outcomes when shocks are restricted to those that affect the entire community and are more plausibly exogenous than other household shocks? 3. Do the effects of these shocks on adolescent outcomes differ by gender? 4. Do nutritional investments (proxied by anthropometric measures) and education investments mediate the

relationship between economic shocks and adolescents' cognitive outcomes?

Overall, our analyses show that multiple shocks in the year of birth adversely affect girls' educational outcomes. Specifically, girls who experience two or more economic shocks are more likely to be unable to read sentences in Chichewa, unable to recall numbers (working memory), have lower overall math scores, educational attainment, and composite summary index scores compared to girls who experienced no shock in their year of birth. We find similar results for economic shocks that affect the entire community and are more plausibly exogenous than other household shocks. Importantly, our results reveal gendered associations of early-life adversity on adolescent cognition and educational outcomes, given that we do not find similarly strong associations among boys. Notably, we find evidence of greater household investment in boys' education in response to shocks.

2 Background: Limited Evidence on the Long-term Effects of Early-life Adversity on Adolescents in LICs

The fetal origins hypothesis states that the prenatal environment can affect the fetus, with both short and long-term consequences for health outcomes (Barker 1990). Prior studies have expanded on this, hypothesizing the effects of both prenatal and postnatal investments on long-term human capital development (Almond *et al.* 2018; Heckman 2007). This is predicated on the assumption that the development of human capital is linked across the life-course. A dearth of investment during this critical period, for instance as a result of negative shocks that adversely affect a household, can be harmful for outcomes measured a decade or more later in life. Thus, children with unfavorable prenatal or early childhood conditions may not only suffer worse outcomes in later periods, they may also have lower returns on the investments made in them due to early disadvantages (Almond and Currie 2011; Heckman 2007).

Shocks in the gestation period (prenatal) and early childhood (postnatal) can affect children through both biological and social pathways (Almond *et al.* 2018), but disentangling these pathways is often difficult. Biologically, prenatal malnutrition can alter brain neural receptor pathways through permanent effects on the hippocampus and cerebellum (Levitsky and Strupp 1995). In addition, negative prenatal shocks can result in adverse birth outcomes like low birth weight, which

has been linked to low educational attainment and poor test scores in childhood and adulthood (Almond and Currie 2011; Almond *et al.* 2018). Postnatal malnutrition can also inflict damage on brain development (Levitsky and Strupp 1995; Uauy and Dangour 2006). However, biological effects on cognitive health may not manifest until a later period, suggesting that the effects of prenatal and postnatal shocks may be irregular over age (Heckman 2007).

Shocks may also affect educational outcomes through social pathways, with long-term implications for educational outcomes and test scores. For instance, parental preferences may determine investments in child health and education in response to a shock, affecting the timing of school enrollment and the likelihood of remaining enrolled and on track in school. Recent additions to these hypotheses pay particular attention to the role of parental investments. Linking postnatal investments in response to shocks in utero, Almond *et al.* (2018) hypothesize that postnatal investments in children depend on parents' preferences, budget constraints, and constraints in production technology. In turn, these preferences, which can include gender preferences, may mitigate or worsen the long term cognitive impact of negative shocks experienced in the prenatal and early childhood periods (Becker and Tomes 1976; Behrman *et al.* 1982).

Despite the reality that experiences of early-life adversity are common in LICs, the literature documenting the relationship between negative prenatal and postnatal shocks and long-term educational outcomes has several limitations. First, studies on high income countries (HICs) and middle income countries (MICs) (Aizer *et al.* 2016; Almond *et al.* 2015; Greve *et al.* 2017; von Hinke Kessler Scholder *et al.* 2014) often investigate shocks that are more relevant to HIC or MIC contexts rather than LIC contexts.

Second, LIC studies on early-life adversity have often investigated extreme negative shocks, which are important, but by their very definition, are relatively rare.[1] Examples include: El-Nino floods in Ecuador (Rosales 2013), famine in Ghana (Ampaabeng and Tan 2013), genocide and war in Rwanda and Zimbabwe (Alderman *et al.* 2006; Bundervoet and Fransen 2018), drought in India, Burkina Faso, and Zimbabwe (Akresh *et al.* 2012; Alderman *et al.* 2006; Hoddinott and Kinsey 2001; Millett and Shah 2012). Across all of these studies, the key finding is that children exposed to shocks in utero and early childhood have lower test scores and educational attainment. These effects can also persist across gener-

[1]The economic shocks we use in our study are much more frequent: individuals who participated in the MLSFH survey in 2008 reported to have experienced on average 2.1 economic shocks between 2003 and 2008. 5, 22, 33 and 40% of the respondents reported 0,1,2 and 3 negative shocks, respectively.

ations. For instance, Tafere (2016) finds intergenerational effects of famine and shows that the children of Ethiopian mothers who were exposed to famine between ages 0-3 are more likely to have lower test scores, educational attainment, and poorer health. A rare example of a study that has focused on moderate shocks is from Ethiopia (Beshir and Maystadt 2020) and shows that exposure to seasonal food insecurity experienced in utero results in lower math scores at age 8 and 12.

Third, a further limitation of the existing literature is its emphasis on a single positive or negative shock in utero. Studies that examine more than one shock typically analyze whether a negative shock can be compensated by a positive shock, usually a conditional cash transfer (Adhvaryu *et al.* 2018; Aguilar and Vicarelli 2011; Duque *et al.* 2018). To our knowledge, no previous studies examine the impact of multiple, moderate negative shocks experienced in utero and early childhood on adolescents' educational and cognitive outcomes. This is important to investigate in sub-Saharan African low-income countries, such as Malawi, where households are likely to experience multiple shocks related not only to income, but also excess adult mortality due to epidemics like HIV. Furthermore, previous studies that have distinguished between the effects of shocks to the household and shocks to the entire community have focused on school enrollment (Hyder *et al.* 2015), and not the long-term educational and cognitive outcomes of children who experience these shocks in the year of birth. Community level shocks, which are more likely to be exogenous, might make it difficult for households to buffer a shock through the support of their neighbors or social network, thus causing greater severity in detrimental impacts on children's outcomes.

Fourth, while previous studies have tested for gendered effects, there has been limited attention on the gendered mechanisms through which these effects might manifest. For instance, parents' gender preferences may influence the investment choices they make for their sons and daughters, and these preferences may be reinforced when making investment decisions after experiencing negative shocks. Related evidence from sub-Saharan Africa is particularly scarce. Most evidence of general gender bias in parental educational investment comes from South Asia (Azam and Kingdon 2013; Kaul 2018). In sub-Saharan Africa, there is mixed evidence of gender bias in intra-household allocation of resources towards health and education (Haddad and Reardon 1993; Hadley *et al.* 2008; Sauerborn *et al.* 1996). A recent study from Ethiopia finds that boys exposed to seasonal food insecurity in utero are more likely to have low math scores at age 12, compared to girls. However, these differences cannot be explained by parental education

and health investments (Beshir and Maystadt 2020).In addition, these studies do not consider how parents' informal social networks, which may be an important resource when households face budget constraints, reinforce or mitigate gender bias when providing support.

3 Data and Measures

Our analyses are based on the Adverse Childhood Experiences (ACE) project (Kidman *et al.* 2020) of the Malawi Longitudinal Study of Families and Health (MLSFH) (Kohler *et al.* 2015). This MLSFH ACE project focuses on ACEs and transitions to adulthood, collecting data in rural areas in three districts in Malawi (Mchinji, Rumphi and Balaka) in 2017 and 2018 (and forthcoming in 2021). Data on MLSFH ACE adolescents were linked to prior MLSFH data for the adolescents' parents, dating back to 1998. This study draws on the currently available first wave of MLSFH ACE adolescent surveys collected in 2017–18, when respondents were 10–16 years old.[2] Importantly, the MLSFH ACE data provide comprehensive measures on a range of cognitive outcomes among adolescents, which we use as the main dependent variables in our study. The data also has measures on a number of other adolescent experiences including health, violence, and relationships with caregivers.

At least one parent (or household member)[3] of the 2017–18 ACE adolescent respondent was previously surveyed in 2008 or 2010, when they were asked to report economic shocks that they or their household experienced over previous years.[4] We match adolescent's year of birth as reported in the ACE study to their household's information collected in 2008 and 2010, which includes economic shocks reported between 2003 and 2008.[5]

We only have information about economic shocks for the period between 2003 and 2010. Thus, out of the 2,089 adolescents that were interviewed as part of the ACE study, 273 adolescents were excluded from the analysis because they

[2]These adolescents were selected from the 2008 and 2010 Household Rosters of the MLSFH.

[3]Parents, grandparents and aunts/uncles represent 77%, 16% 3.4% of these individuals, respectively.

[4]The 2008 questionnaire asked about shocks that occurred in the past five years, from 2003 to 2008, and the 2010 questionnaire asked about shocks that happened over the past two years, covering the period from 2008 to 2010.

[5]Note that all adolescents in our sample were born between 2003 and 2008. We use shocks reported in the 2010 survey for the year 2008 so that we include economic shocks that occurred after the 2008 study.

were born in 2001 or 2002. Moreover, we excluded a further 257 adolescents who were born between 2003 and 2007, and whose households were surveyed only in 2010 and thus had no shock data for the year of their birth. Our final sample includes 1,559 adolescents, for whom we have information about whether their household experienced economic shocks in the year that they were born.

Cognitive measures: The MLSFH ACE data provide several measures of cognitive abilities that encompass three different domains: literacy, mathematical skills, and working memory. We derive two outcome variables for each of these domains: one that characterizes the total score (continuous variable) obtained in the various tests, and another that takes the value 1 if adolescents obtain a score of 0 in a specific domain, and 0 otherwise. These dichotomous variables allow to explore the effects of economic shocks at birth at the lower end of the various cognitive scores. We provide details for tests in each domain in Appendix A.

For other measures of education, we also included schooling attainment and on-time progression in school. For schooling attainment, we measure highest grade attained. For on-time progression in school, we used a dichotomous variable that takes the value 1 if adolescents are at least 3 years behind the expected grade for their age, and 0 otherwise.[6]

Our set of outcome variables is therefore constituted of four continuous and four dichotomous variables. To deal with issues of overrejection of the null hypothesis due to multiple inference, we follow Anderson (2008) and create summary indices for each of these two sets of outcomes. This approach also has the advantages of providing an estimate of the overall effect of the economic shocks and of potentially being "*more powerful than individual-level tests –multiple outcomes that approach marginal significance may aggregate into a single index that attains statistical significance*"(Anderson 2008, p. 1484).[7] In the results section below, we first present the associations between economic shocks experienced at birth and the two summary indices, and then detail these associations for each of our four types of outcome variables.

Economic shocks: In the 2008 and 2010 MLSFH surveys, respondents were asked to report economic shocks experienced by their households that ***negatively***

[6]"Age for grade" is a measure of delayed entry and/or grade repetition based on the adolescents' age and the grade in which they should be as per the expected school schedule.

[7]The summary index is a weighted mean of multiple standardized outcomes in which the weights are calculated through GLS weighting procedure to extract the maximum information from the various items. Missing items are ignored when creating the index. We do however control for the number of outcomes we observe per adolescent using dichotomous variables. Note also that we use those who did not experience any shock at birth as reference when normalizing the outcome variables. Our results are robust to using the entire sample as reference.

Table 1: Descriptive statistics of the economic shocks at birth reported

	Count	Prevalence
All shocks	383	0.248
– ***Death or serious illness*** *of an adult member or someone who provides support for yourself or your family*	93	0.241
– ***Poor crop yields****, loss of crops due to disease or pests, or loss of livestock due to theft or disease, or loss of coupon*	159	0.412
– ***Loss of source of income*** *-such as loss of employment, business failure, someone who had been assisting the household stopped their support*	63	0.163
– ***Big change in price of grain*** *(either increase or decrease)* [a]	116	0.301
– ***Fertilizer subsidy***	2	0.005
– ***Breakup of household****, such as a divorce*	24	0.062
– ***Damage*** *to house due to fire, flood, or other unexpected event*	19	0.049
– ***Other***	2	0.005

Note: These shocks are reported by adolescents' households as part of the MLSFH collected in 2008 and 2010.
[a] "Big change in price of grain" can potentially represent positive or negative shocks depending on whether the household is a net consumer or producer of crops. However, the survey asks respondents whether the economic shocks they report resulted in "income loss", "asset loss", "loss of both" or "neither". Our analysis is restricted to shocks that resulted in income loss, asset loss or both, i.e., negative economic shocks.

affected their income and/or assets. These shocks are reported in Table 1. In both survey years, respondents were asked to report the shocks they experienced, along with the year when the three most "significant" shocks occurred. In addition to the years of occurrence, they were asked whether the shock they reported affected their "own household only", "other households as well", "most households in the community" or "all households in the community". We match the years of occurrence of these economic shocks to the years of birth of the ACE adolescents in our sample.

Descriptive statistics of study population:

Table 2 presents the descriptive statistics of the 1,559 adolescents that constitute our study sample. Panel A shows basic descriptive statistics of the outcome variables we consider in our analysis. The average reading score in our sample was about 4.4, on a scale from 0 to 8. About 32% of the adolescents couldn't read, even partially, the two sentences in Chichewa that were presented to them. On a scale ranging from 0 to 7, the average working memory score of the adolescents in our sample was about 2.5 and about 7.5% of them had a score of 0. The average math score was about 6.9, out of 12 points, and a bit more than 6% of the sample had a score of 0.

Panel B of Table 2 shows the distribution of the economic shocks experienced by the adolescents the year of the birth. About three quarters of the adolescents in our sample experienced no economic shocks at birth, whereas about 19% and

Table 2: Descriptive statistics of the study sample ($N = 1,559$)

	Mean	Std. dev.	25th	75th	Obs.
A. Outcome variables					
Summary index - continuous outcomes	-0.071	1.001	-0.881	0.649	1557
Summary index - discrete outcomes	0.023	1.047	-0.886	0.453	1557
Reading score (sentences)	4.424	3.371	0	8	1544
Can't read Chichewa sentences	0.315	0.465	0	1	1546
Working memory score	2.477	1.623	1	3	1278
Working memory score of 0	0.075	0.264	0	0	1278
Math score	6.853	3.505	5	10	1513
No correct math answers	0.062	0.241	0	0	1513
School attainment (years)	4.658	1.890	3	6	1557
Age for grade $\geqslant 3$	0.617	0.486	0	1	1450
B. Economic shock					
Shock at birth	0.248	0.432	0	0	1559
0 shock at birth	0.752	0.432	1	1	1559
1 shock at birth	0.194	0.395	0	0	1559
2 shocks or more at birth	0.054	0.226	0	0	1559
C. Control variables					
Girl	0.491	0.500	0	1	1559
Age	12.831	1.464	12	14	1559
Central region	0.305	0.460	0	1	1559
South region	0.371	0.483	0	1	1559
North region	0.325	0.468	0	1	1559
Age of the caregiver at birth	31.984	13.334	22	38	1558
Caregiver married at birth	0.872	0.335	1	1	1559
No formal education - caregiver	0.262	0.440	0	1	1559
Primary level education - caregiver	0.654	0.476	0	1	1559
Secondary level education or higher - caregiver	0.084	0.278	0	0	1559
Wealth score	-0.081	1.868	-1.318	0.800	1557

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. "Std. dev." stands for standard deviation. 25th and 75th represent the 25th and 75th percentiles of the distributions, respectively.

5.4% of them experienced one and two shocks or more the year of their birth, respectively. Importantly , Table B1 in Appendix shows that boys and girls do not differ in terms of the number of shocks reported during the year of birth. Moreover, when regressing the number of shocks experienced during the year of birth on a set of household and caregiver characteristics, none of the factors appear statistically significant at conventional levels (see Appendix Table B2). This holds true even when we interact all regressors with the sex of the adolescent.

The tests of joint-significance reported at the bottom of the table confirm these results.

Table 1 reports the types of shocks that the adolescents experienced during their year of birth. The most prevalent negative shocks, which represent about 41% of the economic shocks encountered, correspond to shocks that have resulted in poor crop yields "due to disease or pests, or loss of livestock due to theft or disease, or loss of coupon".[8] Second after poor crop yields comes "big change in price of grain (either increase or decrease)", that represents about 30% of the shocks reported. These two shocks, which account for about 71% of the shocks, are plausibly more exogenous than others as they are more likely to be independent to the respondent's or household's characteristics. In fact, we show in Appendix Tables B3 and B4 that none of the adolescent or caregiver characteristics we consider in our analysis predict these two shocks at conventional significance levels. This is confirmed by the tests of joint-significance we report at the bottom of these two tables. They can thus be used to reinforce the causal interpretation of our effects, as we will discussed below. In order, "death or serious illness", "loss of income", "breakup of household", "damage to house" and loss of "fertilizer subsidy" represent 24.1%, 16.3%, 6.2%, 4.9% and 0.5% of the experienced economic shocks, respectively. Moreover, there exists no statistical difference (at 95% confidence) in the types of shocks experienced by boys and girls in our sample (Appendix Table B1).

Finally, Panel C of Table 2 shows basic descriptive statistics of the adolescents in our sample. Slightly less than half (49.1%) of the adolescents were girls and the average age was about 12.8 years old. Adolescents were evenly distributed across our three study regions. Table B5 in the Appendix shows that there exists no statistical difference in the characteristics of the boys and girls in our sample, except in terms of age, where boys appear to be on average marginally younger than girls (12,7 vs 12.9 years old, respectively). The normalized difference in age between these two groups however is equal to 0.088, which is well below the 0.25 threshold that is often taken as indicative of imbalance (Imbens and Rubin 2015).

[8] Loss of coupon pertains to loss of fertilizer coupon, which is an important factor of production for many individuals in rural Malawi.

4 Analytic Approach

We match ACE adolescents surveyed in 2017 and 2018 to shocks reported by their parents (or caregivers) in 2008 and 2010, to create a sample of ACE adolescents who experienced economic shocks during the year of birth. We then regress our cognitive and education measures on our main independent variable: economic shocks. We have two dichotomous measures of economic shocks. The first is coded 1 if the adolescent experienced one economic shock at birth, and 0 otherwise. The second is coded 1 if they experienced two or more economic shocks at birth, and zero otherwise.[9]

We conduct linear regressions for all continuous dependent variables, including the summary indices, reading, math, and working memory scores, and schooling attainment (measured as highest grade attained). We use probit regressions for all dichotomous dependent variables.

Our econometric specification includes the age of the adolescent (dummy variables for each age in years), characteristics of the caregivers including age, marital status, educational level (no school, primary level of education, secondary level of education and higher of education), and a continuous wealth index based on a set of 20 dwelling characteristics and ownership of household durable assets, constructed using first principal component analysis (Chin 2010; Filmer and Pritchett 1998; Hyder *et al.* 2015; Vyas and Kumaranayake 2006). Wealth measures based on household asset ownership are usually used to control for *stable* household wealth characteristics (Behrman and Knowles 1999; Thomas and Strauss 1992). We use the most up-to-date information available at the year of birth to define these variables. In other words, information collected in wave 5 (2008), wave 4 (2006) and wave 3 (2004) was used to define these variables for children born in 2007-2008, 2005-2006 and 2003-2004 respectively. For missing cases, we use the most recent information available.[10] In addition to these variables, all regressions include region dichotomous variables to control for any systematic differences in the three regions where fieldwork took place (Rumphi

[9]Note that adolescents can experience up to three economic shocks at birth, but given the very low occurrence of experiencing three shocks –only 10 adolescents experienced three economic shocks at birth (0.64% of our sample)– we combine those who experienced three shocks with those who experienced two economic shocks at birth.

[10]Because the wealth index can potentially be directly related to the (previous) experience of economic shocks, as a robustness check we use values of this variables prior to adolescent birth instead of the "current one". Despite a notable decrease in the sample size, we show that results are qualitatively similar to those estimated in the specification with the full sample. More details are provided in the "Robustness checks" section.

in the North, Balaka in the South and Mchinji in the central region of Malawi). Finally, because some adolescents were interviewed in 2017 and others in 2018, all our specifications include a binary variable coded 1 if the survey was conducted in 2017 vs. 2018. This year dummy captures any systematic differences and changes that might have occurred in 2018. For all our analyses, standard errors are clustered at the household level.

5 Results

Our results show that experiencing two or more ("two$^+$") negative economic shocks at birth is negatively associated with cognitive and educational outcomes for girls, while there is no evidence for corresponding detrimental associations for boys. Specifically, Table 3 presents the associations between economic shocks at birth and our set of outcome variables. The first three columns of the top panel show that, on average, adolescents who experience two$^+$ economic shocks at birth have a lower weighted average of the cognitive outcomes considered (about 0.164 points) (column 1). This negative association is observed among girls (column 3, β=-0.337, p-value= 0.031) but not among boys (column 2). The difference in the coefficients between boys and girls is statistically significant at 90% confidence in a one-sided test (z-score=1.586, p-value=0.056). When looking at the summary index derived from the set of discrete outcomes (columns 3-6), adolescents who experience two$^+$ economic shocks at birth had a higher summary index (β=0.302, p-value=0.034), reflecting the negative associations that these shocks have on cognitive abilities.[11] Again, these associations are mainly observed among girls (β=0.551, p-value=0.011). The difference in these associations between boys and girls is statistically significant at 95% confidence in a one-sided test (z-score=-1.657, p-value=0.049). In contrast to experiencing two$^+$ economic shocks at birth, experiencing only one economic shock at birth does not have any impact on adolescents' cognitive abilities as measured by our two summary indices, irrespective of the sex of the adolescent.

Panels A, B, C and D show the corresponding estimates by breaking down the summary indices into their four components; reading skills, working memory, mathematical skills and schooling, respectively. Across the four panels, we observe that adolescents who experience two$^+$ economic shocks at birth consistently have lower cognitive skills relative to those who do not experience any

[11] Remember that the higher the summary index based on discrete outcomes is, the lower the cognitive abilities.

Table 3: Associations between economic shocks at birth and cognitive and educational attainment outcomes

	All (1)	Boys (2)	Girls (3)	All (4)	Boys (5)	Girls (6)
			Summary index			
	Continuous outcomes			Discrete outcomes		
1 shock at birth	0.025	0.061	-0.033	0.030	-0.020	0.088
	(0.056)	(0.077)	(0.085)	(0.066)	(0.087)	(0.103)
2 shocks or more at birth	-0.164	-0.014	-0.337*	0.302*	0.086	0.551*
	(0.103)	(0.132)	(0.156)	(0.142)	(0.179)	(0.216)
Observations	1554	792	762	1554	792	762
			A. Reading skills			
	Reading score			Can't read Chichewa		
1 shock at birth	0.123	0.217	-0.047	-0.014	-0.037	0.035
	(0.204)	(0.288)	(0.300)	(0.092)	(0.124)	(0.149)
2 shocks or more at birth	-0.439	0.004	-0.925+	0.280+	0.164	0.435+
	(0.366)	(0.494)	(0.530)	(0.165)	(0.233)	(0.234)
Observations	1541	786	755	1543	787	756
			B Working memory			
	Working memory score			Score of 0		
1 shock at birth	0.025	0.113	-0.063	0.010	-0.299	0.354
	(0.114)	(0.149)	(0.180)	(0.145)	(0.212)	(0.223)
2 shocks or more at birth	-0.295	-0.112	-0.488	0.477*	0.385	0.670*
	(0.204)	(0.246)	(0.309)	(0.218)	(0.306)	(0.336)
Observations	1276	644	632	1276	644	545
			C. Mathematical skills			
	Math score			Score of 0		
1 shock at birth	-0.042	-0.036	-0.108	0.143	0.054	0.320
	(0.215)	(0.301)	(0.319)	(0.137)	(0.171)	(0.228)
2 shocks or more at birth	-0.563	-0.433	-0.783	0.207	-0.158	0.748*
	(0.377)	(0.527)	(0.536)	(0.214)	(0.308)	(0.311)
Observations	1510	770	740	1510	770	678
			D. Schooling			
	Educational attainment			Age for grade $\geqslant 3$		
1 shock at birth	0.017	0.109	-0.120	-0.024	-0.027	-0.008
	(0.087)	(0.113)	(0.134)	(0.096)	(0.129)	(0.147)
2 shocks or more at birth	-0.114	0.200	-0.413+	0.100	0.007	0.260
	(0.161)	(0.205)	(0.246)	(0.177)	(0.255)	(0.258)
Observations	1554	792	762	1447	738	709

Note: Standard errors in parentheses clustered at the household level (+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$). The sample is derived from the ACE sample collected in 2017 and 2018. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent.

shock. While not always precisely estimated when pooling boys and girls together, these associations are consistently negative, irrespective of whether we

consider the continuous or discrete measures of cognitive abilities. Similar to summary indices, these associations are observed only among girls, where five out of eight coefficients are statistically significant (at least at 90% confidence).

Overall, experiencing a single economic shock during the year of birth does not seem to affect the cognitive outcomes of adolescents in our sample. However, experiencing two$^+$ economic shocks at birth is associated with adolescents' cognitive outcomes, but these associations are statistically significant only among girls.

Economic shocks can be particularly detrimental when they affect entire communities, since this limits households' ability to buffer the impact of shocks by seeking social support from their neighbors. Among the economic shocks reported by respondents in 2008 and 2010, two are "plausibly exogenous" in that they are more likely to not be related to individual and household characteristics or behaviors. "Poor crop yields" and "big change in price of grain" are likely to be beyond an individual household's control and hence largely exogenous (see Appendix Tables B3 and B4). We therefore restrict our economic shock variable to these two "plausibly exogenous" shocks to strengthen the causal interpretation of our estimates. As an additional check for exogeneity, respondents are asked whether the shocks they report affected other households in their community. We are therefore able to restrict these two shocks to those that affected other households in the community in order to reinforce the causal interpretation of our estimates (because these restrictions reduce the number of shocks reported by the respondents, we are not able to differentiate between adolescents who experienced one or two$^+$ exogenous shocks at birth and hence present results in which we combine adolescents who experience one or more exogenous shocks in the same category). Table 4 presents the results for these plausibly exogenous shocks on our dependent variables.

Overall, the associations appear to be more precisely estimated and similar in magnitude to those obtained in our benchmark analysis for adolescents who experienced two$^+$ shocks at birth. Specifically, girls who experience an exogenous shock at birth have a lower weighted average derived from our continuous cognitive measures by about 0.272 points (Column 3, p-value=0.010), whereas the association for boys is not statistically significant (Column 2, p-value=0.887). The difference in these two associations is statistically significant at 5% (z-score=2.099, p-value=0.036). Results using the summary index derived from the set of discrete outcomes are in line with our benchmark results: girls who experience an exogenous shock at birth have a higher summary index (β=0.415, p-value=0.004), whereas this is not the case for boys (β=0.034,

Table 4: Associations between economic shocks at birth and cognitive and educational attainment outcomes using plausible exogenous shocks

	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)
			Summary index			
	Continuous outcomes			Discrete outcomes		
Exogenous shock at birth	-0.111^{+}	0.012	-0.272*	0.193*	0.034	0.415**
	(0.066)	(0.085)	(0.105)	(0.089)	(0.112)	(0.142)
Observations	1554	792	762	1554	792	762
			A. Reading skills			
	Reading score			Can't read Chichewa		
Exogenous shock at birth	-0.345	-0.032	-0.856*	0.240*	0.125	0.436**
	(0.244)	(0.328)	(0.367)	(0.106)	(0.139)	(0.168)
Observations	1541	786	755	1543	787	756
			B. Working memory			
	Working memory score			Score of 0		
Exogenous shock at birth	-0.107	0.143	-0.358	0.171	-0.038	0.456^{+}
	(0.135)	(0.161)	(0.220)	(0.149)	(0.204)	(0.247)
Observations	1276	644	632	1276	644	632
			C. Mathematical skills			
	Math score			Score of 0		
Exogenous shock at birth	-0.790**	-0.493	-1.218**	0.239	-0.014	0.628**
	(0.249)	(0.350)	(0.367)	(0.152)	(0.206)	(0.239)
Observations	1510	770	740	1510	770	740
			D. Schooling			
	Educational attainment			Age for grade $\geqslant 3$		
Exogenous shock at birth	-0.103	0.055	-0.325*	0.095	0.021	0.244
	(0.101)	(0.132)	(0.159)	(0.113)	(0.150)	(0.178)
Observations	1554	792	762	1447	738	709

Note: Standard errors in parentheses clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$). All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. "Exogenous shock at birth" is a dichotomous variable that takes the value 1 if the adolescent experienced a "poor crop yields" or a "big change in price of grain" economic shock at birth that affected other households in the community.

p-value=0.759). The difference in these associations between boys and girls is statistically significant (z-score=-2.102, p-value=0.036). Similar patterns can be seen when breaking down the summary indices into their four components, where differences between girls and boys appear particularly marked in reading and mathematical skills.

6 Robustness checks

We detail in Appendix C the various tests we implement to assess the robustness of our findings. Perhaps the two most significant departures from our benchmark estimations we put in place are the ones that explore the issue related to economic shocks that could potentially be serially correlated and the issue pertaining to the fact that we control for wealth score, a variable that is possibly endogenous. We briefly discuss these two issues below and refer to Appendix C for further details.

One of the concerns in our analysis could be that the associations estimated thus far could be due to serially correlated shocks that happened prior or after the year of birth, and may not be the result of shocks happening during the year of birth. We show in Appendix C that this does not appear to be the case, as shock occurring the year prior to the year of birth or two years after the year of birth do not lead to similar associations. Moreover, the associations between economic shocks at birth and lower cognitive skills are robust to controlling for the average number of shocks per year experienced by the household of the adolescent over the period 2003-2008.[12] This underscores the importance of the long-term cognitive impact of shocks during the year of birth and supports the fact that the associations between economic shocks at birth and cognitive function estimated thus far do indeed capture distress and shocks in the year of birth and not just heterogeneity in some latent and uncontrolled socioeconomic characteristics of the households.

Furthermore, our results appear to be robust to various measures of wealth that we use to control for the household's socioeconomic background. Indeed, one concern is that although the wealth score is constructed from durable household assets, it could also be an outcome variable, given that economic shocks could affect households' wealth and become a pathway to impacting children's cognitive health and outcomes. However, as detailed in Appendix C, we show that our results are robust to using various other socioeconomic status measures, including land ownership and wealth score measured in 2004, which predates most of the births of adolescents in our sample.

[12] We exclude the shocks reported during the year of birth when computing the average number of shocks experienced by the households between 2003 and 2008.

7 Possible Mechanism

Our analysis thus far has established that economic shocks in the year of birth are negatively associated with girls' cognitive and educational outcomes but such associations are not observed among boys. Because it is hard to precisely establish when cognitive abilities are developed, a proper mediation analysis that investigates the pathways through which economic shocks experienced at birth affect cognitive outcomes among adolescents is difficult to implement with our data. Indeed, many (if not most) candidate mediators could be not only the determinants of cognitive abilities, but also the results of them. In this section, we nonetheless hint towards possible mechanisms that might explain our results.

One candidate is early-life physical development, as it is an important determinant of later-life cognitive outcomes. However, we discuss and show in Appendix D that adolescents who are subject to economic shocks at birth do not appear to differ in terms of height, either measured in 2017/2018 or in 2008, from those who do not experience any such shocks.

Another possible mechanism could be that households that experience economic shocks adopt more extreme gender attitudes, favoring investment in boys' education over girls. In the face of adversity and tightening budget constraints, households may have to make difficult choices and may favor boys, or buffer boys from the consequences of shocks, over girls. The associations between economic shocks at birth and cognitive outcomes could therefore be moderated by gender attitudes and difference in investment in education. We find suggestive evidence that supports this mechanism.

Indeed, as discussed in Appendix D, we find that girls who experienced a negative economic shock during the year of birth received lower educational investment from their households compared to girls who did not experience any shocks at birth. We do not observe corresponding associations for boys. In turn, we show that investment in education at the household level predicts the cognitive and educational outcomes of the adolescents in our sample. We find that higher investment in education at the household level appears to be particularly beneficial for girls and less so for boys. This is consistent with the above results: girls outcomes are more sensitive to investment in education, and economic shocks decrease the amount of investment that is spent on their own education.

Overall, we find suggestive evidence that investment in education could be one of the reasons why we observe negative associations between economic shocks at birth and cognitive outcomes and educational attainment for girls but not for

boys. We find evidence that these gender differences possibly and partially stem from changes in investment in education, where boys appear to be relatively protected from cuts in investment whereas girls suffer from investment cuts following negative economic shocks that occur during the year of their birth.

8 Discussion

Our study is among the first to examine the association of moderate, frequently-occurring shocks in early life on adolescent cognition and schooling attainment in a LIC. We find that two or more moderate economic shocks in the year of birth adversely affect adolescent girls' educational and cognitive outcomes, though we do not observe the same pattern for boys, unlike previous studies (Beshir and Maystadt 2020). We also find that effects on girls' educational and cognitive outcomes are larger for shocks that affect the entire community, potentially making it difficult for households to buffer their impact by seeking help from neighbors. We also find suggestive evidence for educational investment as a possible pathway that might explain gender differences in the long-term impact of shocks. While we cannot formally test educational investment as a mediating mechanism, our results indicate that households compensate boys' but not girls' education in response to shocks in the year of birth. This is consistent with our expectation that lower educational investment in early childhood may be a possible pathway to girls' disadvantage in educational and cognitive outcomes during adolescence.

As a possible biological pathway (based on limited sample size), we find no evidence that height mediate the relationship between shocks in the year of birth and adolescent educational outcomes. However, this measure may be too crude for capturing the cognitive impact of experiencing economic shocks in utero. Notably, we do not find that shocks experienced two years after birth affect either adolescent girls' or boys' educational and cognitive outcomes. Given that more recent shocks to household resources are expected to affect educational investments in children (Hyder *et al.* 2015), this finding hints at the possibility of biological mechanisms driving long-term gender differences in educational outcomes.

Overall, similar to evidence on pathways from Ethiopia (Beshir and Maystadt 2020), our study encourages future investigation of both biological and social pathways that might help explain why in utero or early life shocks result in gender differences in adolescent's educational and cognitive outcomes in low income countries. Our findings lend support to policies aimed at alleviating educational

inequalities in Malawi (Psaki *et al.* 2018), and sub-Saharan Africa more broadly. Although the gender gap in primary school completion rates in Malawi has narrowed in recent years (Brossard *et al.* 2010; Psaki *et al.* 2018), overall primary school completion remain low. Despite seeming gender equality in low educational attainment among all adolescents, the pathways to school dropout may still be gendered. For instance, girls may experience drop out (and thus have low educational attainment) due to pregnancy, whereas boys may dropout of school to participate in paid work (Psaki *et al.* 2018). Differential pathways to school dropout require different interventions. Our results also highlight that economic shocks in the year of birth may be an additional gendered pathway that puts girls at an educational disadvantage. Therefore, policymakers should intervene early to alleviate the long-term educational impact of these shocks for girls. Refining the nature and design of such interventions may hinge on further evidence on what role biological and social pathways play in generating gender differences in educational outcomes. Evidence of detrimental impact on cognitive development in utero may imply greater investment in the health and well being of pregnant mothers, whereas reduced educational investment may suggest a need for early economic incentives for girls' education. However, regardless of which mechanism is more dominant, existing social protection programs, such as cash transfer programs, could be used to assist households that experience multiple, negative shocks, particularly those with pregnant women.

The importance of our findings notwithstanding, our study has some limitations. First, for better causal interpretation, testing models with family fixed effects using sibling data would be useful, but we are unable to do so given data limitations. Second, household shocks in our study are self-reported and these reports may be subject to recall bias (this concern, however, is somewhat alleviated as shocks were reported by parents in 2008 and 2010 at the time when the adolescents were born, rather than being recalled retrospectively from more than a decade ago). Third, variation in tests of cognitive skills based on age and grade level may yield a more nuanced understanding of the cognitive impact of shocks on the ability to learn progressively difficult concepts. Fourth, selective survival could potentially explain the difference in the associations we find across sex in the case where a higher fraction of male fetuses that were exposed to economic shocks die compared to female fetuses. The dataset at hand unfortunately does not allow to directly test this hypothesis. Following Currie *et al.* (2018), we can however perform an indirect test by using the sex of the adolescent at birth as a signal of changes to miscarriage rates, since male fetuses have a higher risk of miscarriage (Halla and Zweimüller 2014; Sanders and Stoecker 2015). As re-

ported in the Appendix Table D8, experiencing economic shocks at birth does not predict the sex of the adolescents we have in our sample. This suggests that differential selection into birth because of miscarriages is unlikely to bias my results.

Overall, our study is among the first to show evidence of girls' long-term educational disadvantage as a result of experiencing multiple, moderate early life economic shocks. These shocks represent an additional pathway through which girls' educational progress may be curtailed in Malawi. More broadly, our findings emphasize that LIC program developers and policymakers consider vulnerability from early life shocks as an important target for intervention, including early-life shocks that are "only" fairly commonly experienced in utero or during early life.

Acknowledgement and statements

Funding statement: Research reported in this publication was supported by the Eunice Kennedy Shriver National Institute of Child Health & Human Development of the National Institutes of Health under Award Numbers R01HD090988, R01HD087391 and R01 RHD053781. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. We also gratefully acknowledge the generous support from the Swiss Programme for Research on Global Issues for Development (SNF r4d Grant 400640_160374) and the Swiss National Science foundation (grant number: P2LAP1_187736).

Conflicts of interest: The authors have no relevant financial or non-financial interests to disclose.

Data availability statement: The public-use data of the Malawi Longitudinal Study for Families and Health (MLSFH) are available from https://malawi.pop.upenn.edu/malawi-data-mlsfh. Additional data of the MLSFH Adverse Childhood Experiences (ACE) project that are used for our analyses can be requested from the authors, and will ultimately be made publicly available as part of the MLSFH.

Acknowledgment: We would like to thank Jere R. Behrman, Kate Prickett, participants of the 2021 Annual Congress of the PAA, and the MLSFH team for their comments and feedback that greatly improve the quality of our manuscript.

References

Adhvaryu, A., Nyshadham, A., Molina, T., and Tamayo, J. (2018). Helping children catch up: Early life shocks and the PROGRESA experiment. Technical report, National Bureau of Economic Research.

Aguilar, A. and Vicarelli, M. (2011). El Nino and Mexican children: medium-term effects of early-life weather shocks on cognitive and health outcomes. *Cambridge, United States: Harvard University, Department of Economics. Manuscript*.

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

Akresh, R., Bagby, E., De Walque, D., and Kazianga, H. (2012). Child ability and household human capital investment decisions in Burkina Faso. *Economic Development and Cultural Change*, **61**(1), 157–186.

Alderman, H., Hoddinott, J., and Kinsey, B. (2006). Long term consequences of early childhood malnutrition. *Oxford Economic Papers*, **58**(3), 450–474.

Almond, D. and Currie, J. (2011). Killing me softly: The fetal origins hypothesis. *Journal of Economic Perspectives*, **25**(3), 153–72.

Almond, D., Mazumder, B., and Van Ewijk, R. (2015). In utero Ramadan exposure and children's academic performance. *The Economic Journal*, **125**(589), 1501–1533.

Almond, D., Currie, J., and Duque, V. (2018). Childhood circumstances and adult outcomes: Act II. *Journal of Economic Literature*, **56**(4), 1360–1446.

Ampaabeng, S. K. and Tan, C. M. (2013). The long-term cognitive consequences of early childhood malnutrition: the case of famine in Ghana. *Journal of Health Economics*, **32**(6), 1013–1027.

Anderson, M. L. (2008). Multiple inference and gender differences in the effects of early intervention: A reevaluation of the abecedarian, perry preschool, and early training projects. *Journal of the American statistical Association*, **103**(484), 1481–1495.

Azam, M. and Kingdon, G. G. (2013). Are girls the fairer sex in India? Revisiting intra-household allocation of education expenditure. *World Development*, **42**, 143–164.

Barker, D. J. (1990). The fetal and infant origins of adult disease. *BMJ: British Medical Journal*, **301**(6761), 1111.

Beach, B., Ferrie, J. P., and Saavedra, M. H. (2018). Fetal shock or selection? The 1918 Influenza pandemic and human capital development. Technical report, National Bureau of Economic Research.

Becker, G. S. and Tomes, N. (1976). Child endowments and the quantity and quality of children. *Journal of Political Economy*, **84**(4, Part 2), S143–S162.

Behrman, J. R. and Knowles, J. C. (1999). Household income and child schooling in Vietnam. *The World Bank Economic Review*, **13**(2), 211–256.

Behrman, J. R., Pollak, R. A., and Taubman, P. (1982). Parental preferences and provision for progeny. *Journal of Political Economy*, **90**(1), 52–73.

Beshir, H. A. and Maystadt, J.-F. (2020). In utero seasonal food insecurity and cognitive development: Evidence on gender imbalances from Ethiopia. *Journal of African Economies*, **29**(4), 412–431.

Brossard, M., Coury, D., and Mambo, M. (2010). *The education system in Malawi*. The World Bank.

Brown, R. (2018). The Mexican drug war and early-life health: The impact of violent crime on birth outcomes. *Demography*, **55**(1), 319–340.

Bundervoet, T. and Fransen, S. (2018). The educational impact of shocks in utero: Evidence from Rwanda. *Economics & Human Biology*, **29**, 88–101.

Chin, B. (2010). Income, health, and well-being in rural Malawi. *Demographic research*, **23**(35), 997.

Cook, C. J., Fletcher, J. M., and Forgues, A. (2019). Multigenerational effects of early-life health shocks. *Demography*, **56**(5), 1855–1874.

Currie, J. and Vogl, T. (2013). Early-life health and adult circumstance in developing countries. *Annu. Rev. Econ.*, **5**(1), 1–36.

Currie, J., Mueller-Smith, M., and Rossin-Slater, M. (2018). Violence while in utero: The impact of assaults during pregnancy on birth outcomes. *NBER working paper 24802*.

Deb, P. and Norton, E. C. (2018). Modeling health care expenditures and use. *Annual Review of Public Health*, **39**, 489–505.

Duque, V., Rosales-Rueda, M., Sanchez, F., *et al.* (2018). How do early-life shocks interact with subsequent human-capital investments? Evidence from administrative data. In *IZA World of Labor Conference*.

Filmer, D. and Pritchett, L. (1998). Estimating wealth effects without expenditure data–or tears: An application to educational enrollments in states of India. *Policy Research Working Papers No. 1994.*

Georgiadis, A., Benny, L., Galab, S., Reddy, P., Woldehanna, T., *et al.* (2017). Growth recovery and faltering through early adolescence in low-and middle-income countries: Determinants and implications for cognitive development. *Social Science & Medicine*, **179**, 81–90.

Greve, J., Schultz-Nielsen, M. L., and Tekin, E. (2017). Fetal malnutrition and academic success: Evidence from Muslim immigrants in Denmark. *Economics of Education Review*, **60**, 20–35.

Haddad, L. and Reardon, T. (1993). Gender bias in the allocation of resources within households in Burkina Faso: a disaggregated outlay equivalent analysis. *The Journal of Development Studies*, **29**(2), 260–276.

Hadley, C., Lindstrom, D., Tessema, F., and Belachew, T. (2008). Gender bias in the food insecurity experience of Ethiopian adolescents. *Social Science & Medicine*, **66**(2), 427–438.

Halla, M. and Zweimüller, M. (2014). Parental response to early human capital shocks: evidence from the chernobyl accident. *Discussion Paper 7968, Institute for the Study of Labor IZA*.

Heckman, J. J. (2007). The economics, technology, and neuroscience of human capability formation. *Proceedings of the national Academy of Sciences*, **104**(33), 13250–13255.

Hoddinott, J. and Kinsey, B. (2001). Child growth in the time of drought. *Oxford Bulletin of Economics and Statistics*, **63**(4), 409–436.

Hyder, A., Behrman, J. R., and Kohler, H.-P. (2015). Negative economic shocks and child schooling: Evidence from rural Malawi. *Development Southern Africa*, **32**(4), 458–476.

Imbens, G. W. and Rubin, D. B. (2015). *Causal inference in statistics, social, and biomedical sciences*. Cambridge University Press.

Kaul, T. (2018). Intra-household allocation of educational expenses: Gender discrimination and investing in the future. *World Development*, **104**, 336–343.

Kidman, R., Piccolo, L., and Kohler, H.-P. (2020). Adverse childhood experiences: Prevalence and association with adolescent health in Malawi. *American Journal of Preventive Medicine*, **58**(2), 285–293.

Kohler, H.-P., Watkins, S. C., Behrman, J. R., Anglewicz, P., Kohler, I. V., Thornton, R. L., Mkandawire, J., Honde, H., Hawara, A., Chilima, B., Bandawe, C., and Mwapasa, V. (2015). Cohort profile: The Malawi Longitudinal Study of Families and Health (MLSFH). *International Journal of Epidemiology*, **44**(2), 394–404.

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

Levitsky, D. A. and Strupp, B. J. (1995). Malnutrition and the brain: changing concepts, changing concerns. *The Journal of Nutrition*, **125**(suppl_8), 2212S–2220S.

Millett, B. and Shah, M. (2012). The effects of in-utero shocks on cognitive test scores: Evidence from droughts in India. Technical report, Mimeo.

Park, R. E. (1966). Estimation with heteroscedastic error terms. *Econometrica (pre-1986)*, **34**(4), 888.

Parman, J. (2015). Childhood health and human capital: New evidence from genetic brothers in arms. *The Journal of Economic History*, **75**(1), 30–64.

Psaki, S. R., McCarthy, K. J., Mensch, B. S., *et al.* (2018). Measuring gender equality in education: Lessons from trends in 43 countries. *Population and Development Review*, **44**(1), 117–142.

Rosales, M. F. (2013). Impact of early-life shocks on human capital formation: evidence from el Nino floods in Ecuador. *University of Chicago, Job Market Paper*.

Sanders, N. J. and Stoecker, C. (2015). Where have all the young men gone? using sex ratios to measure fetal death rates. *Journal of health economics*, **41**, 30–45.

Sauerborn, R., Berman, P., and Nougtara, A. (1996). Age bias, but no gender bias, in the intrahousehold resource allocation for health care in rural Burkina Faso. *Health Transition Review*, pages 131–145.

Tafere, K. (2016). Inter-generational effects of early childhood shocks on human capital: Evidence from Ethiopia. *Working paper, No. 333-2016-14569*.

Thomas, D. and Strauss, J. (1992). Prices, infrastructure, household characteristics and child height. *Journal of Development Economics*, **39**(2), 301–331.

Thomas, D., Strauss, J., and Henriques, M.-H. (1990). Child survival, height for age and household characteristics in Brazil. *Journal of Development Economics*, **33**(2), 197–234.

Uauy, R. and Dangour, A. D. (2006). Nutrition in brain development and aging: role of essential fatty acids. *Nutrition Reviews*, **64**(suppl_2), S24–S33.

UNICEF (2020). Girls' education. https://www.unicef.org/education/girls-education. Accessed: 2020-09-21.

von Hinke Kessler Scholder, S., Wehby, G. L., Lewis, S., and Zuccolo, L. (2014). Alcohol exposure in utero and child academic achievement. *The Economic Journal*, **124**(576), 634–667.

Vyas, S. and Kumaranayake, L. (2006). Constructing socio-economic status indices: how to use principal components analysis. *Health Policy and Planning*, **21**(6), 459–468.

WHO (1995). The use and interpretation of anthropometry. Report 8854, World Health Organization.

Wolf, S. and McCoy, D. C. (2019). Household socioeconomic status and parental investments: Direct and indirect relations with school readiness in Ghana. *Child Development*, **90**(1), 260–278.

Online Appendix

A Cognitive measures

The MLSFH ACE data provide several measures of cognitive abilities that encompass three different domains: literacy, mathematical skills, and working memory.

Reading score: Our initial outcome variable is "reading score", which ranges from 0 to 8. Adolescents were presented with four different sentences, two in Chichewa and two in English, that they were asked to read. For each of these sentences, they received a score of 0 if they were not able to read any part of the sentence, 1 point if they were able to read only part of the sentence, and 2 points if they were able to read the whole sentence. For our measure, we added scores for all four sentences. To explore the effects of economic shocks at birth at the lower end of the reading score distribution, we also created a dichotomous variable that takes the value 1 if adolescents were not able to read any part of the two Chichewa sentences, and 0 otherwise.

Mathematical skills: We created a measure for mathematical skills based on 12 questions that assess different analytical abilities.Therefore, the Math score ranges from 0 to 12. The first two questions asked adolescents to fill in missing numbers in a short sequence of numbers, and order five numbers in descending order. The next eight questions tested adolescents' ability to perform simple additions, subtractions, multiplications and divisions (two questions for each domain). The last two questions were two short word problems that adolescents were asked to solve. As an example, one of the word problems asked, "You have 75 tambala and you want to buy a pencil that cost 67 tambala. How much change would you get?". Adolescents were given one point for correctly answering each question. For our measure, we added their scores on each question. Similar to our measure for reading ability, we also created a dichotomous variable for Math that takes the value 1 if adolescents were not able to answer to any of the math questions correctly, and 0 otherwise.

Working memory: Our third cognitive measure is working memory. Adolescents were asked to repeat a list of numbers backwards. We created a measure of working memory that ranges from 0 to 7. A series of only two numbers was asked first, and became progressively larger, reaching a list of eight digits.[1] An adolescent is given a point for each additional number he or she is able to recall. A score of 0 is therefore given to an adolescent who is not able to repeat a list of two numbers and a score of 7 to someone who is able to repeat the list of eight numbers. As we did for our two previous outcome variables, we created a dichotomous variable for working memory that takes the value 1 if adolescents had a working memory score of 0, and 0 otherwise.

[1] This measure was added to the survey between rounds of data collection, and thus is only available for those respondents in the 2018 round.

B Additional descriptive statistics and details on economic shocks

Table B1: Number and type of shocks experienced by boys (N = 794) and girls (N = 765)

	Boys	Girls	Difference (p-value)
Number of shock			
0 shock at birth	0.739	0.766	0.222
1 shock at birth	0.209	0.178	0.118
2 shocks or more at birth	0.052	0.056	0.690
Type of shocks			
Death or serious illness	0.067	0.052	0.228
Poor crop yields	0.096	0.108	0.405
Loss income	0.042	0.039	0.814
Big change in price of grain	0.086	0.063	0.085
Fertilizer subsidy	0.001	0.001	0.979
Breakup of houshold	0.011	0.020	0.185
Damage to house	0.016	0.008	0.125
Other	0.001	0.001	0.979

Note: These shocks are reported by adolescents' households as part of the MLSFH collected in 2008 and 2010. P-values are the results of t-tests that compare the mean number of shocks experienced by adolescents in our sample by sex.

Table B2: Predictors of the number of shocks at birth

	Shock(s) at birth	Shock(s) at birth	Shock(s) at birth	Shock(s) at birth	Shock(s) at birth	Shock(s) at birth
Girl	-0.062	-0.062	-0.063	-0.015	0.227	0.237
	(0.068)	(0.068)	(0.068)	(0.123)	(0.312)	(0.363)
South region	0.040	0.042	0.056	0.158	0.165	0.190^{+}
	(0.079)	(0.079)	(0.078)	(0.107)	(0.107)	(0.109)
North region	0.027	0.025	-0.021	-0.054	-0.060	-0.090
	(0.082)	(0.082)	(0.092)	(0.114)	(0.114)	(0.126)
Caregiver married at birth		-0.027	-0.042		0.040	0.019
		(0.109)	(0.110)		(0.144)	(0.144)
Age of the caregiver at birth		0.003	0.004		0.005	0.006
		(0.003)	(0.003)		(0.003)	(0.004)
Primary level education - caregiver			0.055			0.091
			(0.088)			(0.122)
Secondary level education - caregiver			0.057			-0.079
			(0.147)			(0.209)
Wealth score			0.020			0.023
			(0.020)			(0.027)
Girl × South region				-0.257	-0.266	-0.283^{+}
				(0.167)	(0.167)	(0.165)
Girl × North region				0.148	0.148	0.122
				(0.171)	(0.171)	(0.190)
Girl × Caregiver married at birth					-0.125	-0.114
					(0.217)	(0.217)
Girl × Age of the caregiver at birth					-0.004	-0.004
					(0.006)	(0.006)
Girl × Primary level education - caregiver						-0.054
						(0.180)
Girl × Secondary level education - caregiver						0.269
						(0.300)
Girl × Wealth score						-0.013
						(0.039)
Observations	1559	1558	1556	1559	1558	1556
Test of joint-significance						
Wald χ^2(.)-statistics	1.00	2.83	4.19	7.27	10.72	13.43
P-value	0.801	0.727	0.840	0.201	0.295	0.569

Note: Standard errors in parentheses clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$). The coefficients are the results of ordered probit models for which the outcome variable is a categorical that takes the values 0, 1 or 2 for zero, one or two or more shocks experienced at birth, respectively. The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010.

Table B3: Predictors of experiencing poor crop yields at birth

	Poor crop yields	Poor crop yields	Poor crop yields	Poor crop yields	Poor crop yields	Poor crop yields
Girl	0.012	0.012	0.013	0.028	0.044	0.058
	(0.016)	(0.016)	(0.016)	(0.027)	(0.067)	(0.080)
South region	0.010	0.011	0.012	0.035	0.035	0.041
	(0.018)	(0.018)	(0.018)	(0.025)	(0.025)	(0.026)
North region	0.009	0.009	0.012	0.004	0.003	0.003
	(0.019)	(0.019)	(0.021)	(0.025)	(0.025)	(0.029)
Caregiver married at birth		0.007	0.009		0.006	0.006
		(0.023)	(0.023)		(0.032)	(0.032)
Age of the caregiver at birth		0.000	0.001		0.001	0.001
		(0.001)	(0.001)		(0.001)	(0.001)
Primary level education - caregiver			0.011			0.025
			(0.019)			(0.028)
Secondary level education - caregiver			0.015			0.010
			(0.035)			(0.048)
Wealth score			-0.004			-0.003
			(0.004)			(0.006)
Girl × South region				-0.050	-0.050	-0.057
				(0.038)	(0.038)	(0.038)
Girl × North region				0.009	0.010	0.016
				(0.039)	(0.039)	(0.043)
Girl × Caregiver married at birth					0.003	0.007
					(0.046)	(0.047)
Girl × Age of the caregiver at birth					-0.001	-0.001
					(0.001)	(0.001)
Girl × Primary level education - caregiver						-0.024
						(0.040)
Girl × Secondary level education - caregiver						0.011
						(0.073)
Girl × Wealth score						-0.003
						(0.008)
Observations	1559	1558	1556	1559	1558	1556
Test of joint-significance						
F-statistics	0.39	0.37	0.43	0.81	0.59	0.56
P-value	0.763	0.872	0.905	0.541	0.807	0.906

Note: Standard errors in parentheses clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$). The coefficients are the results of linear regressions for which the outcome variable is a dichotomous variable that takes the values 1 if the adolescent experienced a "poor crop yields" shock at birth, and 0 otherwise. The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010.

Table B4: Predictors of experiencing big changes in the price of grain at birth

	Big change in price of grain	Big change in price of grain	Big change in price of grain	Big change in price of grain	Big change in price of grain	Big change in price of grain
Girl	-0.023^{+}	-0.023^{+}	-0.024^{+}	-0.031	-0.049	-0.040
	(0.013)	(0.013)	(0.013)	(0.023)	(0.059)	(0.067)
South region	0.017	0.017	0.021	0.018	0.018	0.025
	(0.016)	(0.016)	(0.016)	(0.024)	(0.024)	(0.025)
North region	0.005	0.005	0.003	-0.008	-0.008	-0.009
	(0.016)	(0.016)	(0.018)	(0.024)	(0.024)	(0.027)
Caregiver married at birth		0.008	0.007		0.000	-0.003
		(0.021)	(0.021)		(0.031)	(0.031)
Age of the caregiver at birth		0.000	0.000		0.000	0.000
		(0.001)	(0.001)		(0.001)	(0.001)
Primary level education - caregiver			0.020			0.031
			(0.017)			(0.027)
Secondary level education - caregiver			0.006			-0.013
			(0.034)			(0.041)
Wealth score			-0.000			-0.000
			(0.004)			(0.006)
Girl × South region				-0.002	-0.001	-0.007
				(0.032)	(0.032)	(0.032)
Girl × North region				0.027	0.028	0.024
				(0.032)	(0.032)	(0.036)
Girl × Caregiver married at birth					0.016	0.021
					(0.040)	(0.041)
Girl × Age of the caregiver at birth					0.000	0.000
					(0.001)	(0.001)
Girl × Primary level education - caregiver						-0.021
						(0.034)
Girl × Secondary level education - caregiver						0.042
						(0.053)
Girl × Wealth score						-0.001
						(0.008)
Observations	1559	1558	1556	1559	1558	1556
Test of joint-significance						
F-statistics	1.35	0.90	0.82	1.01	0.64	0.71
P-value	0.257	0.483	0.587	0.411	0.767	0.779

Note: Standard errors in parentheses clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$). The coefficients are the results of linear regressions for which the outcome variable is a dichotomous variable that takes the values 1 if the adolescent experienced a "big change in the price of grain" shock at birth, and 0 otherwise. The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010.

Table B5: Descriptive statistics of adolescents in our sample by sex

	Boys	Girls	Difference (p-value)
Control variables			
Age	12.742	12.923	0.015
Central region	0.324	0.285	0.097
South region	0.368	0.374	0.803
North region	0.309	0.341	0.169
Age of the caregiver at birth	31.980	31.988	0.990
Caregiver married at birth	0.870	0.873	0.863
No formal education - caregiver	0.273	0.251	0.317
Primary level education - caregiver	0.641	0.667	0.288
Secondary level education or higher - caregiver	0.086	0.082	0.815
Wealth score	-0.153	-0.005	0.118

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. P-values are the results of t-tests that compare the mean characteristics of adolescents in our sample by sex.

C Robustness checks

We test other specifications to check the robustness of our findings. First, our benchmark results pertaining to the associations between negative economic shocks and our two summary indices use adolescents who do not experience any shock at birth as (sex-specific) reference group to normalize the outcomes. We show in Tables C1 and C2 that using a norm based on 1) those who did not experience any shock at birth irrespective of sex, 2) sex only irrespective of the number of shocks experienced at birth, or 3) the entire sample leads to very similar results.

Second, Tables C3 and C4 present corresponding analysis but this time interacting economic shocks during the year of birth with sex, instead of running separate regressions by sex. This new specification is not as flexible as our benchmark specification as it has the undesirable property to "force" coefficients—other than economic shocks—to be similar across sex. Because processes and characteristics that govern cognitive and educational outcomes can vary across gender in this context (UNICEF 2020), such a specification is probably too restrictive and unlikely to fit the data well. We allow not only shocks but also age effects to depend on sex, in an attempt to resolve a part of this restriction. Similar to our benchmark analysis, no clear relationship between the occurrence of economic shocks during the year of birth and cognitive outcomes can be observed for boys. A clear negative relationship can be seen for girls however, for whom the detrimental effects become larger as the number of economic shocks occurring during the year of birth increases.

One concern in our analysis is that the associations estimated thus far could be due to serially correlated shocks that happened prior or after the year of birth, and may not be the result of shocks happening during the year of birth. To rule out this possibility, we include in the same econometric specification both economic shocks occurring during the year of birth and those occurring two years after the year of birth.[2] Table C5 shows that including economic shocks two years after birth does not alter the associations between cognitive function and economic shocks occurring in the year at birth. Note also that including only economic shocks occurring two years after birth does not explain any of our outcome variables (Table C6). In the same spirit, economic shocks occurring the year prior to the year of birth are not associated with lower cognitive characteristics either (Table C7). Finally we show in Table C8 that the associations between economic shocks at birth and lower cognitive skills are robust to controlling for the average number of shocks per year experienced by the household

[2]We include in the econometric specification economic shocks occurring two years after the year of birth to make sure these shocks do not happen right after birth, for instance for those born in December of a given year.

of the adolescent over the period 2003-2008.[3] This underscores the importance of the long-term cognitive impact of shocks during the year of birth and supports the fact that the associations between economic shocks at birth and cognitive function estimated thus far does indeed capture distress and shocks in the year of birth and not just heterogeneity in some latent and uncontrolled socioeconomic characteristics of the households.

An additional concern is that the wealth score we include as a control variable in our benchmark specification could also be an outcome variable, given that economic shocks could affect households' wealth and become a pathway to impacting children's cognitive health and outcomes. Although our wealth measure is constructed from durable household assets that may be relatively stable over time, including such an independent variable in our model could capture some of the associations between economic shocks at birth cognitive and educational outcomes. However, we show that our results are robust to other versions of wealth measures. First, instead of a wealth score, we include in our model household land ownership as a proxy for socioeconomic status. Table C9 shows that controlling for land ownership does not alter our previous findings.[4] In addition, the only assets for which we have information about whether respondents owned them in 1998, 2001, 2004, 2006, 2008 and 2010 were mattress, radio, bicycle, pit latrine and lamp. Using this subset of assets, we created an indicator variable that takes the value 1 if a respondent owned a particular asset, and summed these indicator variables over the five different assets. We did that for survey years 1998, 2001, 2004, 2006, 2008 and 2010, and took the average of these asset scores, conditioning again on having at least two observations. Table C10 shows that our results are robust to including this measure of socioeconomic status. Table C11 also presents results controlling for wealth score measured in 2004, which predates most of the births of adolescents in our sample. Despite the large decrease in the sample size since not all adolescents had caregivers that were interviewed in 2004, Table C11 shows that the associations between economic shocks and cognitive and educational outcomes are similar to those estimated in our benchmark specification, but less precisely estimated due to smaller sample size. We also present results from a specification in which wealth score is not controlled for. In that case, under the assumption that economic shocks and wealth score are negatively correlated, we would expect economic shocks to have larger associations on cognitive and educational outcomes than when

[3]We exclude the shocks reported during the year of birth when computing the average number of shocks experienced by the households between 2003 and 2008.

[4]To construct our measure of land ownership, we compute the percentile rank of respondent's land ownership in each wave 1998, 2001, 2004, 2006, 2008 and 2010, and take the average of these percentile ranks, conditioning on having at least two observations for each respondents.

wealth score is controlled for.[5] This is indeed what we see in our results (Table C12). Overall, our results are robust to various specifications of wealth measures, including wealth measures that preceded the birth of the adolescents in our sample.

[5]Not including wealth index in the analysis therefore helps to identify the *total associations* of the shocks on cognitive outcome, but weakens the plausibility of the exogeneity of the shocks.

Table C1: Associations between economic shock at birth and summary indices - continuous outcomes. Robustness checks based on the reference group used as norm

	All (1)	Boys (2)	Girls (3)
No shock at birth, irrespective of sex			
1 shock at birth	0.025	0.062	-0.032
	(0.056)	(0.076)	(0.084)
2 shocks or more at birth	-0.164	-0.011	-0.330*
	(0.103)	(0.131)	(0.153)
Observations	1554	792	762
Sex, irrespective of the number of shocks at birth			
1 shock at birth	0.026	0.060	-0.030
	(0.056)	(0.079)	(0.085)
2 shocks or more at birth	-0.169	-0.024	-0.334*
	(0.104)	(0.136)	(0.155)
Observations	1554	792	762
Entire sample			
1 shock at birth	0.026	0.060	-0.028
	(0.056)	(0.077)	(0.085)
2 shocks or more at birth	-0.169	-0.020	-0.332*
	(0.104)	(0.133)	(0.153)
Observations	1554	792	762

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$). The summary index is a standardized weighted index based on our four continuous variables following a GLS weighting procedure as described in (Anderson 2008).

Table C2: Associations between economic shock at birth and summary indices - discrete outcomes. Robustness checks based on the reference group used as norm

	All	Boys	Girls
	(1)	(2)	(3)
No shock at birth, irrespective of sex			
1 shock at birth	0.030	-0.022	0.088
	(0.067)	(0.095)	(0.101)
2 shocks or more at birth	0.302*	0.090	0.517*
	(0.142)	(0.187)	(0.207)
Observations	1554	792	762
Sex, irrespective of the number of shocks at birth			
1 shock at birth	0.031	-0.017	0.086
	(0.063)	(0.086)	(0.098)
2 shocks or more at birth	0.282*	0.077	0.514*
	(0.137)	(0.177)	(0.207)
Observations	1554	792	762
Entire sample			
1 shock at birth	0.031	-0.017	0.085
	(0.063)	(0.088)	(0.094)
2 shocks or more at birth	0.282*	0.077	0.491*
	(0.137)	(0.180)	(0.220)
Observations	1554	792	762

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$). The summary index is a standardized weighted index based on our four continuous variables following a GLS weighting procedure as described in (Anderson 2008).

Table C3: Associations between economic shocks at birth and continuous outcome variables - interactions between shock and sex

Total interactions	Summary index continuous (1)	Reading score (2)	Working memory (3)	Math score (4)	Educational attainment (5)
Sex-specific age dummies					
1 shock at birth - Boys	0.066	0.234	0.101	-0.003	0.109
	(0.075)	(0.287)	(0.148)	(0.298)	(0.113)
2 shocks or more at birth - Boys	0.002	0.045	-0.069	-0.418	0.208
	(0.130)	(0.489)	(0.243)	(0.524)	(0.202)
1 shock at birth - Girls	-0.028	-0.023	-0.077	-0.111	-0.101
	(0.083)	(0.299)	(0.181)	(0.319)	(0.133)
2 shocks or more at birth - Girls	-0.330*	-0.926+	-0.527+	-0.739	-0.415+
	(0.151)	(0.526)	(0.311)	(0.540)	(0.242)
Observations	1554	1541	1276	1510	1554

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. Age dummy variables are also interacted with sex. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table C4: Associations between economic shocks at birth and discrete outcome variables - interactions between shock and sex

Total interactions	Index discrete (1)	Can't read Chichewa (2)	WM score of 0 (3)	Math score of 0 (4)	Age for grade $\geqslant 3$ (5)
Sex-specific age dummies					
1 shock at birth - Boys	-0.032	-0.041	-0.276	0.040	-0.015
	(0.091)	(0.125)	(0.218)	(0.173)	(0.130)
2 shocks or more at birth - Boys	0.060	0.140	0.282	-0.186	-0.014
	(0.186)	(0.235)	(0.308)	(0.312)	(0.252)
1 shock at birth - Girls	0.103	0.023	0.325	0.321	-0.023
	(0.097)	(0.145)	(0.205)	(0.219)	(0.142)
2 shocks or more at birth - Girls	0.538*	0.433+	0.701*	0.696*	0.238
	(0.212)	(0.227)	(0.319)	(0.294)	(0.252)
Observations	1554	1543	1276	1510	1447

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. Age dummy variables are also interacted with sex. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table C5: Associations between economic shocks at birth and cognitive outcomes and educational attainment - including also shocks occurring two years after the year of birth

	All (1)	Boys (2)	Girls (3)	All (4)	Boys (5)	Girls (6)
			Summary index			
	Continuous outcomes			Discrete outcomes		
1 shock at birth	0.050	0.086	0.000	0.014	-0.047	0.084
	(0.058)	(0.081)	(0.088)	(0.068)	(0.091)	(0.108)
2 shocks or more at birth	-0.173	0.016	-0.398*	0.318*	0.077	0.585**
	(0.109)	(0.142)	(0.159)	(0.151)	(0.194)	(0.221)
1 shock 2 years after birth	0.014	0.025	0.012	-0.062	-0.041	-0.107
	(0.053)	(0.072)	(0.078)	(0.055)	(0.075)	(0.082)
2 shocks or more 2 years after birth	0.119+	0.094	0.159+	-0.056	-0.074	-0.012
	(0.070)	(0.097)	(0.097)	(0.084)	(0.111)	(0.116)
			A. Reading skills			
	Reading score			Can't read Chichewa		
1 shock at birth	0.180	0.245	0.054	-0.030	-0.051	-0.002
	(0.211)	(0.300)	(0.306)	(0.096)	(0.129)	(0.154)
2 shocks or more at birth	-0.486	-0.033	-0.954+	0.330+	0.194	0.506*
	(0.386)	(0.532)	(0.547)	(0.177)	(0.253)	(0.249)
1 shock 2 years after birth	0.054	0.058	0.078	-0.085	-0.108	-0.074
	(0.179)	(0.255)	(0.249)	(0.086)	(0.112)	(0.132)
2 shocks or more 2 years after birth	0.358	0.208	0.527	-0.062	0.048	-0.223
	(0.252)	(0.356)	(0.348)	(0.113)	(0.153)	(0.167)
			B. Cognitive skills			
	Cognitive score			Score of 0		
1 shock at birth	0.094	0.189	0.009	-0.062	-0.439+	0.312
	(0.119)	(0.158)	(0.187)	(0.153)	(0.240)	(0.232)
2 shocks or more at birth	-0.298	-0.066	-0.599+	0.478*	0.421	0.609+
	(0.223)	(0.265)	(0.340)	(0.232)	(0.319)	(0.368)
1 shock 2 years after birth	0.082	0.146	0.012	-0.113	0.004	-0.316
	(0.115)	(0.151)	(0.171)	(0.129)	(0.172)	(0.212)
2 shocks or more 2 years after birth	0.204	0.189	0.272	-0.126	-0.276	0.006
	(0.151)	(0.191)	(0.206)	(0.177)	(0.253)	(0.249)
			C. Math skills			
	Math score			Score of 0		
1 shock at birth	-0.045	-0.072	-0.025	0.155	0.055	0.334
	(0.221)	(0.310)	(0.325)	(0.140)	(0.177)	(0.235)
2 shocks or more at birth	-0.494	-0.522	-0.585	0.210	-0.204	0.898**
	(0.400)	(0.561)	(0.567)	(0.233)	(0.342)	(0.330)
1 shock 2 years after birth	-0.131	-0.275	0.084	-0.091	-0.121	-0.049
	(0.190)	(0.265)	(0.271)	(0.126)	(0.160)	(0.220)
2 shocks or more 2 years after birth	0.136	-0.148	0.439	-0.157	-0.183	-0.082
	(0.266)	(0.356)	(0.380)	(0.173)	(0.221)	(0.256)
			D. Schooling			
	Educational attainment			Age for grade $\geqslant 3$		
1 shock at birth	0.019	0.124	-0.120	-0.028	-0.062	0.020
	(0.090)	(0.117)	(0.139)	(0.099)	(0.132)	(0.152)
2 shocks or more at birth	-0.109	0.295	-0.508*	0.047	-0.133	0.270
	(0.173)	(0.227)	(0.251)	(0.194)	(0.267)	(0.285)
1 shock 2 years after birth	0.002	-0.017	0.037	-0.054	-0.024	-0.106
	(0.086)	(0.115)	(0.124)	(0.087)	(0.125)	(0.127)
2 shocks or more 2 years after birth	0.057	0.062	0.058	0.115	0.030	0.178
	(0.109)	(0.152)	(0.154)	(0.121)	(0.166)	(0.171)

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table C6: Associations between economic shocks at birth and cognitive outcomes and educational attainment - including only shocks occurring two years after the year of birth

	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(1)	(2)	(3)
	Summary index					
	Continuous outcomes			Discrete outcomes		
1 shock 2 years after birth	0.015	0.022	0.023	-0.070	-0.041	-0.129
	(0.052)	(0.072)	(0.077)	(0.055)	(0.074)	(0.082)
2 shocks or more 2 years after birth	0.115^{+}	0.089	0.156	-0.061	-0.074	-0.023
	(0.070)	(0.096)	(0.095)	(0.082)	(0.108)	(0.114)
	A. Reading skills					
	Reading score			Can't read Chichewa		
1 shock 2 years after birth	0.054	0.050	0.099	-0.092	-0.111	-0.090
	(0.178)	(0.254)	(0.249)	(0.085)	(0.111)	(0.132)
2 shocks or more 2 years after birth	0.343	0.198	0.509	-0.062	0.046	-0.221
	(0.250)	(0.353)	(0.346)	(0.111)	(0.151)	(0.165)
	B. Cognitive skills					
	Cognitive score			Score of 0		
1 shock 2 years after birth	0.081	0.144	0.018	-0.118	-0.007	-0.365^{+}
	(0.114)	(0.150)	(0.171)	(0.128)	(0.170)	(0.212)
2 shocks or more 2 years after birth	0.198	0.183	0.255	-0.139	-0.300	-0.071
	(0.150)	(0.190)	(0.203)	(0.177)	(0.248)	(0.243)
	C. Math skills					
	Math score			Score of 0		
1 shock 2 years after birth	-0.116	-0.260	0.101	-0.106	-0.119	-0.120
	(0.189)	(0.265)	(0.269)	(0.126)	(0.159)	(0.216)
2 shocks or more 2 years after birth	0.147	-0.129	0.439	-0.167	-0.177	-0.155
	(0.264)	(0.354)	(0.374)	(0.172)	(0.222)	(0.251)
	D. Schooling					
	Educational attainment			Age for grade $\geqslant 3$		
1 shock 2 years after birth	0.003	-0.028	0.060	-0.053	-0.018	-0.115
	(0.085)	(0.114)	(0.122)	(0.086)	(0.124)	(0.125)
2 shocks or more 2 years after birth	0.056	0.048	0.077	0.118	0.039	0.180
	(0.107)	(0.151)	(0.149)	(0.120)	(0.164)	(0.169)

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table C7: Associations between economic shocks at birth and cognitive outcomes and educational attainment - including only shocks occurring one year before the year of birth

	All (1)	Boys (2)	Girls (3)	All (4)	Boys (5)	Girls (6)
			Summary index			
	Continuous outcomes			Discrete outcomes		
1 shock 1 year before birth	0.083	0.084	0.071	-0.011	-0.023	-0.027
	(0.072)	(0.097)	(0.115)	(0.086)	(0.118)	(0.123)
2 shocks or more 1 year before birth	0.041	0.146	-0.020	0.134	-0.124	0.335
	(0.152)	(0.181)	(0.266)	(0.284)	(0.263)	(0.493)
			A. Reading skills			
	Reading score			Can't read Chichewa		
1 shock 1 year before birth	-0.070	-0.023	-0.167	0.025	-0.078	0.214
	(0.251)	(0.322)	(0.396)	(0.115)	(0.149)	(0.178)
2 shocks or more 1 year before birth	-0.030	0.259	-0.409	0.070	0.017	0.186
	(0.610)	(0.670)	(1.035)	(0.302)	(0.406)	(0.454)
			B. Cognitive skills			
	Cognitive score			Score of 0		
1 shock 1 year before birth	0.169	0.040	0.276	0.226	0.212	0.260
	(0.156)	(0.212)	(0.242)	(0.163)	(0.218)	(0.276)
2 shocks or more 1 year before birth	0.017	0.098	0.082	-0.500	-[a]	-0.288
	(0.245)	(0.243)	(0.466)	(0.548)		(0.823)
			C. Math skills			
	Math score			Score of 0		
1 shock 1 year before birth	0.082	-0.010	0.229	0.035	-0.032	-0.041
	(0.273)	(0.359)	(0.405)	(0.155)	(0.194)	(0.271)
2 shocks or more 1 year before birth	-0.341	0.014	-0.531	0.420	0.174	0.283
	(0.595)	(0.867)	(0.911)	(0.353)	(0.627)	(0.477)
			D. Schooling			
	Educational attainment			Age for grade $\geqslant 3$		
1 shock 1 year before birth	0.108	0.182	0.012	-0.133	-0.052	-0.244
	(0.110)	(0.134)	(0.186)	(0.121)	(0.162)	(0.192)
2 shocks or more 1 year before birth	0.059	0.179	0.005	0.143	-0.166	0.299
	(0.248)	(0.281)	(0.430)	(0.320)	(0.436)	(0.447)

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$). [a]: When looking at the probability of having a cognitive skills score of 0, no coefficient for boys who experience two or more economic shocks at birth can be estimated because of lack of variation.

Table C8: Associations between economic shocks at birth and cognitive and educational attainment outcomes, controlling for average number of shocks per year

	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)
			Summary index			
	Continuous outcomes			Discrete outcomes		
1 shock at birth	0.041	0.083	-0.024	0.026	-0.009	0.057
	(0.059)	(0.081)	(0.090)	(0.069)	(0.091)	(0.108)
2 shocks or more at birth	-0.145	0.047	-0.349*	0.288+	0.026	0.544*
	(0.117)	(0.148)	(0.175)	(0.156)	(0.190)	(0.233)
			A. Reading skills			
	Reading score			Can't read Chichewa		
1 shock at birth	0.175	0.320	-0.045	-0.021	-0.040	0.027
	(0.213)	(0.306)	(0.308)	(0.097)	(0.131)	(0.155)
2 shocks or more at birth	-0.449	0.057	-0.973+	0.303	0.206	0.430
	(0.405)	(0.547)	(0.583)	(0.185)	(0.261)	(0.262)
			B. Working memory			
	Working memory score			Score of 0		
1 shock at birth	0.032	0.105	-0.040	0.019	-0.213	0.260
	(0.119)	(0.155)	(0.188)	(0.155)	(0.220)	(0.245)
2 shocks or more at birth	-0.279	-0.056	-0.507	0.491*	0.571+	0.557
	(0.227)	(0.275)	(0.340)	(0.245)	(0.342)	(0.373)
			C. Mathematical skills			
	Math score			Score of 0		
1 shock at birth	-0.018	-0.011	-0.088	0.209	0.145	0.341
	(0.229)	(0.321)	(0.335)	(0.143)	(0.175)	(0.250)
2 shocks or more at birth	-0.582	-0.302	-0.999+	0.276	-0.284	0.863*
	(0.422)	(0.585)	(0.575)	(0.250)	(0.404)	(0.344)
			D. Schooling			
	Educational attainment			Age for grade $\geqslant 3$		
1 shock at birth	0.007	0.122	-0.148	-0.052	-0.081	-0.022
	(0.094)	(0.122)	(0.144)	(0.101)	(0.137)	(0.152)
2 shocks or more at birth	-0.108	0.280	-0.465	0.063	-0.113	0.266
	(0.190)	(0.235)	(0.286)	(0.202)	(0.291)	(0.287)

Note: Standard errors in parentheses clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$). The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's households as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent.

Table C9: Associations between economic shocks at birth and cognitive outcomes and educational attainment - land ownership (percentile rank)

	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)
			Summary index			
	Continuous outcomes			Discrete outcomes		
1 shock at birth	0.039	0.106	-0.054	0.022	-0.051	0.107
	(0.059)	(0.080)	(0.090)	(0.068)	(0.091)	(0.109)
2 shocks or more at birth	-0.145	-0.022	-0.315^{+}	0.317*	0.115	0.585*
	(0.111)	(0.140)	(0.172)	(0.152)	(0.187)	(0.240)
Observations	1463	737	726	1463	737	726
			A. Reading skills			
	Reading score			Can't read Chichewa		
1 shock at birth	0.175	0.332	-0.068	-0.031	-0.067	0.052
	(0.214)	(0.304)	(0.309)	(0.095)	(0.128)	(0.151)
2 shocks or more at birth	-0.379	-0.069	-0.809	0.263	0.205	0.394
	(0.376)	(0.518)	(0.559)	(0.167)	(0.239)	(0.248)
Observations	1450	731	719	1452	732	720
			B. Cognitive skills			
	Cognitive score			Score of 0		
1 shock at birth	0.047	0.212	-0.156	0.011	-0.393^{+}	0.489*
	(0.120)	(0.154)	(0.191)	(0.152)	(0.236)	(0.230)
2 shocks or more at birth	-0.286	-0.141	-0.473	0.502*	0.392	0.745*
	(0.216)	(0.261)	(0.330)	(0.225)	(0.314)	(0.358)
Observations	1202	600	602	1202	600	518
			C. Math skills			
	Math score			Score of 0		
1 shock at birth	-0.005	0.095	-0.168	0.163	0.050	0.381
	(0.223)	(0.313)	(0.332)	(0.141)	(0.184)	(0.232)
2 shocks or more at birth	-0.554	-0.430	-0.816	0.242	-0.092	0.850**
	(0.404)	(0.549)	(0.590)	(0.220)	(0.319)	(0.326)
Observations	1421	716	705	1421	716	648
			D. Schooling			
	Educational attainment			Age for grade $\geqslant 3$		
1 shock at birth	0.028	0.136	-0.139	-0.045	-0.049	-0.022
	(0.090)	(0.115)	(0.141)	(0.099)	(0.132)	(0.150)
2 shocks or more at birth	-0.080	0.209	-0.442	0.108	0.018	0.275
	(0.175)	(0.220)	(0.276)	(0.184)	(0.267)	(0.273)
Observations	1463	737	726	1366	689	677

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), land ownership (average percentile rank) and sex of the adolescent. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table C10: Associations between economic shocks at birth and cognitive outcomes and educational outcomes - asset ownership subset

	All (1)	Boys (2)	Girls (3)	All (4)	Boys (5)	Girls (6)
			Summary index			
	Continuous outcomes			Discrete outcomes		
1 shock at birth	0.031	0.082	-0.038	0.032	-0.033	0.099
	(0.057)	(0.079)	(0.087)	(0.067)	(0.090)	(0.105)
2 shocks or more at birth	-0.157	-0.009	-0.338*	0.303*	0.078	0.560*
	(0.110)	(0.139)	(0.169)	(0.152)	(0.186)	(0.237)
Observations	1480	748	732	1480	748	732
			A. Reading skills			
	Reading score			Can't read Chichewa		
1 shock at birth	0.139	0.250	-0.030	-0.027	-0.059	0.029
	(0.209)	(0.300)	(0.303)	(0.095)	(0.129)	(0.151)
2 shocks or more at birth	-0.381	0.034	-0.900	0.259	0.127	0.445+
	(0.377)	(0.517)	(0.557)	(0.169)	(0.237)	(0.246)
Observations	1468	742	726	1470	743	727
			B. Cognitive skills			
	Cognitive score			Score of 0		
1 shock at birth	0.041	0.162	-0.090	-0.023	-0.421+	0.413+
	(0.116)	(0.153)	(0.183)	(0.152)	(0.238)	(0.231)
2 shocks or more at birth	-0.312	-0.142	-0.498	0.516*	0.371	0.778*
	(0.211)	(0.254)	(0.321)	(0.224)	(0.312)	(0.350)
Observations	1219	610	609	1219	610	524
			C. Math skills			
	Math score			Score of 0		
1 shock at birth	-0.046	-0.025	-0.113	0.170	0.073	0.319
	(0.219)	(0.307)	(0.326)	(0.140)	(0.176)	(0.233)
2 shocks or more at birth	-0.638	-0.451	-0.932	0.264	-0.094	0.748*
	(0.404)	(0.545)	(0.588)	(0.221)	(0.311)	(0.328)
Observations	1439	727	712	1439	727	655
			D. Schooling			
	Educational attainment			Age for grade $\geqslant 3$		
1 shock at birth	0.015	0.119	-0.137	-0.002	-0.007	0.020
	(0.089)	(0.115)	(0.138)	(0.099)	(0.133)	(0.149)
2 shocks or more at birth	-0.115	0.215	-0.474+	0.061	-0.043	0.218
	(0.174)	(0.215)	(0.271)	(0.183)	(0.260)	(0.269)
Observations	1480	748	732	1379	698	681

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth score based on a subset of assets own by the household and sex of the adolescent. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table C11: Associations between economic shocks at birth and cognitive outcomes and educational outcomes - wealth score 2004

	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)
			Summary index			
	Continuous outcomes			Discrete outcomes		
1 shock at birth	0.015	0.016	-0.010	0.001	-0.037	0.004
	(0.072)	(0.096)	(0.110)	(0.084)	(0.107)	(0.142)
2 shocks or more at birth	-0.184	-0.056	-0.355	0.415^{+}	0.136	0.736*
	(0.153)	(0.184)	(0.247)	(0.213)	(0.229)	(0.357)
Observations	924	454	470	924	454	470
			A. Reading skills			
	Reading score			Can't read Chichewa		
1 shock at birth	0.119	0.214	-0.105	-0.002	-0.017	0.037
	(0.264)	(0.379)	(0.381)	(0.118)	(0.160)	(0.197)
2 shocks or more at birth	-0.487	-0.335	-0.733	0.423^{+}	0.358	0.562
	(0.500)	(0.629)	(0.818)	(0.218)	(0.293)	(0.361)
Observations	918	451	467	919	452	467
			B. Cognitive skills			
	Cognitive score			Score of 0		
1 shock at birth	0.042	0.107	0.007	-0.135	-0.526^{+}	0.236
	(0.147)	(0.181)	(0.235)	(0.182)	(0.277)	(0.303)
2 shocks or more at birth	-0.339	-0.081	-0.636	0.545*	0.276	0.820^{+}
	(0.295)	(0.341)	(0.439)	(0.271)	(0.375)	(0.429)
Observations	763	374	389	763	374	338
			C. Math skills			
	Math score			Score of 0		
1 shock at birth	-0.224	-0.177	-0.356	0.056	-0.183	0.238
	(0.279)	(0.391)	(0.416)	(0.173)	(0.217)	(0.289)
2 shocks or more at birth	-0.865	-0.452	-1.464^{+}	0.343	-0.072	0.906*
	(0.546)	(0.703)	(0.853)	(0.276)	(0.351)	(0.424)
Observations	893	439	454	893	439	422
			D. Schooling			
	Educational attainment			Age for grade $\geqslant 3$		
1 shock at birth	-0.023	-0.015	-0.098	-0.047	0.100	-0.177
	(0.113)	(0.145)	(0.172)	(0.121)	(0.168)	(0.178)
2 shocks or more at birth	-0.192	0.010	-0.476	0.072	0.091	0.093
	(0.237)	(0.275)	(0.420)	(0.251)	(0.337)	(0.411)
Observations	924	454	470	863	426	437

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household measured in 2004 and sex of the adolescent. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table C12: Associations between economic shocks at birth and cognitive outcomes - not controlling for wealth score

	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)
			Summary index			
	Continuous outcomes			Discrete outcomes		
1 shock at birth	0.048	0.094	-0.021	0.016	-0.041	0.083
	(0.057)	(0.077)	(0.088)	(0.066)	(0.088)	(0.103)
2 shocks or more at birth	-0.189^{+}	-0.032	-0.372*	0.320*	0.100	0.577**
	(0.105)	(0.134)	(0.158)	(0.142)	(0.180)	(0.216)
Observations	1556	792	764	1556	792	764
			A. Reading skills			
	Reading score			Can't read Chichewa		
1 shock at birth	0.188	0.325	-0.024	-0.037	-0.075	0.042
	(0.208)	(0.291)	(0.304)	(0.092)	(0.123)	(0.146)
2 shocks or more at birth	-0.525	-0.066	-1.038*	0.313*	0.190	0.484*
	(0.362)	(0.497)	(0.522)	(0.159)	(0.231)	(0.225)
Observations	1543	786	757	1545	787	758
			B. Cognitive skills			
	Cognitive score			Score of 0		
1 shock at birth	0.060	0.158	-0.066	-0.001	-0.293	0.389^{+}
	(0.116)	(0.147)	(0.186)	(0.144)	(0.210)	(0.220)
2 shocks or more at birth	-0.337	-0.137	-0.558^{+}	0.501*	0.380	0.725*
	(0.209)	(0.250)	(0.316)	(0.218)	(0.306)	(0.341)
Observations	1277	644	633	1277	644	545
			C. Math skills			
	Math score			Score of 0		
1 shock at birth	0.027	0.082	-0.088	0.131	0.018	0.324
	(0.218)	(0.302)	(0.324)	(0.136)	(0.173)	(0.228)
2 shocks or more at birth	-0.652^{+}	-0.501	-0.910^{+}	0.224	-0.148	0.759*
	(0.386)	(0.531)	(0.552)	(0.213)	(0.309)	(0.314)
Observations	1512	770	742	1512	770	680
			D. Schooling			
	Educational attainment			Age for grade $\geqslant$ 3		
1 shock at birth	0.056	0.165	-0.100	-0.041	-0.055	-0.008
	(0.089)	(0.115)	(0.136)	(0.096)	(0.129)	(0.145)
2 shocks or more at birth	-0.156	0.164	-0.470^{+}	0.146	0.025	0.327
	(0.166)	(0.212)	(0.256)	(0.178)	(0.259)	(0.256)
Observations	1556	792	764	1449	738	711

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education) and sex of the adolescent. Note that wealth score is not controlled for in these estimations. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

D Possible mechanisms

Anthropometrics

Early-life physical development is an important determinant of later-life cognitive outcomes. The gender differences we find could therefore stem from the fact that economic shocks at birth impact the physical development of girls differently from that of boys in the early years of life, leading to differences in cognitive and educational outcomes in adolescence. However, Table D1 shows that adolescents who experience economic shocks during the year of their birth do not appear to have different anthropometric characteristics as measured by height and height z-scores[6], where height is generally used as a proxy for stress exposure and deprivation experienced in utero and early in life (Beach *et al.* 2018; Currie and Vogl 2013; Parman 2015; Thomas *et al.* 1990; WHO 1995). Note that this holds true for both girls and boys. For a sub-sample of adolescents, we also have measures for their height in early childhood, as part of data collected for the 2008 MLSFH survey. We do not find any statistically significant associations between economic shocks during the year of birth and adolescent's height and height z-scores[7] measured during early childhood in 2008 (Table D2). Our results indicate that adolescent's height and height z-score are not affected by economic shocks experienced at birth. We therefore find no evidence for a biological impact using height. This is however a rough marker for biological development and may not be adequate to capture more subtle physiological changes.

Investment in schooling

We start our analysis by looking closely at the importance of early investment in education. Adolescents who live in households that experience economic shocks during the year of birth might receive lower investment in education, which could result in lower cognitive and educational outcomes later in life. The 2010 MLSFH survey contains a module on investment in education in which respondents were asked how much they have invested in the investment of children in their household who were between 5 and 25 years of age. We merge this information to adolescents in our sample to assess to what extent their experience of a negative economic shock at birth affected the investment in education of their caregiver in 2010. Note that the following

[6]The z-score is derived using the characteristics of the height distribution in our sample of adolescents. It is sex and age (in years) specific. We cannot use the WHO growth standards to compute the z-score because these standards exist only for children up to 5 years of age.

[7]The z-score is derived using the WHO standard height characteristics, which are available only for children up to 5 years old.

analysis is restricted to adolescents who were born in 2005 and before, which results in a substantial reduction in the size of our sample.

As detailed below, we find suggestive evidence that investment in education could be the reason why we observe negative associations between economic shocks at birth and cognitive outcomes and educational attainment for girls but not for boys. We find evidence that these gender differences possibly stem from changes in investment in education, where boys appear to be relatively protected from cuts in investment whereas girls suffer from investment cuts following negative economic shocks that occur during the year of their birth.

Table D3 presents the associations between experiencing an economic shock at birth and educational investment.[8] Because of the nature of our dependent variable, we estimate two-part models to account for the large number of 0's and the substantial skewness in the distribution, which are typical in expenditure data. We specify our two-part model by choosing a probit specification for the extensive margin analysis, a log transform for the link function[9] and a gamma distribution to define the variance as being proportional to the square of the mean of our outcome variable.[10] The results of the associations between economic shocks and investment in education, both at the extensive (probit) and intensive margin (GLM) are presented in Table D3. The outcome variable in the first three columns corresponds to the total amount that was invested in education in 2010 for a particular adolescent in the ACE sample. Columns 4 to 6 and 7 to 9 break this total down by whether the amount is coming from the household or by someone else outside the household. Note that in this specification we control for the total number of children present in the household, the total number of girls, the age order and the number of children that are reported in the educational investment module of the 2010 MLSFH survey. Column 3 of Table D3 shows that girls who experienced a negative economic shock during the year of birth received lower educational investment from their households compared to girls

[8] Again, because of the small sample size, we are unable to differentiate between adolescents who experienced one or more shocks at birth and hence present results in which these two categories are combined.

[9] In our benchmark specification, the θ coefficient of a Box-Cox approach test is equal to 0.131, which is close to 0 and hence corresponds to the natural log transform (Deb and Norton 2018). The result is very similar when we do not control for any covariates in the specification.

[10] We follow Deb and Norton (2018) and proceed to a modified Park test (Park 1966) that consists in estimating a GLM (with log link and gamma distribution) from which we derive the conditional expected mean and squared error term for each observation. We then regress the squared error term on conditional expected mean and look at the value of that coefficient to determine the most appropriate distribution to use. In our benchmark specification, the coefficient associated with that regression equals 2.220, and we cannot reject the hypothesis that the coefficient is equal to 2 (p-value=0.680), which suggests the use of a gamma distribution (Deb and Norton 2018).

who did not experience any shocks at birth. The lower investment is coming from the intensive margin, meaning that girls who experienced a shock at birth were not more or less likely to receive a positive amount, but the amount they were receiving was significantly lower than others. We do not observe corresponding associations for boys (Column 2). When examining where the money is coming from, we observe that it is mostly the investment in education coming from persons outside the household that reduce the investment on girls—both at the intensive and extensive margins—whereas the household itself does not seem to change its investment in education behavior after an economic shock.

Tables D4 and D5 show that it is economic shocks at birth that affect investment in education later in life, and that economic shocks that occur two years after the year of birth do not lead to similar associations. This is surprising given that shocks that occur two years after the year of birth are temporally closer to when decisions about investment in schooling are made.

Moreover, our analysis suggests the presence of some compensatory behaviors in terms of investment in education for boys. Table D6 shows that economic shocks that occur during the year of birth of a boy not only increase mean investment in education for boys within the household, but that economic shocks during the year of birth of girls increase mean investment on boys as well.

Finally, we show that investment in education at the household level predicts the cognitive and educational outcomes of the adolescents in our sample. Table D7 analyzes the associations between investment on schooling (at the household level) and cognitive outcomes, when considering investment in education as a continuous measure using a inverse hyperbolic sine transformation.[11] This table suggests that higher investment in education at the household level appears to be particularly beneficial for girls and less so for boys. This is consistent with the results from the previous table: girls outcomes are more sensitive to investment in education, and economic shocks decrease the amount of investment that is spent on their own education.[12]

[11] This transformation is roughly similar to the natural logarithm but allows for 0 (specifically, the transformation approaches $\ln(x+1)$ for small values of X, and $\ln(x)$ for large values of x).

[12] Ideally, one would want to assess the effects of economic shocks at birth on investment in education for a particular child and consequently their effects on cognitive and educational attainment. It is however not possible to do so in our sample given that we have information about investment in education only for adolescents who are born prior to 2005.

Table D1: Associations between economic shocks at birth and anthropometric characteristics of the adolescents measured in 2017/2018

	Height in cm			Height z-score		
	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)
1 shock at birth	0.463	0.066	0.953	0.080	0.020	0.141
	(0.504)	(0.661)	(0.764)	(0.072)	(0.091)	(0.110)
2 shocks or more at birth	0.647	0.447	1.014	0.094	0.080	0.143
	(0.837)	(1.159)	(1.193)	(0.122)	(0.167)	(0.177)
Observations	1499	767	732	1499	767	732

Note: The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table D2: Associations between economic shocks at birth and anthropometric characteristics of the adolescents measured in 2008

	Height in cm			Height z-score		
	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)
Shock at birth	-0.940	-0.706	-0.766	-0.175	-0.115	-0.141
	(0.750)	(0.990)	(1.232)	(0.226)	(0.309)	(0.355)
Observations	313	157	156	313	157	156

Note: The sample is derived from the ACE sample collected in 2017 and 2018 and match to information collected in 2008 as part of the 2008 MLSFH survey. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years), month of birth and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table D3: Associations between economic shocks and investment in education

	Total			Household			Others		
	All	Boys	Girls	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Extensive margin (Probit)									
Shock at birth	0.020	-0.061	0.138	-0.009	-0.101	0.114	-0.179	0.090	-0.615^{+}
	(0.182)	(0.235)	(0.265)	(0.181)	(0.233)	(0.265)	(0.206)	(0.271)	(0.340)
Intensive margin (GLM)									
Shock at birth	-0.144	0.328	-0.417^{+}	-0.037	0.212	-0.196	-0.618	0.500	-1.436*
	(0.170)	(0.249)	(0.224)	(0.172)	(0.263)	(0.218)	(0.467)	(0.744)	(0.578)
Observations	692	333	359	694	334	360	694	333	361

Note: The sample is derived from the ACE sample collected in 2017 and 2018 for which we have information about the amount that were spent for their schooling. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household, sex of the adolescent, total number of children present in the household, the total number of girls, the age order and the number of children that are reported in the educational investment module of the 2010 MLSFH survey. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table D4: Associations between economic shocks and investment in education - including only shocks that occurred 2 years after the year of birth

	Total			Household			Others		
	All	Boys	Girls	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Extensive margin (Probit)									
Shock 2 years after birth	0.012	0.113	-0.122	0.049	0.163	-0.084	-0.027	-0.067	0.037
	(0.124)	(0.168)	(0.180)	(0.123)	(0.163)	(0.179)	(0.141)	(0.204)	(0.194)
Intensive margin (GLM)									
Shock 2 years after birth	-0.030	0.130	-0.147	-0.077	0.110	-0.234	-0.005	0.341	0.259
	(0.112)	(0.151)	(0.155)	(0.111)	(0.151)	(0.158)	(0.309)	(0.407)	(0.368)
Observations	692	333	359	694	334	360	694	333	361

Note: The sample is derived from the ACE sample collected in 2017 and 2018 for which we have information about the amount that were spent for their schooling. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household, sex of the adolescent, total number of children present in the household, the total number of girls, the age order and the number of children that are reported in the educational investment module of the 2010 MLSFH survey. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table D5: Associations between economic shocks and investment in education - including also shocks that occurred 2 years after the year of birth

	Total			Household			Others		
	All	Boys	Girls	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Extensive margin (Probit)									
Shock at birth	0.023	-0.047	0.101	0.001	-0.081	0.090	-0.187	0.082	-0.616^{+}
	(0.183)	(0.238)	(0.262)	(0.182)	(0.235)	(0.263)	(0.209)	(0.270)	(0.344)
Shock 2 years after birth	0.014	0.110	-0.106	0.049	0.157	-0.070	-0.042	-0.061	-0.006
	(0.124)	(0.169)	(0.179)	(0.124)	(0.163)	(0.177)	(0.144)	(0.203)	(0.200)
Intensive margin (GLM)									
Shock at birth	-0.154	0.347	-0.475*	-0.051	0.223	-0.259	-0.625	0.740	-1.355*
	(0.174)	(0.253)	(0.225)	(0.173)	(0.265)	(0.215)	(0.470)	(0.925)	(0.677)
Shock 2 years after birth	-0.044	0.149	-0.200	-0.081	0.118	-0.257	-0.042	0.465	0.143
	(0.113)	(0.152)	(0.158)	(0.112)	(0.152)	(0.158)	(0.304)	(0.501)	(0.396)
Observations	692	333	359	694	334	360	694	333	361

Note: The sample is derived from the ACE sample collected in 2017 and 2018 for which we have information about the amount that were spent for their schooling. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household, sex of the adolescent, total number of children present in the household, the total number of girls, the age order and the number of children that are reported in the educational investment module of the 2010 MLSFH survey. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table D6: Associations between economic shocks at birth and investment in education at the household level

	Mean investment on boys		Mean investment on girls	
	Boys	Girls	Boys	Girls
	(1)	(2)	(3)	(4)
Extensive margin (Probit)				
Shock at birth	0.028	0.466*	0.260	0.105
	(0.202)	(0.226)	(0.187)	(0.161)
Intensive margin (GLM)				
Shock at birth	0.264^{+}	-0.014	0.206	0.141
	(0.148)	(0.157)	(0.163)	(0.159)
Observations	431	403	480	562

Note: The sample is derived from the ACE sample collected in 2017 and 2018 for which we have information about the amount spent on education at the household level. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household, sex of the adolescent, total number of children present in the household, the total number of girls, the number of children that are reported in the educational investment module of the 2010 MLSFH survey as well as their average age and the one of the girls in the module. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table D7: Associations between investment in education and cognitive and educational attainment outcomes

	All	Boys	Girls	All	Boys	Girls
	(1)	(2)	(3)	(4)	(5)	(6)
			Summary index			
	Continuous outcomes			Discrete outcomes		
Investment in education (ihst)	0.028**	0.025+	0.031*	-0.022*	-0.012	-0.033*
	(0.010)	(0.014)	(0.013)	(0.011)	(0.015)	(0.013)
Observations	1632	819	813	1632	819	813
			A. Reading skills			
	Reading score			Can't read Chichewa		
Investment in education (ihst)	0.093**	0.069	0.113*	-0.034*	-0.017	-0.054**
	(0.036)	(0.049)	(0.045)	(0.016)	(0.021)	(0.021)
Observations	1616	812	804	1612	809	803
			B Working memory			
	Working memory score			Score of 0		
Investment in education (ihst)	-0.005	0.001	-0.011	-0.004	0.017	-0.028
	(0.022)	(0.028)	(0.028)	(0.024)	(0.032)	(0.032)
Observations	1317	654	663	1310	650	660
			C. Mathematical skills			
	Math score			Score of 0		
Investment in education (ihst)	0.095*	0.070	0.121*	-0.023	-0.022	-0.033
	(0.038)	(0.053)	(0.047)	(0.020)	(0.026)	(0.027)
Observations	1590	797	793	1583	793	715
			D. Schooling			
	Educational attainment			Age for grade $\geqslant 3$		
Investment in education (ihst)	0.080**	0.071**	0.090**	-0.043*	-0.027	-0.062**
	(0.016)	(0.022)	(0.020)	(0.018)	(0.025)	(0.023)
Observations	1632	819	813	1494	760	734

Note: The sample is derived from the ACE sample collected in 2017 and 2018 for which we have information about the amount spent on education by their household. All regressions control for age (in years) and region fixed effects, age and marital status of the caregiver at birth, educational level of the caregiver (no school, primary level of education, secondary level of education and higher of education), a continuous wealth index of the household and sex of the adolescent. We also control for the number of children living in the household. "ihst" stands for inverse hyperbolic sine transformation. Standard errors are clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$).

Table D8: Indirect tests for mortality selection

	Female OLS (1)	Female OLS (2)	Female Probit (3)	Female Probit (4)
1 shock at birth	-0.049	-0.028	-0.124	-0.070
	(0.033)	(0.035)	(0.082)	(0.087)
2 shocks or more at birth	0.012	0.074	0.031	0.190
	(0.058)	(0.061)	(0.145)	(0.155)
Age: 11 years old		-0.076		-0.194
		(0.062)		(0.159)
Age: 12 years old		0.009		0.024
		(0.062)		(0.155)
Age: 13 years old		0.063		0.158
		(0.062)		(0.155)
Age: 14 years old		0.016		0.039
		(0.061)		(0.153)
Age: 15 years old		0.061		0.153
		(0.066)		(0.167)
Age of the caregiver at birth		-0.000		-0.000
		(0.001)		(0.003)
South region		0.033		0.084
		(0.032)		(0.081)
North region		0.036		0.090
		(0.036)		(0.090)
Caregiver married at birth		0.010		0.027
		(0.038)		(0.097)
Primary level education - caregiver		0.020		0.051
		(0.033)		(0.083)
Secondary level education - caregiver		-0.015		-0.039
		(0.058)		(0.147)
Wealth score		0.010		0.026
		(0.007)		(0.019)
Observations	1559	1556	1559	1556

Note: Standard errors in parentheses clustered at the household level ($^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$). The coefficients are the results of linear regressions for which the outcome variable is a dichotomous variable that takes the values 1 if the adolescent is a girl. The sample is derived from the ACE sample collected in 2017 and 2018. Economic shocks are reported by adolescent's household as part of the MLSFH collected in 2008 and 2010.