Economics of Education Review 72 (2019) 107–120

Contents lists available at ScienceDirect

Economics of Education Review

journal homepage: www.elsevier.com/locate/econedurev

Effects of adult health interventions at scale on children's schooling: Evidence from antiretroviral therapy in Zambia☆

Adrienne M. Lucas[a,*], Margaret Chidothe[b], Nicholas L. Wilson[c]

[a] Department of Economics, Lerner College of Business and Economics, University of Delaware and NBER, 419 Purnell Hall, Newark, DE 19716, USA
[b] Department of Economics, Wellesley College, USA
[c] Department of Economics, Reed College, USA

ARTICLE INFO

Keywords:
Health
HIV/AIDS
Education
ART
Zambia

JEL classification:
I15
I18
I25
I28
J13
O15
O18

ABSTRACT

In 2007, approximately one in five children in Zambia lived with an HIV positive adult. We identify the effect of adult antiretroviral therapy (ART) availability at scale on children's educational outcomes by combining data on the expansion of ART availability with two national household surveys that include HIV testing. Through a triple difference specification, we find that the availability of ART increased the likelihood that children in households with HIV positive household heads started school on time and were the appropriate grade-for-age. Two mechanisms were likely decreased incidental infections in the household and related care giving duties.

1. Introduction

In the southern cone of Africa more than 10 percent of prime aged adults are HIV positive and 20% of children live with an HIV positive adult, creating a public health crisis with multigenerational effects (UNAIDS, 2015). HIV has no cure. Instead, the international response has been to treat those already infected and try to prevent additional infections. The primary treatment response has been the subsidized distribution of adult antiretroviral therapy (ART) to infected adults. Epidemiological studies have shown that the adherence to the prescribed ART regime increases adult health (Hammer, 1997; Wools-Kaloustian et al., 2006), and this improved adult health could have important benefits for children. Previous research has shown the effect of ill adult health on children. For example, Pitt and Rosensweig (1990), Yamano and Jayne (2005), and Evans and Miguel (2007) found that the ill health of others in the household impeded children's educational access and attainment through care giving duties, labor substitution, and money available for nutrition and school expenses. In this paper we focus on the opposite question: the effect of a national, adult public health intervention on the children of the targeted adults. Specifically, we estimate the impacts of the at-scale, i.e. national, provision of ART on the schooling of children living in households with infected adults. Even though the national and international response to HIV/AIDS has been to provide free or subsidized ART, the effect of adult ART provision at scale (and corresponding improvement in adult health) on children's schooling is unknown. Research is complicated by both a lack of data and compelling sources of exogenous variation in exposure to treatments. This study will provide

☆ Lucas greatfully acknowledges support from a University of Delaware General University Research grant. For useful comments and suggestions, we thank Natalie Bau, Jim Berry, Tushar Bharati, Kristin Butcher, Marcus Goldstein, Pinar Keskin, Isaac Mbiti, Patrick McEwan, Jonah Rockoff, Manisha Shah, Kartini Shastry, Matt White, and seminar participants at Drexel University, Haverford College, International Food Policy Research Institute, Northeastern University, Swarthmore College, Temple University, the University of Delaware, the University of South Florida, Virginia Tech, the International Health Economics Association World Congress, the Northeast Universities Development Consortium Conference, and the United Nations University WIDER Conference on Human Capital and Growth. For excellent research assistance we thank Anna Keleher and Samantha Sweeney.

* Corresponding author.
E-mail address: alucas@udel.edu (A.M. Lucas).

https://doi.org/10.1016/j.econedurev.2019.04.006
Received 27 October 2017; Received in revised form 13 February 2019; Accepted 13 April 2019
Available online 09 May 2019

the first estimates of the effect of a large scale subsidized adult ART program on children's schooling.

We identify the effect of the availability of adult ART on children's schooling through the timing and location of free ART availability and variation in adult HIV status, a triple difference specification. Zambia, the focus of our study, is one of the highest HIV prevalence countries in the world and has one of the most successful ART distribution campaigns in sub-Saharan Africa as one of the original President's Plan for AIDS Relief (PEPFAR) target countries. Prior to the availability of ART in Zambia, one in seven adults aged 15–49 was HIV positive and one in five children of primary school age was living with a mother, father, or household head who was HIV positive (DHS 2002). In 2003 ART was effectively unavailable and by 2007, 40% of households were within 10 km of a treatment facility that distributed free ART. We combine unique health facility level data on the dates of initial ART availability and geographic coordinates of the facilities that provided ART with two national household surveys that include HIV testing modules. Because we are studying a nationwide program at scale, unfortunately we are somewhat limited by the available data. Due to privacy concerns we are unable to assign exact HIV status to all of the adults in our sample. In the interest of symmetry and to alleviate concerns of selective test refusal, we instead rely on the likely HIV status of the individual based on the HIV status of others in the demographic group. More details on the exact construction of this measure are in the Data Section.[1] We include extensive controls in our primary specifications and numerous robustness checks to ensure that this data limitation is not confounding our estimates.[2]

Our triple difference is then the interaction of a health facility ever providing free ART (spatial variation), whether the health facility distributed free ART prior to the date of the household survey (temporal variation), and the likely HIV status of adults in the household (variation in likely HIV status). This triple difference identifies the effect of adult ART availability on children's educational outcomes in households with likely HIV positive adults, net of any location, time, or location by time variation that is common to both likely HIV positive and likely HIV negative households (e.g. differential development trends by region). Further, it controls for any differences across time for likely HIV positive and negative households. While we are unaware of any education programs that targeted children in HIV positive households or any programs that targeted households near to health facilities that distributed ART, our use of the interaction of likely HIV status and a time dummy variable and the use of the interaction of being near a health facility that distributed ART and a time dummy variable would control for these possibilities. Finally, we are unaware of any concurrent programs that specifically targeted HIV positive households in locations in which ART was available, other than the specific ART availability.[3] Therefore, our estimates are the effect of adult ART availability on children's educational outcomes.

We find that expanded ART availability increased the likelihood that primary school aged children who lived with a likely HIV positive household head enrolled in school on time and were the correct grade for age, a proxy for timely school progression. We do not find any evidence that ART availability differentially increased the likelihood of children being enrolled in school beyond the first two years of primary school, perhaps not surprising given that government primary schools did not charge fees, eliminating a common enrollment barrier. The results are similar if the reference adult is the mother or father. Because our labor market participation measures are coarse, we cannot confirm or reject that this increase is due to changes in the extensive margin of the adult labor supply. In contrast, we find substantial decreases in illness among children under 5, indicating that one potential mechanism is a decrease in incidental infections in the household or related care giving duties.

One strand of the existing economic literature on HIV/AIDS has focused on the detrimental relationship between adult HIV and adults' and children's outcomes. Both Akbulut-Yuksel and Turan (2013) and Fortson (2011) found that children in households with an HIV positive mother or in regions with a high with HIV prevalence had less schooling than expected. Ainsworth and Filmer (2006) and Kasirye and Hisali (2010) found a decrease in child school attendance during parental illnesses and prior to parental death. Focusing on adults only, Levinsohn, McLaren, Shisana, and Zuma (2013) used propensity score matching and found that HIV positive adults in South Africa were less likely to be employed.

Another strand of the literature has focused on the effects of the free or subsidized provision of ART and has taken one of three approaches. The first type used smaller scale clinic- or employer-based studies and focused on HIV positive adult recipients of ART with variation coming from the timing of the initiation of treatment. All individuals in these studies had sought treatment and were adhering to treatment. Hammer (1997) and Thirumurthy, Zivin, and Goldstein (2008) used longitudinal data on individuals in Western Kenya and found that the initiation of ART increased recipients' labor supply and that children in household's with HIV positive adults increased their weekly school attendance by over 20%. Habyarimana, Mbakile, and Pop-Eleches (2010) used a similar strategy with longitudinal data from a diamond company in Botswana and found that the initiation of ART decreased worker absenteeism. A second approach relied on temporal and spatial variation in ART availability, effectively difference-in-differences, but considered the effect on the whole population regardless of HIV status (e.g. Baranov & Kohler, 2014; Bendavid, Holmes, Bhattacharya, & Miller, 2012; Friedman, 2014; McLaren, 2010). A third approach used a strategy similar to the current paper with the HIV status of individuals or other adults in the household as an additional source of variation. Baranov, Bennett, and Kohler (2015) used HIV status to limit their analysis to HIV negative households and found that ART availability increased the intensive margin of labor supply in three rural districts in Malawi. Lucas and Wilson (2013) and Lucas and Wilson (2018) used a similar identification strategy to the current paper and found that the

[1] Formally, for each individual we define their demographic group by gender, age, province, and living in an urban or rural location, the most precise group possible given the privacy concerns.

[2] Zambia is not the only African country with two national Demographic and Health Surveys (DHS) household modules undertaken since 2000. We selected Zambia for this study for three reasons. First, we wanted a country with a severe HIV epidemic, and only four countries with two DHS since 2000 – Lestho, Malawi, Zambia, and Zimbabwe – have HIV prevlance levels above 7%. Second, we wanted a country with a relatively rapid and widespread expansion of PEPFAR related activities between the two survey rounds. As of 2017, Lestho had not yet reached the level of ART coverage Zambia had in 2007. Malawi only recently reached that level, and its second DHS was seven years ago. Finally, we chose not to study Zimbabwe since between the two DHS rounds (2005 and 2011) the country experienced massive hyperinflation and a collapse of basic health services. Further, we limit our study within Zambia to the period ending in 2007 for two reasons. First, all data were collected during PEPFAR I when the focus was primarily on expansion of ART availablility and not broader support of the health sector. When PEPFAR was reauthorized by the US Congress in 2008 and became PEPFAR II, the focus expanded to include broader support for the health sector, which could confound our estimates. Second, as PEPFAR's scope expanded, it started reaching clinics that were not in place prior to the start of the ART program; clinics that could have been endogenously placed, causing bias in our estimates. Therefore, while our data might not be ideal, they are the best available to study the effect of ART scale-up on educational outcomes.

[3] During the period under study (2002–2007), a social safety net of cash transfers operated in only four of the seventy-two districts in Zambia. These cash transfers targeted the most destitute households (Regional Hunger and Vulnerability Program 2007). Even though HIV status was not part of the selection mechanism, to ensure that this program is not biasing our results, in the robustness section we remove these districts from the analysis.

availability of adult ART increased the weight of children under 5 years old in households with likely HIV positive adults and the weight of likely HIV positive women.

Our paper adds to the existing literature on five important margins. First, we have longer run outcomes (e.g. grade progression and enrollment decisions) that were not available in previous studies. Second, because we are using a national household survey we are able to estimate the effect over all HIV positive households, even those who did not seek, were not yet eligible given their disease progression, or did not adhere to treatment. Existing studies focus on individuals seeking and adhering to care at clinics. In a low-resource setting providing public health at-scale could have very different effects than providing care in individual clinics. Third, our estimates are the net effect on HIV positive households, eliminating any changes in outcomes that are common across all households. Fourth, we test the opposite side of the literature that has found that parental illness has negative effects on children's schooling – can at scale public health improve parental health to overcome this deficit? Fifth, the ART distribution and expansion model in Zambia is common to other countries supported by the United States President's Emergency Plan for AIDS Relief (PEPFAR), and our estimates present a likely scenario for similar PEPFAR supported countries.

2. Background

2.1. HIV/AIDS

The HIV/AIDS epidemic is one of the most pressing public-health challenges faced by developing countries, especially those in the southern cone of Africa where more than 10% of the population aged 15–59 are afflicted with the disease (UNAIDS, 2015). HIV is a virus, primarily transmitted through heterosexual intercourse in sub-Saharan Africa (Dunkle et al., 2008). The initial symptoms of HIV are similar to a mild flu. This disease then remains with infected individuals, causing a slow decline in health as the immune system weakens and the disease progresses to AIDS. The most common measure of the robustness of an individual's immune system in the context of HIV/AIDS is an individual's CD4 T-cell count per micro liter of blood. CD4 T-cells are white blood cells that are responsible for fighting infections. As the disease progresses, these cells are destroyed resulting in infected individuals' immune systems to progressively weaken. This decrease in white blood cells leads to increased likelihood of malaria, tuberculosis, severe influenza, and other infectious diseases even prior to the onset of AIDS (Whitworth et al., 2000; Cohen et al., 2013; Sonnenberg et al., 2005).

Untreated HIV eventually leads to AIDS when an individual's immune system is severely compromised with fewer than 200 CD4 T-cells per micro liter of blood. The rate of clinical progression from initial HIV infection to AIDS has been observed to vary between individuals, from 2 weeks up to 20 years (Navarro, 2000). In the absence of treatment, the median time of progression from HIV to AIDS is 9–10 years (UNAIDS Inter-Agency Task Team on Education, 2000). In the absence of antiretroviral therapy, estimates of the median survival time upon the manifestation of AIDS is about one year (Lee, 2001; Morgan, Mahe, Mayanja, & Whitworth, 2002).

HIV/AIDS does not have a cure. Instead, infected individuals are prescribed anti-retroviral therapy (ART), a drug cocktail therapy that impedes the course of HIV/AIDS and has been shown to improve the health status of HIV positive patients (Hammer, 1997; Wools-Kaloustian et al., 2006).

2.2. HIV/AIDS in Zambia

In Zambia the first reported AIDS case was in 1984 (World Health Organization, 2005). Small scale state provision of subsidized ART began in Zambia in 2002 at the University Teaching Hospital in Lusaka and at the Ndola Central Hospital in Ndola. Even with partial subsidization, the annual cost of treatment totaled at least US$2000, one and a half times an urban nurse's salary, almost four times a cleaner's salary, and more than four times the per capita GDP of Zambia (International HIV/AIDS Alliance, 2004). In addition a limited number of private companies, in particular the mining industry, provided ART to their employees at a subsidized rate.[4]

The official commitment to the provision of universal free ART to adults occurred in June 2004 (World Health Organization, 2006). Since this announcement, both the Global Fund to Fight AIDS, Tuberculosis and Malaria and the United States President's Emergency Plan For AIDS Relief (PEPFAR) have donated hundreds of millions of dollars annually to increase ART availability. In 2005, the average price for the most common ART drug combinations was US$268 per treated person per year (World Health Organization, 2006). In Zambia, this expense was paid by donors and not the individual recipients.

During the period under study, the WHO standard followed in Zambia was to provide ART at the start of a patient's descent into AIDS, at approximately a CD4 T-cell count of around 200 per micro liter of blood (Stringer et al., 2006; World Health Organization, 2006). Since this was a previously untreated population, the average CD4 count of those treated was likely much lower, resulting in many very sick individuals receiving treatment (Médecins sans Frontiéres, 2003). In a previously untreated population in South Africa, Médecins sans Frontiéres (2003) found that after 12 months of treatment, the mean weight gain was 10 kg and patients reported a decrease in pain and discomfort and an increase in the ability to care for oneself and engage in typical activities. Further, the incidence rate of tuberculosis among the treated declined by two thirds.

The scale-up of ART provision in Zambia was dramatic. In 2003, less than 10% of those needing ART were receiving treatment and only 3 sites were open in the entire country. In 2005, 25% of those requiring treatment were receiving it from 110 different clinics (World Health Organization, 2006). Even though some private companies continued to provide treatment to their employees, over 95% of those treated were receiving treatment in the public sector (World Health Organization, 2006).

The scale-up of treatment facilities started with the most advanced hospitals (Zambia Ministry of Health, 2008).[5] Each province had at least one such facility, but many households were not within a reasonable treatment distance. The program was then extended to smaller primary care facilities, e.g. district hospitals and health centers. By the end of 2007, 64% of the 440,000 people in Zambia needing ART had access to it, and a third of all health facilities in the country were able to offer treatment (Zambia Ministry of Health, 2008).

During our period of study, almost all individuals who were treated received the "first-line" ART treatments that are cheaper and easier to administer than later stage treatments (World Health Organization, 2006).[6] Even though the ART was free to recipients, some

[4] Our health facilities data do not include clinics that only served specific corporations. Therefore, individuals who received ART through their employers prior to the wider availability of ART will be misclassified as not receiving ART.

[5] In our triple difference specification we include interaction terms that control for time varying differences between locations that did and did not receive ART in addition to controls for any time invariant differences between districts. See Section 3 for additional details.

[6] Most of the ART treatment during the period of our study was for adults. In 2005, about 8% of the recipients of ART in the public sector were children (WHO 2006). We will not be able to rule out this direct treatment of children as the cause of our results, but given the number of adults versus children treated, the direct treatment is likely not the dominant channel. Further, during the period of ART scale-up, ART regimens were also used for the prevention of mother-to-child transmission (PMTCT). Even the earliest beneficiaries of PMTCT would not be old enough to appear in the schooling data that we use for the analysis. A 2009 study of Cameroon, Cote d'Ivoire, South Africa, and

clinics continued to charge user fees. By early 2006 all of these point of service user fees for HIV treatment had been eliminated (World Health Organization, 2006).

Since ART has been shown to be more effective if provided to someone who was well nourished, ART clinics in Zambia provided nutritional advice and counseling to those receiving ART. Since these two actions coincided, we cannot separately identify their effects. As this coupling is often standard practice in ART provision, one would expect a similar program in other settings.[7]

Despite being shown to increase patient health in clinic based studies, ART taken to scale in a low resource setting could be less effective. First, during PEPFAR I, the treatment period of our study, the focus was the rapid distribution of ART treatments, and money and support was not provided to support the health sector more broadly. Therefore, distributing ART and providing follow-up care to HIV patients could have offset other health facility activity. Second, unlike clinic based studies, patients might not correctly adhere to the prescribed regime. Based on a study in 2005–2007 in Kenya, 29% of ART patients dropped out of their program for at least 90 days (Unge et al. 2009)

2.3. Education in Zambia

Primary school in Zambia starts at age 7, lasts 7 years, and is not compulsory (UNESCO, 2010). Secondary education spans grades 8–12, and students are typically aged 15–19 years old (Zambian Ministry of Education, 2011).

In 2002 Zambia introduced the Free Basic Education (FBE) program that eliminated the school fees for grades 1–7 (Zambian Ministry of Education, 2011).[8] School uniforms were no longer compulsory, but many schools continued to require them. Further, some schools continued to administer supplementary fees for school development projects, and parents were still responsible for books, other supplies, transportation, and food. Therefore, despite the elimination of formal fees, both other schooling related expenses and the need to work to earn money continued to be a barrier to schooling for some children (Robson & Sylvester, 2007). According to official statistics, approximately 7% of students in primary school in 2005 repeated a grade (UNESCO, 2010). Children continue on to a subsequent grade based on the assessment of their current teachers in consultation with their parents.

3. Empirical strategy

We exploit the scale-up in the availability of free ART in a triple difference specification to identify the effect of adult ART availability on children's schooling outcomes. The primary conceptual difficulties in identifying the effects of adult ART are the non-random placement of treatment centers and take-up, retention, and adherence to treatment. Within a country, or even between countries, regions that were earlier recipients of ART could be richer or have a higher population densities, attributes that could affect children's schooling independent of ART availability. Further, not all infected adults might seek or adhere to treatment, resulting in clinic-based estimates differing from the effects at scale. Our triple difference strategy overcomes both of these difficulties by identifying the effect of adult ART availability off of the differences between likely HIV positive and likely HIV negative individuals and using household instead of clinic based surveys. Our estimates are the net effect of the scale up of ART, not necessarily the take-up, retention in care, and adherence to ART.

To identify the effect of ART at scale, we rely on variation in geography, survey timing relative to initial ART provision, and adult HIV status. The household data are repeated cross-sectional household surveys collected in 2002 and 2007 that we combine with unique data on the start date and geographic coordinates of each ART service provider.[9] More details on the data appear in Section 4. Formally, we estimate the effect with a triple difference specification

$$\begin{aligned}Y_{ijt} = \alpha + \beta(HIV_{ijt}{*}ART_j{*}post_t) + \gamma_1 HIV_{ijt} + \gamma_2 ART_j \\ + \gamma_3 post_t + \gamma_4(HIV_{ijt}{*}ART_j) + \gamma_5(HIV_{ijt}{*}post_t) + \gamma_6(ART_j{*}post_t) + \mathbf{X}'_{ijt}\mathbf{\Gamma} \\ + \varepsilon_{ijt}\end{aligned} \quad (1)$$

where Y_{ijt} is the outcome of interest (e.g. enrolled in school, being the correct grade for age) for individual i in geographic cluster j at time t, HIV_{ijt} is the likely HIV status of the reference adult (e.g. household head) for child i, ART_j is a dummy variable that takes the value of 1 if the household is within 10 km of an ART treatment center in 2007, and $post_t$ is a dummy variable that takes a value of 1 if the household was surveyed in 2007.[10] $\mathbf{X}'_{ijt}$ contains additional control variables: dummy variables for the month of survey, female, living in an urban location, the age group of the reference adult, interactions between the reference adult age group and $post_t$, the age of the child, the district, and the interactions between district dummy variables and $post_t$. We assume our standard errors, ε_{ijt}, are independent across districts but allow them to correlated within a district.[11] The coefficient of interest is β, the effect of having a clinic that distributes ART near a household with an HIV positive reference adult. Because we include dummy variables that jointly vary by location and survey timing, this effect is net of any other temporal or spatially varying attributes that might be common across likely HIV positive and likely HIV negative households (e.g. a change in the price of copper that might differentially affect districts in the "post" period). By design we are focusing our analysis on the households of those targeted to benefit directly from ART. Further because we are including dummy variables for the age group of the reference adult and its interaction with post and dummy variables for the child's age, we are controlling for life cycle dynamics. For such dynamics to be biasing our results they must be both differential by ART availability and HIV status. In our robustness section we include additional controls for birth order.

One of our main education outcomes of interest is whether the child is the correct grade-for-age. This measure combines timely entry and progressing through one grade each year. Students who start school after the official age of entry of seven will never be grade-for-age, while even those who start on time could be retained in a grade, causing them to no longer be grade-for-age.

At a minimum, this measure captures a delay in eventual educational attainment, at a cost to the schooling sector in the inefficient use of resources if students are spending multiple years in a single grade and to students in a delayed start of their working lives and therefore

(*footnote continued*)
Zambia found that fewer than 50% of infants born to HIV positive mothers at health centers that provided PMTCT completed the full course of treatment (UNICEF, 2009), and a WHO report based on data from 2008 deemed that Zambia had made "no progress" towards the millenium development goal of reducing the under 5 mortality rate (World Health Organization, 2010). Even if additional younger siblings survived, the effect of this survival on older siblings is uncertain, but the survival is unlikely to generate an increased likelihood of school attendance.

[7] A more comprehensive food assitance program that included supplemental nutrition assistance was started in February 2009, after our window of study (Tirivayi & Groot, 2014).

[8] While not contemporaneous to the increased provision of ART, this program did occur between the our first household survey (2002) and our second household survey (2007). Our triple difference specification removes any policy changes that uniformly affected households regardless of HIV status.

[9] The first household survey occurred from November 2001 to June 2002. We refer to it as the 2002 survey for simplicity.

[10] For reasons of privacy and consent, exact HIV status cannot be assigned to all adults. The algorithm for attaching likely HIV status to each adult is discussed in the Data Section.

[11] In 2007 Zambia had 72 districts.

lifetime income. These are two substantial concerns in low resource settings.

In addition to being a desirable outcome itself, we believe that grade-for-age, while not perfect, is a decent proxy for a child's likelihood of completing primary school, and does not simply represent a delay in eventual educational attainment. Both Shepard and Smith (1989) and National Center for Education Statistics (1997) found that students who were not grade-for-age had lower achievement outcomes and higher drop out rates. Further, Oreopoulos, Page, and Stevens (2006) used grade-for-age among children aged 7–15 as a proxy for "children's long-run success" (page 737). While the cited studies focused on developed countries, the likelihood of dropping out as children become older could be even larger in African countries as older children are both more complementary to and easily substitutes for adult labor, increasing the opportunity cost of school as children age. Lewin (2009) based on an analysis of 44 countries in sub-Saharan Africa, highlighted both within-school and external factors that contribute to over-age students being more likely to dropout. Within the schooling environment, older students might have less motivation, be increasingly frustrated from being in a class with younger students with different levels of maturity, not be the targeted age of the pedagogy, and feel the curriculum irrelevant. External factors include an increasing opportunity cost of time and pregnancy and family obligations for girls. Consistent with these barriers to completion for older students, in Kenya, Tanzania, and Uganda, enrollment rates peak at age 11, prior to the expected age at completion of primary school (Jones, Schipper, Ruto, & Rajani, 2014). Based on data from 45 countries in sub-Saharan Africa, Ruff (2016) found a negative relationship between student grade retention and primary school completion. In Ethiopia, regions with the highest rate of grade repetition also have the highest drop-out rates (Rossiter, Azubuike, & Rolleston, 2017). As additional evidence of the difficulty in completing primary school for older students, Lucas and Mbiti (2012) found that the removal of school fees for primary school in Kenya had a smaller effect on older primary school children, especially girls. Further, most salient to girls, the likelihood of pregnancy and marriage increases with age. At age 7 in Kenya, Tanzania, and Uganda, the number of girls exceeds the number of boys enrolled in school. By age 9 this is no longer the case in Kenya and Uganda, and the number of boys exceed the number of girls by age 14 in Tanzania (Jones et al., 2014). Across all three countries girls are more likely than boys to drop out in their early teenage years. This is confirmed in Kremer, Miguel, and Thorton (2009) who note that grade 6 girls are more likely to drop out than grade 6 boys in Kenya. In KwaZulu-Natal, South Africa, each year of delayed entry increased the likelihood of a female student dropping out by 51% and grade repetition was associated with a 73% increase in school drop-out (Grant & Hallman, 2008). In Zambia, child marriage is common with 42% of marriages occurring prior to the woman reaching age 18 (Mann, Quigley, & Fischer, 2015).

The availability of ART treatment could affect the schooling outcomes for children living in households with HIV positive adults in at least eight ways. First, fewer incidences of adult illness means children will not be kept home from school to provide care or support.[12] Second, children would be less likely to be substitutes for adult labor in employment, household production, or child care.[13] Third, an increase in income could provide money necessary for school supplies, uniforms, transportation, and other school expenses. Fourth, increased household income or increased productivity of household enterprises through improved health could increase children's nutritional intake and food security, and thus increase school attendance and outcomes (Food & Agriculture Organization of the United Nations HIV/AIDS Programme, 2003; Glewwe & Miguel, 2008 for a summary of the literature on the relationship between children's nutrition and schooling outcomes).[14] Fifth, children would be exposed to fewer pathogens because adults with stronger immune systems would be less susceptible to incidental infections. Sixth, the availability of ART could reduce HIV related stigma. Seventh, a longer time horizon for parents could increase the perceived return to educating their children (Lorentzen, McMillan, and Wacziarg 2008). Finally, children who are less worried about the health status of their parents might be able to focus more on their studies. Our reduced form effect is the sum of all of the potential channels through which the presence of an ART treatment center might affect the children in a household with an HIV positive adult. Additional specifications attempt to parse out some of the potential mechanisms.

4. Data

For our analysis we combine individual survey data from two rounds of the Zambian Demographic and Health Survey (DHS) with unique data on the geographic location of health facilities in Zambia as of 2006 as well as the month and year in which these facilities started offering free ART, if this date occurred prior to June 2008.

The Zambian DHS are national household surveys with data on individual level demographic, economic, health, and education outcomes. We use two rounds of this repeated cross section. The DHS-IV survey was collected from November 2001 to June 2002, prior to the availability of free ART, and the DHS-V was collected April to October 2007, after the partial scale-up of free ART. For each child within a surveyed household the data contain gender, age, school enrollment status, and current grade as well as the gender of, age of, and relationship to the household head. If the child's mother or father are in the household, they are similarly identified. Further, for each child under the age of 60 months, the adult respondent was asked whether the child had diarrhoea, fever, or cough in the two weeks preceding the survey. At the household level the data contain the district of residence and a normalized wealth measure based on household assets.

As part of both the DHS-IV and DHS-V a subsample of females aged 15–49 and males aged 15–59 were tested for HIV. Due to privacy concerns and incomplete testing coverage, we are not able to match each adult with his or her HIV status.[15] Instead, we use an individual's likely HIV status based on the portion of individuals who tested positive for HIV in a respondent's gender by age group by province by urban status cell (e.g. 30–35 year old females in rural Northern Province). These values are calculated separately for each of the two survey

[12] Bicego et al. (2003) found that orphans were less likely to be grade for age. Our findings show that this delay could have started prior to parental death.

[13] Dillon (2013) found that children in Mali were substitutes for adult labor in child care and household production when a household adult experienced a negative health shock.

[14] Based on a 2004 cross section of households in Northern Province, Zambia prior to the widespread availability of ART, 24% of households with an HIV positive adult reported eating at most one meal per day, approximately twice as high as the percentage of households unaffected by HIV/AIDS. Further, households with an HIV positive adult reported a 9 percentage point larger decline in the amount of land under cultivation between 1997 and 2002 than unaffected households (Curry, Wiegers, Garbero, Stokes, & Hourihan, 2006).

[15] In the DHS-IV about 75% of eligible individuals were tested with the response rate appearing to be unbiased in relation to patterns of HIV infection (Dzekedzeke, 2003). In the interest of respondent privacy, the HIV test results in the DHS-IV lack unique identifiers. In the DHS-V, 75% of respondents in the relevant age ranges consented to be tested and can be linked to the test results through unique identifiers, 18% refused to be tested, and the remainder were unavailable (Tembo-Mwanamwenge & Kasongo, 2009). The reason for a missing test is not provided at the individual level. For consistency across the two samples and within each sample, we apply the same procedure to all individuals.

Table 1
Summary statistics.

	2001	2007
ART available within 10 km	0.07	0.46
	(0.26)	(0.50)
Likelihood of HIV + Household head	0.17	0.19
	(0.11)	(0.08)
Likelihood of HIV + Mom	0.21	0.21
	(0.11)	(0.09)
Likelihood of HIV+ Dad	0.16	0.19
	(0.11)	(0.08)
Mom visited clinc in prior 12 months	0.74	0.54
	(0.44)	(0.50)
Mom ever tested for HIV	0.09	0.43
	(0.28)	(0.49)
Age	11.76	11.67
	(3.36)	(3.28)
Attending school	0.67	0.82
	(0.47)	(0.39)
Grade for age	0.27	0.43
	(0.44)	(0.49)
Household has a bednet	0.31	0.71
	(0.46)	(0.45)
Bednetused previous night	0.16	0.29
	(0.37)	(0.45)
Dad is household head	0.60	0.57
	(0.49)	(0.49)
Mom is household head	0.12	0.13
	(0.32)	(0.33)
Someone else is household head	0.28	0.30
	(0.45)	(0.46)
Orphan	0.02	0.04
	(0.16)	(0.18)
Household wealth (normalized measure based on assets)	0.07	0.01
	(1.05)	(1.03)
Illness in prior two weeks		
Diarrhea	0.21	0.16
	(0.41)	(0.37)
Fever	0.45	0.18
	(0.50)	(0.39)
Cough	0.39	0.26
	(0.49)	(0.44)

Notes: Standard deviations appear in parenthesis. Source: Calculations based on 2002 and 2007 Zambia DHS. The unit of observation is a primary school aged child with five exceptions: Household wealth is at the household level for households with a primary school aged child and the four illness measures are for children aged 0–5.

rounds.[16,17] For each child we assign the likely HIV status of his household head, his mother, and his father, if these individuals were identified in the household roster.[18]

Our primary specifications use the household head as the reference adult as all children in the sample have a household head, but not all have a mother and/or father in the household for reasons that could be related to the presence or absence of adult ART therapy.[19] For about 60% of children their household head was their father, with mother as the second most likely person (12%). Thirty-three percent did not live with their mothers, 44% did not live with their fathers, and 30% lived with neither a mother nor father, but only 4% reported both parents being deceased. Robustness checks control for these different family structures.

To determine the availability of ART for a household we combine unique data on the location and date of ART availability (if ever) for the health facilities with the locations of the sample cluster centroids from the DHS.[20] We calculate whether a household was within 10 km of a ART treatment facility prior to the 2007 DHS survey, effectively calculating an "ever ART" measure for the entire sample.[21] Of all health facilities open in 2008, 242 of them (18%) started distributing ART prior to the 2007 survey. These unique health facilities data further provide the start date of other HIV services, i.e. voluntary counseling and testing and prevention of mother to child transmission, that we use in robustness checks.

Table 1 contains summary statistics, separately by DHS survey round. According to the data, 7% of the sample was within the 10km treatment radius of an ART treatment facility in the 2002 data. While technically available, ART was prohibitively expensive for most people. Therefore, in our specifications we do not consider this availability as a part of the free ART scale-up. Seventeen to 19% of children in our sample lived with an HIV positive household head, with moms, when present, somewhat more likely to be HIV positive than dads, when present. Data were not collected on initiation of treatment. Women were asked whether they visited a clinic for any reason in the last 12 months. The likelihood of visitation decreased between the two surveys, but health generally increased over this period making trips for childhood illnesses less likely. Children were more likely to be attending school and be the correct age for their grade in the 2007 survey round. Fig. 1 shows the national age profile of HIV risk. In our empirical specification we exploit variation between genders, ages, provinces, and urban vs. rural.

5. Results

We first estimate the effect of adult ART provision on children's schooling outcomes, then explore a number of potential mechanisms.

5.1. Schooling

Table 2 presents evidence of the effect of adult ART availability on three schooling measures through the estimation of Eq. (1) as a linear probability model.[22] In all columns the sample is limited to children of primary school age who have a household head in the HIV testing age range.[23] In each column the coefficient of interest is the one on the triple interaction of HIV positive * ART ever * post, the differential effect of ART availability on children in households with likely HIV positive household heads. The HIV status of the household head is calculated as explained in Section 4.

[16] Since patients taking ART are less infectious than those who are in the final stages of AIDS, one concern is that ART availability altered the HIV prevalence. We do not find evidence of this. The relationship between HIV prevalence at the cell level and portion of respondents who were within the treatment radius of an ART clinic is not statistically significant once we control for HIV prevalence in 2001 and province, urban, and female dummy variables.

[17] Our data have 481 different populated cells with an average of 27 adults in each cell.

[18] We use a broad definition of father to include both biological fathers and men married to the child's mother to increase the sample size since we cannot always differentiate between the two.

[19] Children whose parents were deceased would still be included in this analysis as long as they were living with someone aged 15 or older, even if that

(footnote continued)
person was an older sibling. In the robustness section we control for orphan status.

[20] Our data include 1349 health facilities.

[21] For privacy concerns, DHS sample cluster centroids are displaced in a random fashion, potentially leading to attentuation bias in our estimates.

[22] The appendix Table A.1 shows the general trends in schooling using a simple difference-in-differences strategy, removing the triple interaction term from Eq. (1) as well as any measure of HIV status. That table shows that education was generally increasing over the period as measured by both school attendance and being grade-for-age.

[23] Since each child in our regression must be at least 7 years old at the time of the survey, these children will have been too old to have benefited from any increased provision of PMTCT.

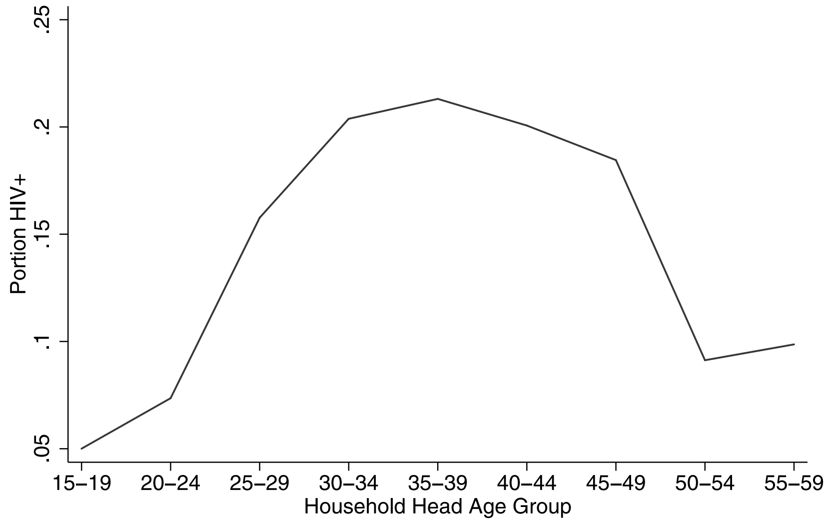

Fig. 1. Age profile of HIV status.

Table 2
Effect of adult ART on children's schooling.

	Enrolled (1)	Grade for age (2)	Timely entry (3)
HIV+ * ART Ever * Post	0.166	0.494***	0.753**
	(0.146)	(0.155)	(0.375)
HIV+	0.120	0.219**	0.377*
	(0.083)	(0.091)	(0.193)
ART Ever	0.057	0.115***	0.084
	(0.035)	(0.042)	(0.060)
Post	−0.070	0.345	0.188
	(0.177)	(0.215)	(0.423)
HIV+ * ART Ever	−0.098	−0.228**	−0.331
	(0.091)	(0.113)	(0.234)
HIV+ * Post	−0.148	−0.245	−0.425
	(0.128)	(0.154)	(0.329)
ART Ever * Post	−0.055	−0.115*	−0.162*
	(0.045)	(0.060)	(0.097)
Observations	12,128	12,128	1,933
Rsquared	0.19	0.22	0.24
Coefficient of interest in standard deviations			
HIV+ * ART Ever * Post	0.364	1.044***	1.508**
	(0.321)	(0.328)	(0.752)

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors clustered at the district level appear in parenthesis. The sample is limited to children in expected grades 1–7 with a valid HIV approximation for their household head. All columns are linear probability models and include dummy variables for child age, household head age group, district, month of survey, urban, female, household head age group times post, and district dummy variables times post.

According to column 1, ART availability did not differentially affect the likelihood that a child in a household with an HIV positive household head was enrolled in school during the current school year, an extensive measure of schooling, as the coefficient is positive but statistically insignificant.[24] In 2007, government schools did not charge fees and over 80% of the sample reported being enrolled in school. Therefore, this lack of effect might not be surprising given the low cost of enrolling in school. Further, our large standard error does not rule out a change in enrollment. In contrast, ART availability increased the likelihood that children in households with HIV positive household heads were the correct grade for their age, a measure of the intensive margin of schooling that combines timely entry and progression (column 2). Based on the magnitude of the coefficient, for a child in a household with a household head who was HIV positive with certainty, the likelihood of being grade for age increased by 49 percentage points with the availability of ART. This represents a one standard deviation increase in this likelihood. None of our demographic cells have a value of 1 for likely HIV status. Within our sample, a change from the median value of head HIV status to 0 would lead to an expected increase in likelihood of being grade for age by 8 percentage points (17% of a standard deviation), and a change from the 10th to 90th percentile would result in an expected 19 percentage point change (41% of a standard deviation). Over this period, the likelihood of being age for grade in locations that received ART increased 31 percentage points. We estimate that ART availability caused 29% of this change.

While these estimates might appear large, recall that they include all direct and indirect benefits that might accrue to children in households with HIV positive household heads due to the availability of adult ART.[25]

As noted, being grade for age is the result of starting school on time at age 7 as well as progressing through one grade each year. Unfortunately, our data do not contain either of these measures. We present results in column 3 of the effect of ART availability on timely entry only for those who should have been in their first year of school at the time of the survey. As with grade-for-age, we find a positive and statistically significant relationship between this measure of schooling and our regressor of interest. Scaling this coefficient, comparing the median HIV status to zero implies a change in the probability of timely entry of 12 percentage points (15% of a standard deviation). During this period, the likelihood of timely entry in regions that received ART increased 43 percentage points. We estimate that ART availablilty caused 31% of this change.

While the other coefficients in the table are not of direct interest to the research question, they show that children in households with HIV positive household heads were more likely to be attending school and be the correct grade for age. In Zambia, as with other countries of sub-Saharan Africa, HIV rates increase with education, and these

[24] Precisely, the survey asks whether the child has attended any school in the last year, effectively a measure of enrollment.

[25] Our results are not directly comparable to Fortson (2011), who estimates the relationship between regional HIV prevalence and completed schooling, including both HIV positive and HIV negative households. Based on her estimates, one would expect approximately 1 fewer years of schooling for 15–49 year olds due to HIV/AIDS, in the absence of treatment.

coefficients likely reflect that relationship (Fortson, 2008). Further, children from locations that ever received ART were more likely to be the correct grade-for-age. Since our identification strategy leverages temporal, spatial, and HIV status differences, these time invariant characteristics do not affect the validity of our strategy.[26]

We tested for differences by child gender across all three schooling outcomes and while the point estimates are larger for boys in all cases, we fail to reject that the coefficients are equal for boys and girls (results not presented).

Table 3 tests for differential effects by grade, replacing the single triple interaction from Eq. (1) with separate interactions for each primary grade. Unlike in the overall average in column 1 of Table 2, in column 1 of Table 3 we find that adult ART availability differentially increased the likelihood that students in primary grades 1 and 2 were attending school. Further we are able to reject the equality of coefficients across all primary grades. Therefore, for school enrollment the benefits appear to be concentrated with the youngest cohorts. And while we cannot directly test the mechanism, this finding suggests that the dominant mechanism is not care giving – or at least care giving that is preventing children from being enrolled in school – as this effect would be stronger in the older aged children. Column 2 contains analogous estimates on the effect of being grade-for-age. In this case, all grade levels are more likely to be grade-for-age with no clear age pattern, indicating that adult ART availability affects the likelihood of grade progression.

Table 3
Effect of adult ART on children's schooling – analysis by grade.

	Enrolled (1)	Grade for age (2)
Primary 1	0.484***	0.492***
	(0.170)	(0.165)
Primary 2	0.413**	0.537***
	(0.167)	(0.179)
Primary 3	0.175	0.298
	(0.151)	(0.187)
Primary 4	0.056	0.348*
	(0.160)	(0.195)
Primary 5	−0.059	0.487***
	(0.166)	(0.163)
Primary 6	−0.027	0.331*
	(0.159)	(0.192)
Primary 7	0.115	0.238**
	(0.087)	(0.096)
Test of equality of coefficients		
F statistic	8.20	1.97
p-value	0.00	0.09
Observations	12,128	12,128
Rsquared	0.20	0.23

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. The coefficients presented are those from the interaction of HIV*ART*post*relevant grade level, primary 1 through 7. Standard errors clustered at the district level appear in parenthesis. The sample is limited to children in expected grades 1–7 with a valid HIV approximation for their household head. All columns are linear probability models and include dummy variables for child age, household head age group, district, month of survey, urban, female, household head age group times post, and district dummy variables times post.

In Table 4 we provide estimates for differential effects by both distance and duration of exposure. In column 1, we replaced the triple interaction of interest in Eq. (1) with a series of 5 km distance interactions (i.e. 0–5 km, 5–10 km, 10–15 km, and 15–20 km) and included the appropriate double interactions. Based on column 1, the benefit is concentrated within 10 km of a health facility that provided free ART. The coefficients for larger distances are positive, but smaller in magnitude and statistically insignificant. This confirms our use of 10 km in our primary specifications. In column 2, we augmented Eq. (1) with an additional triple interaction term replacing the single "post" with the number of months that ART was available. The point estimate on both the original triple interaction term and the new one are positive, as expected, but separately insignificant. The test of joint significance confirms that these regressors are jointly statistically significant.

Table 4
Effect of adult ART on children's schooling – distance and timing gradients.

	Grade for age	
	(1)	(2)
0–5 km	0.575***	
	(0.174)	
5–10 km	0.984**	
	(0.426)	
10–15 km	0.241	
	(0.363)	
15–20 km	0.655	
	(0.438)	
HIV+ * ART Ever * Post		0.279
		(0.220)
HIV+ * ART Ever * Months of ART		0.005
		(0.007)
Test coefficients are jointly equal to 0		
F-statistic		3.30
p-value		0.04
Observations	12,128	12,128
Rsquared	0.23	0.23

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. In column 1 the coefficients presented are those from the interaction of HIV*ART*post where the distance band is substitiuted for ART. Standard errors clustered at the district level appear in parenthesis. The sample is limited to children in expected grades 1–7 with a valid HIV approximation for their household head. All columns are linear probability models and include dummy variables for child age, household head age group, district, month of survey, urban, female, household head age group times post, and district dummy variables times post.

5.2. Mechanisms

Adult ART could have improved children's schooling through a number of channels. First, we test for the impact of adult ART on the labor supply of adults who were the household heads of the children in our sample. Specifically, we estimate Eq. (1) with a household head as the unit of observation, limiting the sample to household heads of a primary school aged child, and a measure of labor supply as the outcome of interest. Unfortunately, our data are not particularly well suited for this analysis. The labor force participation measures are coarse measures of the extensive margin of labor supply with over 80% of household heads reporting in 2002 that they were currently working or had worked in the last 12 months. Additionally, because of the structure of the DHS, the labor supply questions only cover about half of all household heads in our sample. Nevertheless, we report these estimates in Table 5.

In columns 1 and 2 of Table 5 we do not find any statistically significant relationship between the provision of ART and the likelihood that the household head was working at the time of the survey (column 1) or had worked in the last 12 months (column 2). As an potential indictment of our data quality, none of the lower level coefficients have

[26] The negative coefficient on HIV+ times post reflects a convergence of the likelihood of being grade-for-age for children with likely HIV positive household heads. In our data, our HIV measure is increasing in wealth, but the relationship is less pronounced in 2007 than in 2001. This negative coefficient could be reflecting the changing composition of being HIV positive. As we directly control for this likelihood, it should not generate bias in our coefficients of interest.

a statistically significant relationship with these outcomes. In results not presented, we further find no evidence of a statistically significant relationship with working full time or working for pay. This lack of result should not be taken to indicate no effect. Our large standard errors lead to confidence intervals that include point estimates similar to those found in Thirumurthy et al. (2008) using a clinic based study in Kenya and in McLaren (2010) using difference-in-differences for Black men in South Africa.

Table 5
Mechanisms – labor and wealth.

	Household head		Household wealth	Improved floor material
	Currently working (1)	Worked in the last 12 months (2)	(3)	(4)
HIV + * ART Ever * Post	−0.152	−0.178	0.509	0.166
	(0.229)	(0.139)	(0.540)	(0.250)
HIV +	0.023	0.01	0.417	0.143
	(0.113)	(0.081)	(0.288)	(0.112)
ART Ever	−0.041	−0.023	0.319**	0.131*
	(0.044)	(0.030)	(0.159)	(0.066)
Post	−0.02	0.005	−0.014	0.036
	(0.237)	(0.242)	−0.412	−0.156
HIV + * ART Ever	0.148	0.125	−0.423	−0.167
	(0.176)	(0.105)	(0.436)	(0.179)
HIV + * Post	0.108	0.157	−0.202	0.035
	(0.156)	(0.118)	(0.417)	(0.204)
ART Ever * Post	−0.013	0.012	−0.349**	−0.123*
	(0.054)	(0.037)	(0.163)	(0.068)
Observations	4030	4030	6517	6,472
Rsquared	0.18	0.18	0.67	0.50
Coefficient ofinterest in standard deviations				
HIV + * ART Ever * Post	−0.393	−0.564		0.345
	(0.594)	(0.442)		(0.518)

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors clustered at the district level appear in parenthesis. The sample is limited to households with at least one child in expected grades 1–7 and a valid HIV approximation for their household head. Columns 1, 2, and 4 are linear probability models. Column 3: the dependent variable is a standardized measure of wealth with mean 0 and standard deviation of 1 across all households in the full DHS survey. As this measure is already in standard deviations we do not present the alternative coefficient at the bottom. All columns include dummy variables for household member age group, district, month of survey, urban, female, household member age group times post, and district dummy variables times post.

We further tested for the effect of ART availability on household wealth measured in two ways. First, we use the standardized measure of household wealth, with a mean of 0 and standard deviation of 1, calculated by the DHS based on reported assets. We limit the sample to one observation per household that has at least one child of primary school age. As with our measures of working, we find no statistically significant effect on household wealth (column 3). Given the long term nature of wealth accumulation and the relatively short exposure to ART availability, this result could be different with a longer exposure to ART. Second, we created an indicator variable that takes the value of 1 if the floor of the household dwelling was improved, i.e. not earth, mud, or dung, as a potentially shorter run estimate of a change in wealth. As with the standardized wealth measure, we found a positive and statistically insignificant relationship with our regressor of interest (column 4).

Next we tested for the effect of ART on illnesses. Unfortunately the DHS survey did not ask questions on the health of primary school aged children. Instead, respondents were asked whether each child under 5 years old had diarrhea, a fever, or a cough in the two weeks prior to the survey. These younger children would be subject to the same home disease environment as the primary school aged children. Susceptibility to illness could reflect an underlying nutrition deficit as well as increased intra-household disease transmission due to an adult with a weakened immune system. Table 6 contains the results of separate estimates for each of these measures. The top of each column indicates the dummy variable used as a dependent variable in a re-estimation of Eq. (1) as a linear probability model. While the coefficients are negative, we do not find a statistically significant relationship between increased ART availability and the likelihood of diarrhea or cough for children with HIV positive household heads (columns 1 and 3). In contrast, we find a large, statistically significant decrease in the incidence of fever, consistent with household heads bringing less illness into the household and children having a higher level of nutrition and being better able to fend off illness.[27] Further supporting these illness results, Lucas and Wilson (2013) and Lucas and Wilson (2018) used a similar strategy and found an increase in weight among children under age 5 and likely HIV positive women, indicating a healthier home environment. The decrease in household illness and improved nutrition could have increased the school attendance of primary school aged children through an improvement in their own health or decrease in care giving duties.

Table 6
Mechanisms – illnesses.

	Diarrhea (1)	Fever (2)	Cough (3)
HIV + * ART Ever * Post	−0.16	−0.378**	−0.235
	(0.148)	(0.157)	(0.201)
HIV +	0.034	−0.203**	−0.047
	(0.086)	(0.083)	(0.094)
ART Ever	−0.037	−0.063**	−0.019
	(0.027)	(0.028)	(0.036)
Post	−0.203	−0.454***	−0.189
	(0.151)	(0.158)	(0.172)
HIV + * ART Ever	−0.012	0.233**	0.136
	(0.094)	(0.107)	(0.125)
HIV + * Post	0.206	0.260*	0.044
	(0.146)	(0.141)	(0.168)
ART Ever * Post	0.068*	0.076*	0.042
	(0.040)	(0.045)	(0.067)
Observations	10,372	10,372	10,372
Rsquared	0.08	0.15	0.08
Coefficient of interest in standard deviations			
HIV + * ART Ever * Post	−0.394	−0.761**	−0.484
	(0.364)	(0.315)	(0.414)

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors clustered at the district level appear in parenthesis. The sample consists of children aged up to age 5 with a valid HIV approximation for their household head. All columns are linear probability models. The dependent variable is an indicator variable equal to one if the child had the illness at the top of the column in the two weeks prior to the survey. All columns include dummy variables for child age, household head age group, district, month of survey, urban, female, household head age group times post, and district dummy variables times post.

Because of data limitations we cannot directly test for other mechanisms that might be the channel through which adult ART availability affects children's schooling. Our empirical tests are not meant to be exhaustive, instead pointing out one channel – improved health of young children in the house – through which adult ART availability affects children's schooling.

Due to the questions asked in the DHS we cannot know whether members of the household were receiving ART. During the time under

[27] An alternative explanation could be an increase in vaccination due to increased clinic exposure. In results not presented, children were not differentially likely based on the HIV status of the household head and clinic proximity to have received their BCG vaccine to protect against tuberculosis, polio vaccine, measles vaccine, or DPT vaccine to protect against diptheria, pertussis, and tetanus. Further, they were not differentially likely to have a health card.

study, those receiving ART would have had to make periodic visits to the clinic in order to receive medication. The DHS does inquire of women only whether they "visited a health facility for any reason in the twelve months preceding the interview." (Demographic and Health Surveys 2008) This question is not ideal for a three reasons. First, the question is posed during the family planning section of the survey, priming women to think only of certain kinds of visits. Second, recall from Table 1 that the portion of women who reported visiting a clinic fell by 20 percentage points between the two surveys, with changes for other reasons potentially swamping changes due to ART. Finally, respondents might not consider a visit to pick up an ART prescription as a formal visit to a health facility. Nevertheless, we test whether the women were more likely to have indicated that they visited a health facility and find no differential effect by our triple interaction of interest. Additionally we test whether women were more likely to have ever been tested for HIV, finding that women were substantially more likely to have been tested by the 2007 survey, but the effect is not differential by HIV status and ART availability.

5.3. Alternative adults

Our primary specifications focused on the household head to alleviate concerns about ART altering the likelihood that a mother or father was present in the household. In Table 7 we provide estimates analogous to Table 2 but using the HIV status of either the child's mother or father and the maximum HIV measure across the household head, mother, or father. Recall from Table 1 that the mother was the household head for about 12% of the sample and fathers were the household heads for about 58% of the sample. Almost all of the fathers (97%) were also household heads and 18% of the mothers were household heads. Therefore, for some households the same HIV status would appear in both the household head and mother or father estimations.

of similar magnitude to the result with household head's status, but the result is statistically insignificant using mother's status while remaining statistically significant for father's and adult maximum status. Similarly, the point estimate in column 3 is similar to the household head analog, but only statistically significant for mother's and adult maximum status. Columns 4 to 6 contain the estimates for reported childhood illness. Consistent with a story of physical proximity and incidental infections, the point estimates are statistically significant for diarrhea and cough for both parents, estimates that were not statistically significant when using the status of the household head or adult maximum. On average in our sample, primary school aged children live in households of 6.4 people, 2.5 adults and 3.9 children.

These differences by relationship of the child to the adult could be the result of differing levels of personal and economic interactions between the child and the adult, different economic and household responsibilities by gender, other factors potentially related to HIV that would cause a child to reside with either a father or mother, or different treatment take-up and adherence by gender. Unfortunately, we cannot empirically differentiate these possibilities. Conditional on receiving and adhering to treatment, the effect of ART on men versus women should biologically be the same. Whether women and men were equally likely to seek and adhere to treatment is an open question. In 2005 women in sub-Saharan Africa were more likely than men to seek treatment with 55% of the infected population estimated to be women while over 60% of those receiving ART were women (World Health Organization, 2006). On the other hand, women did not always correctly adhere to the treatment. Zulu (2005) found that among those surveyed in Zambia, 76% of women did not always exactly follow their prescribed regimen and 21% shared their regimen with a non-tested husband.

Given that the illness results are stronger while the schooling results remain similar when considering adults other than the household head, the mechanism is likely more than just illness in the household.

Table 7
HIV status of alternative adults.

	Attends school (1)	Grade for age (2)	Timely entry (3)	Diarrhea (4)	Fever (5)	Cough (6)
Panel A: Mother						
HIV+ * ART Ever * Post	0.238	0.267	0.742*	−0.367**	−0.334*	−0.367**
	(0.173)	(0.253)	(0.375)	(0.146)	(0.185)	(0.146)
Observations	9585	9585	1699	11,379	11,379	11,379
Rsquared	0.20	0.24	0.28	0.08	0.08	0.08
Panel B: Father						
HIV+ * ART Ever * Post	0.008	0.446*	0.660	−0.412**	−0.481***	−0.364*
	(0.204)	(0.232)	(0.514)	(0.173)	(0.181)	(0.212)
Observations	7842	7842	1395	8503	8503	8,503
Rsquared	0.21	0.25	0.27	0.08	0.15	0.08
Panel C: Maximum across Head, Mother, and Father						
HIV+ * ART Ever * Post	0.165	0.413**	0.888**	−0.197	−0.318**	−0.120
	(0.145)	(0.182)	(0.343)	(0.135)	(0.158)	(0.191)
Observations	12,903	12,903	2047	11,380	11,380	11,380
Rsquared	0.19	0.22	0.24	0.08	0.14	0.08

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors clustered at the district level appear in parenthesis. Each panel uses the likely HIV status of a different household member. Panel A: Mother. Panel B: Father. Panel C: Maximum HIV status across household head, mother, and father. A non-missing HIV status for any of these adults is sufficient to be included in this panel. Columns 1–2: The sample is limited to children in expected grade 1–7 with a valid HIV approximation for their household adult as listed in the panel. Column 3: The sample is limited to children who should be grade 1 with a valid HIV approximation for their household adult as listed in the panel. Columns 4–6: The sample is limited to children aged 0 to 5 with a valid HIV approximation for their household adult as listed in the panel. All columns are linear probability models and include dummy variables for child age, household member age group, district, month of survey, urban, female, household member age group times post, and district dummy variables times post.

Column 1 contains the estimates for the likelihood of school attendance with a separate panel for each adult. Similar to the estimates for household heads in which we did not find a statistically significant relationship, the interaction of availability of ART with mother's, father's, or adult maximum HIV status has a positive and statistically insignificant relationship with the likelihood of attending school. When we consider being the correct grade for age (column 2), the results are

Unfortunately, our data do not allow us to test for further mechanisms such as beliefs or the intensive margin of the labor supply.

6. Robustness

Tables 8 and 9 contains additional estimates of our coefficients of interest confirming that the results with our preferred specifications above were not due to bias. Table 8 contains estimates that control for additional programs and covariates. Table 9 contains estimates that redefine the sample and include alternative measures of HIV status. Columns 1 of both Tables repeat the estimates from Table 2 for ease of comparison. Each panel is a separate dependent variable.

One potential concern with our estimation is the presence of concurrent HIV programs. In Column 2 of Table 8 we include controls for the availability of prevention of mother-to-child transmission (PMTCT) of HIV and voluntary counseling and testing (VCT) services, two additional HIV services that were scaled up during our time frame of interest but not colinearly with ART availability. Our point estimates remain quite similar.

HIV status of geographic region, province by urban/rural. The grade for age finding is similarly sized and statistically significant, but the finding for timely entry is smaller and no longer statistically significant.

To be sure we are not capturing differences in family structure or adult life cycle dynamics, we control for alternative family structures in columns 5 and 6. For 3% of our sample, both parents are deceased with 7% having a deceased mother and 14% a decreased father. In column 5 we included dummy variables for a deceased mother, deceased father, and both parents being deceased. Recall that in our primary specifications we control for the age group of the reference adult, its interaction with post, and the age of the child, likely alleviating many of the concerns that our results are biased by life cycle dynamics. As an additional check, in column 6 we include a set of dummy variables for birth order.[29,30] Our findings are robust to both of these inclusions.

Table 8
Specification checks – concurrent programs and covariates.

Dependent Variable as Indicated in Each Panel		Additional covariates						
	Preferred specification (Table 2) (1)	Other HIV services (2)	Teacher HIV status (3)	Average HIV status (4)	Orphan status (5)	Birth order (6)	Indoor residual spraying suitability (7)	anti-malarial availability and use (8)
Panel A: Attended School								
HIV+ * ART Ever * Post	0.166	0.185	0.094	−0.010	0.167	0.131	0.115	0.152
	(0.146)	(0.142)	(0.131)	(0.140)	(0.145)	(0.143)	(0.144)	(0.152)
Observations	12,128	12,128	12,128	12,128	12,128	12,128	12,128	12,128
Rsquared	0.19	0.19	0.19	0.19	0.19	0.19	0.20	0.19
Panel B: Grade for Age								
HIV+ * ART Ever * Post	0.494***	0.498**	0.390***	0.381**	0.495***	0.443***	0.448***	0.496***
	(0.155)	(0.223)	(0.146)	(0.158)	(0.157)	(0.154)	(0.141)	(0.160)
Observations	12,128	12,128	12,128	12,128	12,128	12,128	12,128	12,128
Rsquared	0.22	0.22	0.22	0.22	0.22	0.23	0.25	0.23
Panel C: Timely Entry								
HIV+ * ART Ever * Post	0.753**	0.833*	0.535	0.241	0.763*	0.658*	0.703*	0.746*
	(0.375)	(0.462)	(0.427)	(0.438)	(0.400)	(0.393)	(0.405)	(0.402)
Observations	1,933	1933	1933	1933	1933	1933	1933	1,933
Rsquared	0.24	0.24	0.24	0.25	0.24	0.26	0.27	0.24

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors clustered at the district level appear in parenthesis. Panels A and B: The sample is limited to children of primary school age with a valid HIV approximation for their household head. Panel C: Sample limited to children of grade 1 age. Each panel is a separate dependent variable. All estimates are linear probability models and include child age, household member age group, district, month of survey, urban, and female dummy variables and the following interactions: household member age group times post, and district dummy variables times post. Column 1 from Table 2. Column 2 includes for controls for PMTCT and VCT availability within 10km of the household. Column 3 includes a triple interaction with the average HIV status of teachers in the province. See text for additional details on its calculation. Column 4 includes a triple interaction with average HIV status in the geographic region. Column 5 includes three additional dummy variables: whether the mother of the child is decreased, whether the father of the child is deceased, and whether both parents are deceased. Column 6 includes dummy variables for birth order. Column 7 includes type of flooring (as a proxy for type of wall material) and interactions between type of flooring times post. Column 8 includes controls for household ACT use, community ACT availability and its interaction with head HIV status, use of anti-malarials by pregnant women the household, community use of ant-malarials by pregnant women and its interaction times head HIV status. See text for additional details.

An additional concern is that we are conflating teacher HIV status with household adult HIV status. We used data from round two of the Zambian Southern and Eastern Africa Consortium for Monitoring and Education Quality (SACMEQ) data, collected in 2003, to calculate the gender ratio of teachers in each province.[28] Then based on this gender ratio, we used the HIV data from the 2002 Zambia DHS to estimate the average HIV status of teachers in each province. In the results in column 3, we included this HIV status as an additional triple interaction term as an additional regressor. Our results are robust to this inclusion with the exception of timely entry. While the point estimate is still large, the increase in the standard error and decrease in the point estimate renders the coefficient statistically insignificant. In all cases the point estimates moved in the expected direction, towards 0.

While average HIV in the community could affect households with HIV positive and HIV negative household heads similarly, it will be correlated with household head HIV status. Therefore, similar to the concerns in column 3, in column 4 we include a triple interaction for the average

Also, during the time of our study, malaria control and treatment activities increased in Zambia. One malaria control effort involved indoor residual spraying (IRS), a direct spraying of insecticide on the walls of dwellings. Only permanent walls, i.e. mud, clay, wood, brick or concrete, are suitable for IRS (World Health Organization, 2006). HIV

[28] Teachers' ages are not available in the SACMEQ data.

[29] Due to the structure of the DHS data the birth order was not reported for all of the respondents in our primary sample. For these individuals, we approximate their birth order based on their age relative to the ages of other children in the household and include an additional dummy variable to indicate an approximated birth order.

[30] To further confirm that we are not conflating differences between birth orders that might have occurred in the likelihood of being grade-for-age with ART availability, we re-estimate Eq. (1) replacing all incidences of HIV status with birth order. The coefficient on the triple interaction is both economically and statistically insignificant with a point value of −0.004 and standard error of 0.006. Therefore, we conclude that our results are not being driven by birth order effects.

positive individuals were not specifically targeted for this intervention. Yet, richer households were both more likely to have permanent walls and more likely to be HIV positive. Unfortunately, wall material is unavailable in our 2002 data. As 95% of respondents in the 2007 data that have non-IRS suitable walls have an earth, dung, or mud floor (a single category in the DHS), we use floor type as an approximation of wall type.[31] Therefore to ensure that we are not conflating IRS malaria control efforts with ART availability we include floor-type dummy variables and their interaction with post as additional regressors in column 7. Our findings are robust to this inclusion. Additionally, the IRS spraying was concentrated in urban areas (Masaninga et al., 2013). All of our primary specifications include the interaction of urban times post, controlling for any differences in urban areas between the pre and post period. As a further malaria control activity, bed net availability increased, and one concern is that our results are reflecting an increase in their use, instead of an effect of ART. While HIV positive individuals were not specifically targeted to receive bed nets, one could imagine that because of clinic contact they might be more likely to use a bed net. Our results remain robust to the inclusion of a dummy variable for bed net use (results not shown). Finally, during our period of study the use of anti-malarials for intermittent presumptive treatment (IPTp) for pregnant women and the use of artemisinin-based combination therapy (ACT) for malaria treatment both increased (Chanda et al., 2012). Neither program was universal nor targeted HIV specific households.[32]

In column 8 we control for household use of ACT, availability of ACT in the community, use of anti-malarials by pregnant women in the household, and availability of anti-malarials for pregnant women in the community.[33] These variables and the interactions of the community level variables with HIV status of the household head control for use, availability, and if availability was differential by HIV status of the household head. The findings appear in column 8 and are robust to these inclusions.

In Table 9 we limit the sample in three separate ways to further test for the robustness of our findings. In 2003 Zambia's Ministry of Community Development and Social Services (MCDSS) started a Social Cash Transfer (SCT) scheme in Kalomo district that was designed as a pilot cash transfer to the most destitute 10% of households in the targeted communities (Schubert, 2005). By 2007 the program was operating in

Table 9
Specification checks – sample and HIV status.

Dependent Variables as Indicated in Each Panel					Alternative HIV Measure	
	Preferred Specification (Table 2) (1)	Removing social cash transfer districts (2)	Sample limited to households within 10 km of a health facility (3)	Remove Lusaka Province (4)	above or below median (5)	actual when available (6)
Panel A: Attended School						
HIV+ * ART Ever * Post	0.166	0.170	0.170	0.099	0.062	0.048
	(0.146)	(0.153)	(0.160)	(0.149)	(0.047)	(0.044)
Observations	12,128	11,067	9170	10,709	12,128	12,128
Rsquared	0.19	0.19	0.18	0.20	0.19	0.19
Panel B: Grade for Age						
HIV+ * ART Ever * Post	0.494***	0.502***	0.498***	0.466***	0.152**	0.128**
	(0.155)	(0.169)	(0.181)	(0.163)	(0.059)	(0.059)
Observations	12,128	11,067	9170	10,709	12,128	12,128
Rsquared	0.22	0.23	0.22	0.23	0.23	0.23
Panel C: Timely Entry						
HIV+ * ART Ever * Post	0.753**	0.669	0.808*	0.752*	0.211	0.135
	(0.375)	(0.429)	(0.470)	(0.435)	(0.133)	(0.125)
Observations	1,933	1766	1428	1707	1933	1,933
Rsquared	0.24	0.25	0.25	0.25	0.27	0.27

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors clustered at the district level appear in parenthesis. Panels A and B: The sample is limited to children of primary school age with a valid HIV approximation for their household head. Panel C: Sample limited to children of grade 1 age. Each panel is a separate dependent variable. All estimates are linear probability models and include child age, household member age group, district, year of survey, month of survey, urban, and female dummy variables and the following interactions: household member age group times post, and district dummy variables times Post. Column 1 from Table 2. Column 2 removes the 4 districts with cash transfer schemes. Column 3 limits the sample to households within 10 km of a health facility. Column 4 removes observations in Lusaka province. Column 5 replaces all instances of the HIV measure with one that is an indicator for above or below median HIV likelihood. Column 6 replaces all instances of the HIV measure with an individual's test result if available or the same measure as in Column 5 if not.

[31] At most 2.9% of our 2007 sample had non-IRS suitable walls, this includes the 0.8% that had wall type "unknown" or "other," which may or may not have been IRS-suitable.

[32] Even though artemisinin-based combination therapy (ACT) was theoretically available nationwide in Zambia in 2004, based on a survey of health facilities in Zambia in 2006, 40% did not have ACT in stock at the time of the survey and on average clinics were out of stock 30% of the year (Barnes, Chanda, & Barnabas, 2009; Zurovac et al., 2007). Further while ACT is 100% effective when used correctly, incorrect treatment seeking and treatment administering behavior led to only a 25% systems effectiveness as late as 2012 (Littrell et al., 2013).

[33] Both rounds of the DHS collected data on whether a respondent used an anti-malarial during her last pregnancy and whether any children under the age of 5 took ACT or another anti-malarial in the previous two weeks. Based on the responses we create four additional controls and two interactions for the availability and use of anti-malarials. First, we include a dummy variable if any woman in the household reported the use of an anti-malarial during pregnancy. For households without a response to this question, we code this variable as zero and include a dummy variable to indicate a missing response to keep the same sample as the main specification. Second, as a measure of the local availability of anti-malarials for pregnant women, we calculate the share of women in a cluster who reported using an anti-malarial while pregnant. We include this variable and its interaction with the household head's HIV status, in case this availability differentially affected households by HIV status, as additional regressors. Third, we include a dummy variable equal to one if any child under five in the household took ACT in the past two weeks, the only measure of ACT availability in the DHS. For any households from the 2007 survey that did not have any children under 5, we gave this variable a value of 0 and included an additional indicator for a missing value. All households in the 2002 sample have a value of 0 for this variable. Fourth, as a measure of local availability of ACT, we calculated the percent of children who took ACT relative to all children who took any anti-malarial at the cluster level. We include this variable and its interaction with household head HIV status in case this availability differentially affected households by HIV status, as additional regressors.

Chipata, Katete, Kazungula, and Monze districts (Hunger & Programme, 2007; Seidenfeld & Handa, 2011). The amount of the transfer was designed to allow each household to purchase a 50 kg bag of maize per month, enough to increase household consumption from one meal to two meals per day (Hunger & Programme, 2007). The program did not specifically target HIV positive households, relying instead on perceived destitution. To ensure that our results are not being driven by this program, we provide estimates in column 2 that eliminate these districts from the analysis. The point estimates are quite similar to the estimates over the full sample.

Even though we control for time invariant and time varying heterogeneity by both district and ART availability, in column 3 we limit our sample to households that were within 10 km of a health facility to ensure that we are not misappropriating access to health care as access to ART. In column 4 we remove Lusaka Province, the capital of Zambia, to alleviate concerns that our results are driven by or substantially different for Lusaka Province. The point estimates are remarkably similar to the original point estimates.

In the final two columns of Table 9 we use two alternative HIV measures. Note that these point estimates are not strictly comparable to our previous estimates without appropriate scaling. First in column 5 we used a binary HIV measure defined as HIV status above or below the median HIV status in the sample. This replaces all instances of HIV in Eq. (1). The point estimates under this specification match the significance of the original grade-for-age findings, but are smaller in magnitude. The point estimates are larger than those from column 1 when considering the 25th to 75th percentile change in HIV status. In Column 6 we use replace all instances of HIV in Eq. (1) with actual HIV status if it is known, using the binary HIV status from column 5 in the case of a missing test result or inability to link an individual due to privacy concerns, additionally controlling for the use of this imputation. The results are similar to those in column 5.

Therefore, we find our results robust to the alternative estimates presented.

7. Discussion and conclusions

This study uses the 2002 and 2007 Zambia DHS repeated cross sections of households combined with uniquely collected administrative data on availability of antiretroviral therapy (ART) to identify the effect of subsidized adult ART therapy at scale on educational outcomes of children in households with likely infected adults.

We find that availability of adult ART resulted in educational gains for primary school aged children in households with likely HIV positive adults. Provision of free ART increased the likelihood that children in households with HIV positive household heads were grade-for-age and entered school at the correct age. We do not find an overall effect on the likelihood of being enrolled in school, our proxy for the extensive margin of schooling, but children in primary grades 1 and 2 were more likely to be enrolled. One potential mechanism driving this result is that children in the household are healthier, potentially indicating fewer incidental infections in the household. Therefore, in addition to directly benefiting adults, ART provision to adults in a household assists children already in school, but does not appear to alter likelihood that older children are enrolled in school. When cost effectiveness analyses of ARTs are conducted these additional indirect benefits are often not included. Improved schooling outcomes for students is an additional benefit to be considered when assessing the cost effectiveness of ART provision. Further, our findings confirm the importance of intergerational spillovers of public health interventions and considering the entire household in interventions to increase children's schooling outcomes

Appendix

Table A.1
Trends in children's schooling.

	Attended school during current school year (1)	Grade for age (2)
ART Ever	0.049*	0.060**
	(0.026)	(0.030)
Post	0.139***	0.063*
	(0.031)	(0.037)
ART Ever * Post	−0.051**	−0.005
	(0.024)	(0.035)
F-test that coefficients on Post and ART Ever * Post sum to 0		
F statistic	13.57	2.67
p-value	0.00	0.11
Observations	12,128	12,128
Rsquared	0.16	0.20

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors clustered at the district level appear in parenthesis. The sample is limited to children in expected grade 1–7 with a valid HIV approximation for their household head. All columns are linear probability models and include dummy variables for child age, household head age group, district, month of survey, urban, female, household head age group times post, and district dummy variables times post.

References

Ainsworth, M., & Filmer, D. (2006). Inequalities in children's schooling: AIDS, orphanhood, poverty, and gender. *World Development, 34*(6), 1099–1128.

Akbulut-Yuksel, M., & Turan, B. (2013). Left behind: Intergenerational transmission of human capital in the midst of HIV/AIDS. *Journal of Population Economics, 26*, 1523–1547.

Baranov, V., Bennett, D., & Kohler, H.-P. (2015). *The indirect impact of antiretroviral therapy: Mortality risk, mental health, and HIV-negative labor supply.* Mimeo.

Baranov, V., & Kohler, H.-P. (2014). *The impact of AIDS treatment on savings and human capital investment in Malawi.* Mimeo.

Barnes, K. I., Chanda, P., & Barnabas, G. A. (2009). Impact of the large-scale deployment of artemether/lumefantrine on the malaria disease burden in Africa: Case studies of South Africa, Zambia and Ethiopia. *Malaria Journal, 8*(58), 1–7.

Bendavid, E., Holmes, C. B., Bhattacharya, J., & Miller, G. (2012). HIV development assistance and adult mortality in Africa. *Journal of the American Medical Association, 307*(19), 2060–2067.

Bicego, G., Rutstein, S., & Johnson, K. (2003). Dimensions of the emerging orphan crisis in sub-Saharan Africa. *Social science & medicine, 56*(6), 1235–1247.

Chanda, E., Kamuliwo, M., Steketee, R. W., Macdonald, M. B., Babaniyi, O., & Mukonka, V. M. (2012). An overview of the malaria control programme in Zambia. *ISRN*

Preventive Medicine, 2013.
Cohen, C., Moyes, J., Tempia, S., Groom, M., Walaza, S., Pretorius, M., ... Madhi, S. A. (2013). Severe influenza-associated respiratory infection in high HIV prevalance setting, South Africa, 2009–2011. *Emerging Infectious Diseases, 19*(11), 1766–1774.
Curry, J., Wiegers, E., Garbero, A., Stokes, S., & Hourihan, J. (2006). *Gender, HIV/AIDS andrural livelihoods: Micro-level investigations in three African CountriesResearch Paper 2006/10*. UNU-WIDER.
Dillon, A. (2013). Child labour and schooling responses to production and health shocks in Northern Mali. *Journal of African Economies, 22*(2), 276–299.
Dunkle, K. L., Stephenson, R., Karita, E., Chomba, E., Kayitenkore, K., Vwalika, C., ... Allen, S. (2008). New heterosexually transmitted hiv infections in married or cohabiting couples in urban Zambia and Rwanda: An analysis of survey and clinical data. *Lancet, 371*, 2183–2191.
Dzekedzeke, K. (2003). Prevalence of HIV and Syphilis. *Zambia Demographic and Health Survey 2001-2002*.
Evans, D., & Miguel, E. (2007). Orphans and schooling in Africa: A longitudinal analysis. *Demography, 44*(1), 35–57.
Food and Agriculture Organization of the United Nations HIV/AIDS Programme (2003). *Mitigating the impact of HIV/AIDS on food security and rural povertyTechnical Report*. Rome: FAO.
Fortson, J. (2008). The gradient in sub-saharan Africa: Socioeconommic status and hiv/aids. *Demography, 45*(2), 303–322.
Fortson, J. (2011). Mortality risk and human capital investment: The impact of HIV/AIDS in sub-Saharan Africa. *Review of Economics and Statistics, 93*(1), 1–15.
Friedman, W. (2014). *Antiretroviral drug access and behavior change.* Mimeo.
Glewwe, P., & Miguel, E. A. (2008). The impact of child health and nutrition on education in less developed countries. In T. P. Schultz, & J. Strauss (Eds.). *Handbook of development economics*. Elsevier.
Grant, M. J., & Hallman, K. K. (2008). Pregnancy-related school drop-out and prior school performance in Kwazulu-Natal, South Africa. *Studies in Family Planning, 39*(4), 369–382.
Habyarimana, J., Mbakile, B., & Pop-Eleches, C. (2010). The impact of HIV/AIDS and ARV treatment on worker absenteeism: Implications for African firms. *Journal of Human Resources, 45*(4), 809–839.
Hammer, S. (1997). A controlled trial of two nucleoside analogues plus indinavir in persons with human immunodeficiency virus infection and CD4 cell counts of 200 per cubic millimeter or less. *New England Journal of Medicine, 337*(11), 725–733.
Hunger, R., & Programme, V. (2007). *Social cash transfers, Zambia*.
International HIV/AIDS Alliance (2004). *Antiretroviral treatment in Zambia: A study of the experiences of treatment users and health care workersTechnical Report*. United Kingdom: International HIV/AIDS Alliance.
Jones, S., Schipper, Y., Ruto, S., & Rajani, R. (2014). Can your child read and count? Measuring learning outcomes in east Africa. *Journal of African Economies, 23*(5), 643–672.
Kasirye, I., & Hisali, E. (2010). The socioeconomic impact of HIV/AIDS on education outcomes in Uganda: School enrolment and the schooling gap in 2002/2003. *International Journal of Educational Development, 30*(1), 12–22.
Kremer, M., Miguel, E., & Thorton, R. (2009). Incentives to learn. *The Review of Economics and Statistics, 91*(3), 437–457.
Lee (2001). .
Levinsohn, J., McLaren, Z. M., Shisana, O., & Zuma, K. (2013). Hiv status and labor market participation in South Africa. *The Review of Economics and Statistics, 95*(1), 98–108.
Lewin, K. M. (2009). Access to education in sub-Saharan africa: Patterns, problems and possibilities. *Comparative Education, 45*(2), 151–174.
Littrell, M., Miller, J. M., Ndhlovu, M., Hamainza, B., Hawela, M., Kamuliwo, M., ... Steketee, R. W. (2013). Documenting malaria case management coverage in Zambia: A systems effectiveness approach. *Malaria Journal, 12*(1), 371.
Lucas, A. M., & Mbiti, I. M. (2012). Does free primary education narrow gender differences in schooling outcomes? Evidence from Kenya. *Journal of African Economies, 21*(5), 691–722.
Lucas, A. M., & Wilson, N. L. (2013). Adult antiretroviral therapy and child health: Evidence from scale-up in zambia. *American Economic Review: Papers and Proceedings, 103*(3), 456–461.
Lucas, A. M., & Wilson, N. L. (2018). Can antiretroviral therapy at scale improve the health of the targeted in sub-Saharan Africa? *American Journal of Health Economics, 4*(3), 358–382 Summer.
Mann, G., Quigley, P., & Fischer, R. (2015). *Qualitative study of child marriage in six districts of Zambia.* Republic of Zambia.
Masaninga, F., Chanda, E., Chanda-Kapata, P., Hamainza, B., Masendu, H. T., Kamuliwo, M., ... Babaniyi, O. (2013). Review of the malaria epidemiology and trends in Zambia. *Asian Pacific Journal of Tropical Biomedicine, 3*(2), 89–94.
McLaren, Z. (2010). *The effect of access to AIDS treatment on employment outcomes in South Africa*.
Morgan, D., Mahe, C., Mayanja, B., & Whitworth, J. (2002). HIV-1 infection in rural Africa: Is there a difference in median time to AIDS and survival compared with that in industrialized countries? *AIDS, 16*, 597–603.
Médecins sans Frontiéres (2003). *Antiretroviral therapy in primary health care: Experience of the Khayelitsha programme in South AfricaTechnical Report*. Switzerland: World Health Organization.
National Center for Education Statistics (1997). *Dropout rates in the United StatesStatisitcal Analysis Report NCES 97–473*. U.S. Department of Education Office of Educational Research and Improvement.
Navarro, V. (2000). Assessment of the world health report 2000. *Lancet, 356*, 1598–1601.
Oreopoulos, P., Page, M. E., & Stevens, A. H. (2006). The intergenerational effects of compulsory schooling. *Journal of Labor Economics, 24*(4), 729–760.
Pitt, M., & Rosensweig, M. (1990). Estimating the intrahousehold incidence of illness: child health and gender-inequality in the allocation of time. *International Economic Review, 31*(4), 969–989.
Robson, S., & Sylvester, K. B. (2007). Orphaned and vulnerable children in Zambia: the impact of the HIV/AIDS apidemic on basic education for children at risk. *Educational Research, 49*(3), 259–272.
Rossiter, J., Azubuike, O. B., & Rolleston, C. (2017). *Young lives school survey, 2016–17: Evidence from EthiopiaTechnical Report*. United Kingdom: Young Lives.
Schubert, B. (2005). *The pilot social cash transfer scheme Kalomo district-Zambia* Chronic Research Centre Working Paper, (52)
Seidenfeld, D., & Handa, S. (2011). Results of the three year impact evaluation of Zambias cash transfer program in Monze district: Final report. *American Institutes for Research*.
Flunking grades: Research and policies on retention. In L. A. Shepard, & M. L. Smith (Eds.). The Falmer Press.
Sonnenberg, P., Glynn, J. R., Fielding, K., Murray, J., Godfrey-Faussett, P., & Shearer, S. (2005). How soon after infection with HIV does the risk of tuberculosis start to increase? A retrospective cohort study in South African gold miners. *The Journal of Infectious Diseases, 191*(2), 150–158.
Stringer, J., Zulu, I., Stringer, E., Mwango, A., Chi, B., Mtonga, V., ... Sinkala, M. (2006). Rapid scale-up of antiretroviral therapy at primary care sites in Zambia: feasibility and early outcomes. *Journal of the American Medical Association, 296*(7), 782–793.
Tembo-Mwanamwenge, M., & Kasongo, W. (2009). Prevalence of HIV and syphilis. In T. D. R. C. U.o. Z. Central Statistical OfficeMinistry of Health, & M. I. Inc (Eds.). *Zambia demographic and health survey 2007*. Calverton, MD: CSO and Macro International Inc.
Thirumurthy, H., Zivin, J. G., & Goldstein, M. (2008). The economic impact of AIDS treatment labor supply in western Kenya. *The Journal of Human Resources, XLIII*(3), 511–552.
Tirivayi, N., & Groot, W. (2014). *The impact of food transfers for people living with HIV/AIDS: Evidence from Zambia*.
UNAIDS (2015). *AIDSinfo online database* http://www.aidsinfoonline.org/
UNAIDS Inter-Agency Task Team on Education (2000). *Updated stocktaking report education sector responses to HIV and AIDSTechnical Report*. Paris: Secretariat of the UNAIDS Inter-Agency Task Team on Education.
UNESCO (2010). *World data on education*.
Unge, C., Södergård, B., Ekström, A. M., Carter, J., Waweru, M., Ilako, F., ... Thorson, A. (2009). Challenges for scaling up ART in a resource-limited setting: a retrospective study in Kibera, Kenya. *JAIDS Journal of Acquired Immune Deficiency Syndromes, 50*(4), 397–402.
UNICEF (2009). *Children and AIDS: Fourth stocktaking report*.
Whitworth, J., Morgan, D., Quigley, M., Smith, A., Mayanja, B., Eotu, H., ... Ojwiya, A. (2000). Effect of HIV-1 and increasing immunosuppression on malaria parasitaemia and clinical episodes in adults in rural Uganda: a cohort study. *The Lancet, 356*(9235), 1051–1056.
Wools-Kaloustian, K., Kimaiyo, S., Diero, L., Siika, A., Sidle, J., Yiannoutsos, C., ... Tierney, W. (2006). Viability and effectiveness of large-scale HIV treatment initiatives in sub-Saharan Africa: experience from Western Kenya. *AIDS, 20*, 41–48.
World Health Organization (2005). *Zambia summary country profile for HIV/AIDS treatment scale-up*.
World Health Organization (2006). *Progress on global access to HIV antiretroviral therapy: A report on 3 by 5 and beyond.* Geneva: The World Health Organization.
World Health Organization (2010). *Antiretroviral therapy for HIV infection in adults and adolescents: Recommendations for a public health approachTechnical Report*. Geneva: World Health Organization.
Yamano, T., & Jayne, T. S. (2005). Working-age adult mortality and primary school attendance in rural Kenya. *Economic Development and Cultural Change, 53*(3), 619–653.
Zambia Ministry of Health (2008). *Assessing the scale up of HAARTTechnical Report*. Lusaka: Ministry of Health.
Zambian Ministry of Education (2011). *Looking towards the future of education: A stocktaking reportTechnical Report*. Lusaka: Ministry of Education.
Zulu, K. (2005). Fear of hiv serodisclosure and art success: the agony of HIV positive married women in Zambia. Poster Exhibition: The 3rd IAS Conference on HIV Pathogenesis and Treatment. Abstract no. TuPe11.9C03.
Zurovac, D., Ndhlovu, M., Sipilanyambe, N., Chanda, P., Hamer, D. H., Simon, J. L., & Snow, R. W. (2007). Paediatric malaria case-management with Artemether-Lumefantrine in zambia: a repeat cross-sectional study. *Malaria Journal, 6*(31), 1–9.