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AIDS treatment and intrahousehold resource allocation: Children's nutrition and schooling in Kenya☆

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ABSTRACT

The provision of antiretroviral medications is a central component of the response to HIV/AIDS and consumes substantial public resources from around the world, but little is known about this intervention's impact on the welfare of children in treated persons' households. Using longitudinal survey data from Kenya, we examine the relationship between the provision of treatment to adults and the schooling and nutrition outcomes of children in their households. Weekly hours of school attendance increase by over 20% within 6 months after treatment is initiated for the adult patient. We find some weak evidence that young children's short-term nutritional status also improves. These results suggest how intrahousehold allocations of time and resources may be altered in response to health improvements of adults.

1. Introduction

Health and education are the primary forms of human capital, critical for individual welfare and economic development. The threat posed to children's human capital is therefore among the most negative and far-reaching consequence of AIDS-related morbidity and mortality in sub-Saharan Africa. While the provision of life-saving antiretroviral (ARV) treatment has emerged as a central part of the medical and policy response to HIV/AIDS and consumes a large amount of public resources from around the world, very little empirical research has investigated the welfare effects of this important intervention on children living with treated patients. Information on the intergenerational effects of ARV treatment can provide valuable insights into the return on these public investments and result in well-informed public resource allocation decisions. This paper studies how household behavior changes in response to the provision of treatment to an infected adult in the household.

Antiretroviral treatment, which has been shown to dramatically improve patients' health (among many, see Hammer et al., 1997; Wools-Kaloustian et al., 2006) as well as their labor supply (Thirumurthy et al., 2008; Larson et al., 2008), has the potential to reverse the impacts of AIDS-related morbidity and mortality.[2] As the labor productivity of infected adults increases due to treatment, a combination of income and substitution effects will allow households to become less reliant on children's labor.[3] Healthier adults will also require less care-giving from household members, further increasing their time endowment for other activities. Jointly, the income, substitution, and care-giving effects are likely to directly and indirectly improve the schooling outcomes of children. The income effects are also likely to raise food

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[2] A growing empirical literature finds that orphaned children in Africa experience setbacks in their schooling in the years before and after they lose their parents (Case and Ardington, 2006; Evans and Miguel, 2007), although the severity of these impacts does vary substantially across countries (Ainsworth and Filmer, 2006) and there is less empirical evidence on what happens in the years prior to an adult's death. Orphanhood has also been found to result in long-run declines in health status (Beegle et al., 2006).

[3] A large theoretical and empirical literature examines the role of income and substitution effects in individual time allocation decisions (beginning with Becker, 1965), family labor supply (beginning with Ashenfelter and Heckman, 1974) and household investment decisions.

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consumption levels and directly influence young children's nutritional status. Such responses to the positive health "shock" represented by ARV treatment would be consistent with a large literature that examines consumption-smoothing mechanisms used by households in low-income settings with imperfect credit and insurance markets (see, for example, Pitt and Rosenzweig, 1990; Strauss and Thomas, 1995; Kochar, 1995; Jacoby and Skoufias, 1997).

This paper provides evidence on how the provision of treatment affects household decisions to invest in children's health and schooling. In order to measure the effects of ARV treatment, we use longitudinal socio-economic survey data collected over the course of one year from HIV-positive adult patients who had AIDS and received free treatment. The data include information on the schooling and nutritional outcomes of children residing in patients' households. We examine changes over time in these outcomes, focusing on the weekly hours of school attended for children of school-going age and the anthropometric status of very young children. Since the largest health gains from ARV treatment occur within the first three months (Hammer et al., 1997; Wools-Kaloustian et al., 2006), our primary identification strategy relies on variation in the length of time that adult patients had been receiving treatment prior to the start of our survey. We therefore distinguish between treatment households that had already experienced most of the health gains before the start of our survey and those that experience them during our longitudinal survey. We also use linked medical records for the treated adults to further examine the association between adults' health status and children's outcomes.

The results in this paper provide suggestive evidence that treating adult AIDS patients with ARVs results in substantial welfare improvements for children living with the patients. Our results show a significant increase in children's weekly hours of school attendance, particularly for girls. These increases tend to occur within 6 to 9 months after treatment is initiated for adult patients, with no additional increases thereafter — a temporal pattern that is highly consistent with the health and labor supply responses among treated adults. These results on the short-term treatment effect are also fairly robust to the comparison group that is used to control for confounding factors. Finally, as an important verification that the reduced form treatment effects we estimate are driven first and foremost by the health improvements experienced by treated adults, instrumental variables regressions show a significant causal effect of adult health on children's school attendance.

We find less robust evidence of short-term nutritional benefits for young children in treated patients' households. While the small sample size of children with anthropometric data is a key limitation here, there is some evidence that children benefit in the early stages of treatment. It is important to note that such improvements can have long-lasting impacts, as early-childhood nutritional status is an important predictor of future physical and cognitive abilities of children, as well as their labor productivity (Alderman et al., 2001, 2006).

Due to the fact that treatment was made available to all who needed it, our study lacks data from a sample of children living with adults who are known to have AIDS but are exogenously denied ARV treatment (the counterfactual to our treatment group). Consequently, our results provide suggestive but not conclusive evidence on the impact of AIDS treatment on the schooling and health of children living with treated adults. Since the health of adults with AIDS would rapidly decline in the absence of treatment and almost certainly result in death within one year, we suspect that our approach will underestimate treatment impacts. But we cannot rule out the possibility that children's schooling would improve once their parent is gone, thus making our results an overestimate. Nonetheless, based on several empirical strategies, the findings in our paper provide suggestive evidence of sizable benefits to children living in the households of adults who receive ARV treatment.

The next section provides background on the treatment intervention that we study, as well as the household survey data. This is followed by a discussion in Section 3 of our strategy for estimating the relationship between ARV treatment and children's outcomes. Regression results showing the effect of treatment on children's schooling and nutrition are presented in Section 4. Section 5 contains further interpretation of our results and discusses their policy implications.

2. Background and data

The paper uses data from a household survey we conducted in Kosirai Division, a rural region near the town of Eldoret in western Kenya. Our study and sample design are described in an online Appendix and additional details are also in Thirumurthy et al. (2008). Here we provide a brief description of ARV treatment and the data used in our analysis of nutrition and education outcomes.

Almost all HIV-infected individuals experience a weakening of the immune system and progress to developing AIDS. This later stage is associated with substantial weight loss (wasting) and opportunistic infections such as pneumonia and tuberculosis. Once individuals develop AIDS, death is highly imminent without treatment. Highly active antiretroviral therapy[4] has been proven to reduce the likelihood of opportunistic infections and prolong the life of HIV-infected individuals. According to WHO guidelines, this treatment should be initiated around the time that individuals progress to AIDS (WHO, 2002). After several months of treatment, patients are generally asymptomatic and have improved functional capacity.[5] While the effect of ARV therapy on the health of treated patients has been widely documented, much less is known about the broader impact it can have on the social and economic outcomes of patients and their families. Our survey in Kenya was designed to assess these impacts.

Households in the survey area are scattered across more than 100 villages where crop farming and animal husbandry are the primary economic activities and maize is the main crop. The largest health care provider in the survey area is a government-run health center that offers primary care services. The health center also contains a clinic that provides free medical care (including ARV therapy) to HIV-infected individuals. This rural HIV clinic—one of the first in sub-Saharan Africa—was opened in November 2001 by the Academic Model Providing Access to Health Care (AMPATH). Since late-2003, AMPATH has had adequate funding to provide ARV therapy to all patients who are eligible according to the WHO guidelines.

We conducted two rounds of interviews between March 2004 and March 2005, with an interval of roughly 6 months between rounds. Our survey included 206 households with at least one known HIV-positive adult who began receiving ARV therapy at the AMPATH clinic prior to the round 2 interview (ARV households). Variation within this sample in the amount of time that adult patients were on treatment at the start of our survey is an important part of our analysis, as we discuss in Section 3. Our survey also included 503 households that were chosen randomly from the survey area. We use these data to perform additional tests of our assumptions regarding the trajectory of health benefits following treatment initiation.

When analyzing schooling outcomes, we focus on children who were between the ages of 8 and 18 in round 1 and resided in households that were interviewed in both rounds during non-holiday periods. The schooling outcome we examine is the number of hours of school attended by the child in the seven days prior to the interview (excluding travel time to and from the school). Our analysis uses data for 480 children (from 246 households) — 128 children in ARV households and 352 children in random sample households. Attrition of children in round 2 is less than 5% in each of the study groups.

The primary nutritional outcome we examine is the weight-for-height *Z*-score — a measure of thinness or wasting that is particularly sensitive to short-term growth disturbances caused by factors such as inadequate

[4] In this paper, we use the terms "ARV therapy" and "ARV treatment" interchangeably to refer to highly active antiretroviral therapy (HAART).

[5] See, for example, Koenig et al. (2004) or Wools-Kaloustian et al. (2006), as well as the results in Thirumurthy et al. (2008).

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food and illnesses (Waterlow et al., 1977; WHO Working Group, 1986; WHO, 1995). As such, it represents a current estimate of nutritional status and can exhibit considerable variation over short periods of time. The heights and weights of children less than 5 years of age were measured during household visits in each round. The sample for our analysis of nutritional outcomes uses data for 41 uninfected children (from 30 ARV households) and 349 uninfected children (from 238 random sample households).

3. Empirical strategy

This section provides an overview of our empirical strategy for estimating the relationship between ARV therapy and outcomes of children in treated households. Central to our identification strategy is the considerable variation in treatment initiation dates within the ARV households — 22% began treatment shortly after the round 1 interview, an additional 27% were on treatment for less than 3 months at the time of the round 1 interview, and the remainder had been on treatment for more than 3 months at the time of the round 1 interview. Since the health and labor supply response for treated patients is nonlinear and largest in the first three months of treatment, and small to nonexistent thereafter (Wools-Kaloustian et al., 2006; Thirumurthy et al., 2008), our estimation strategy exploits this underlying heterogeneity.

Specifically, we divide the sample of children in ARV households into two sub-groups that — as we show further below — experience very different changes in adult health between the two survey rounds: (a) children living in households where the adult patient began receiving treatment more than 100 days before round 1 (later-stage treatment group that does not experience health changes between rounds), and (b) children living in households where the adult patient began receiving treatment 100 or fewer days before round 1 or very shortly after round 1 began (early-stage treatment group that experiences large health changes between rounds).[6] Since treatment is initiated at the onset of AIDS, it should be noted that in the early-stage ARV households, treated adults are generally very sick during the round 1 interview. Our first empirical approach then compares the trends in children's outcome variables for the two treatment sub-groups:

$$Y_{iht} = \alpha_{ih} + \beta_1\left(ARVHH_{<100,h}{*}ROUND2_t\right) + \sum\nolimits_{\tau=1}^{11} \gamma_\tau MONTH_t^\tau + \varepsilon_{iht} \quad (1)$$

Y_{iht} is the outcome of interest (school attendance and nutritional status) for child i in household h at time t (round 1 or 2), α_{ih} is a fixed effect for child i in household h, and $ARVHH_{<100,h}$ is equal to 1 if household h has an adult who was receiving ARV therapy for 100 of fewer days at the time of the round 1 interview (early-stage ARV households), and $ROUND2_t$ indicates whether the observation is from round 2. Also included are eleven month-of-interview indicator variables that control for monthly fluctuations in outcomes that are common to the "treatment" and comparison groups. In Eq. (1) the later-stage ARV households, which are not experiencing significant changes in adult health between rounds, serve as the comparison group for early-stage treatment households. This allows us to control for the effects of time-varying factors such as seasonal fluctuations in weather, labor demand, malaria, and food availability — all of which are likely to influence children's outcomes in our setting. Specifically, the coefficient β_1 represents the treatment effect during the first 6–9 months after ARV therapy is initiated. If the schooling and nutrition outcomes for children of treated adults are being driven by changes in the health and labor supply of treated adults, we would expect β_1 to be positive.

This estimation strategy relies on two key assumptions. First, it requires that adult patients in early-stage treatment households experience much larger health improvements between survey rounds than patients in later-stage treatment households. As we show in results below, this assumption is well supported by the AMPATH medical records, which reveal much larger weight and CD4 gains for patients in the early stages of treatment. Second, it is assumed that in the absence of large health improvements due to ARV treatment, the trends in schooling and nutrition for children in early-stage households would be similar to those for later-stage households. This second assumption is more difficult to substantiate since the time at which adults enroll in the treatment program is not randomly determined, but in Section 4 we present suggestive evidence in its favor by showing that treated adults in the early- and later-stage treatment households had similar health status at the time of treatment initiation. Given this, the difference in timing of treatment initiation within the ARV sample is likely to have been determined by the date when patients became infected with HIV, which was roughly 8–10 years preceding these observations. The long period of disease progression suggests that the timing of treatment initiation is plausibly exogenous. Furthermore, we find that patients' demographic characteristics and wealth measures — both of which could affect schooling and nutrition trends — are not significantly different at the time of the round 1 interview.

As an additional check on the validity of the identifying assumptions for Eq. (1), we estimate an alternative specification in which we directly compare each of the two types of ARV households to children in the random sample of households:

$$Y_{iht} = \alpha_{ih} + \beta_1\left(\mathrm{ARVHH}_{<100,h}{*}\mathrm{ROUND2}_t\right) + \beta_2\left(\mathrm{ARVHH}_{>100,h}{*}\mathrm{ROUND2}_t\right) + \sum\nolimits_{\tau=1}^{11} \gamma_\tau \mathrm{MONTH}_t^\tau + \varepsilon_{iht} \quad (2)$$

$ARVHH_{>100,h}$ is equal to 1 if household h has an adult who was receiving ARV therapy for more than 100 days at the time of the round 1 interview (later-stage ARV households). When estimating Eq. (2), we will be interested both in the magnitudes of β_1 and β_2, as well the difference between the two coefficients. Since adults in later-stage ARV households do not experience large changes in health status between rounds, β_2 should not be significantly different from zero as long as it is the case that the seasonal and idiosyncratic schooling and nutrition trends for children in random sample and late-stage ARV households are similar. This is an important advantage of Eq. (2) over Eq. (1), as it includes a "falsification test" that further probes the relationship between adult health and children's welfare. In contrast to our expectation about β_2, the large health gains for early-stage treatment households lead us to expect that β_1 is positive and significantly different from zero. Again, our assumption here is that children in the random sample represent a proper control for seasonal and idiosyncratic determinants of outcomes.

The magnitude of β_1 in both Eqs. (1) and (2), however, should be interpreted with caution. The identifying assumptions described above allow us to measure the impacts of treatment relative to those households that experience small or no health changes between survey rounds. But since adults with AIDS would experience dramatic health declines (and even mortality) in the absence of ARV therapy, neither of the comparison groups in Eqs. (1) or (2) are an ideal representation of the counterfactual scenario. As is suggested by the literature on orphans and vulnerable children in Africa, it is quite likely that the deterioration of adult health would lead to declines in children's health and schooling, in which case β_1 would be an underestimate of the impact of treatment. On the other hand, we cannot rule out the possibility that β_1 is an overestimate, since children who lose a parent to AIDS may be taken in by relatives or friends and experience improvements in their health and schooling.

[6] In the sample of children we use for the schooling analysis, the median number of days that adult patients have been on ARV therapy as of round 1 is 99.5. The average is considerably higher (167), and the 25th and 75th percentiles are 10.5 and 285. While health impacts are clearly concentrated in the early months of treatment, the choice of 100 days as the cutoff is still to some extent arbitrary. Experimentation with cutoffs ranging from 90–110 days does not change our results. In addition to evidence that the largest health gains from ARV therapy occur within the first three months of treatment, the adult patients on treatment for less than 100 days as of round 1 have also been found to experience the largest increase in labor supply between rounds 1 and 2 (Thirumurthy et al., 2008).

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Table 1
Characteristics of ARV households and random sample households.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Random sample		<100 days on ARVs in round 1			>100 days on ARVs in round 1			
	Mean	SD	Mean	SD		Mean	SD		
Number of households	170		37			39			
Household structure (round 1)									
Household size	7.1	2.9	6.5	2.2		6.3	2.4		
Number of children (0–18 years)	4.0	2.0	3.7	1.6		3.4	1.7		
Number of children (0–5 years)	0.87	0.94	0.70	0.81		0.74	1.01		
Number of children (8–18 years)	2.6	1.4	2.6	1.3		2.3	1.3		
Number of orphans (0–18 years)	0.38	0.88	1.6	1.6	*	1.1	1.6	*	
Number of extended family members	1.2	1.4	1.4	1.7		1.3	1.6		
Household head characteristics									
Age	49.3	13.9	45.9	9.2		47.6	13.9		
Male	76%		46%		*	51%		*	
Single	21%		59%		*	46%		*	
Widowed	12%		46%		*	28%		*	
Asset ownership (round 1)									
Quantity of land owned (acres)	7.2	9.1	5.6	11.0		6.8	12.5		
Percent landless	17%		17%			15%			
Value of land owned, 1,000 Shillings	697	928	606	1276		642	1333		
Value of livestock owned, 1000 Shillings	62	67	49	100		56	92		
Health status of adult patient									
Weight at time of treatment initiation (kg)			51.4	10.2		54.9	12.6		
Weight at time of round 1 interview (kg)			51.8	10.4		60.2	11.7		*
Weight at time of round 2 interview (kg)			58.3	10.2		61.7	12.1		

Notes: Statistics are reported for only those households that: (a) have children between the ages of 8–18 years; and (b) were interviewed in both rounds on dates that did not contain any school holidays in the past week. Columns 1 and 2 present summary statistics for the random sample of households. Columns 3 and 4 present summary statistics for households in which the adult ARV recipient had been on treatment for less than 100 days (or was about to initiate treatment) as of round 1. An asterisk in column 5 indicates a *p*-value <0.10 from a *t*-test for equality of means for the random sample and the $\mathrm{ARVHH}_{<100}$ sample. Columns 6 and 7 present summary statistics for households in which the adult ARV recipient had been on treatment for more than 100 days as of round 1. An asterisk in column 8 indicates a *p*-value <0.10 from a *t*-test for equality of means for the random sample and the $\mathrm{ARVHH}_{>100}$ sample. An asterisk in column 9 indicates a *p*-value <0.10 from a *t*-test for equality of means the $\mathrm{ARVHH}_{<100}$ and $\mathrm{ARVHH}_{>100}$ samples.

Finally, to verify that adult health improvements due to ARV treatment are indeed driving changes in children's outcomes, we use an instrumental variables (IV) strategy to explore the relationship between children's schooling and adult health.[7] We do this by merging our survey data with information from the AMPATH medical records on the weight of the adult patients being treated (a standard indicator of health responses to ARV therapy). Specifically, we first estimate the following equation

$$Y_{iht} = \alpha_{ih} + \beta_1 \mathrm{WEIGHT}_{ht} + \sum\nolimits_{\tau=1}^{11} \gamma_\tau \mathrm{MONTH}_t^\tau + \varepsilon_{iht} \qquad (3)$$

in which $WEIGHT_{ht}$ is the predicted body weight of the treated adult patient in household *h* at time *t* (round 1 and 2), as predicted by the following first-stage equation:

$$\mathrm{WEIGHT}_{ht} = \alpha_{ih} + \beta_1 \left(\mathrm{ARVHH}_{<100,h} {*} \mathrm{ROUND2}_t\right) + \sum\nolimits_{\tau=1}^{11} \gamma_\tau \mathrm{MONTH}_t^\tau + \varepsilon_{iht}. \qquad (4)$$

In the first-stage Eq. (4), the coefficient β_1 should illustrate the effect that has been shown in the medical literature and that we have reported elsewhere for the sample of patients in this study (Thirumurthy et al., 2008): ARV therapy results in large increases in patients' weight during the early stages of treatment, after which weight gains are minimal.

The results from estimating the equations above with school attendance as the dependent variable will reveal how ARV treatment affects schooling outcomes of children in treated patients' households, relative to their round 1 levels. Since the survey recorded information on the hours of market labor performed by children in the week prior to interview, we can also compare the treatment effect on schooling to that on labor supply, thereby examining whether changes in schooling are offset by changes in labor supply. Thus, as an extension of our analysis, we estimate the equations with children's labor supply as the dependent variable.

[7] Given the limited sample size for our analysis of nutritional status, we only implement the IV strategy for children's school attendance.

4. Results

Table 1 compares the main characteristics in round 1 of households belonging to random sample households and the two different groups of ARV households (denoted $ARVHH_{<100}$ and $ARVHH_{>100}$ above). We only report statistics for households that have children between the ages of 8–18 years *and* were interviewed during non-holiday periods in both rounds (a total of 480 children). Compared to random sample households, both groups of ARV households have significantly different demographic composition. The ARV households are more likely to be headed by single (and often widowed) women. When comparing demographic characteristics of the two groups of ARV households, however, we do not observe any significant differences (column 9 reveals that the *p*-values from *t*-tests of equality of means are above 0.10). Turning to the various wealth measures (land holdings, land value, and the value of livestock), we do not find significant differences between random sample households and either group of ARV households, nor between the two groups of ARV households. Since so many of the households in our survey are engaged in own-farm agricultural activities, these similarities in landholdings suggest that weather patterns in the survey area should not have heterogeneous effects on the labor demand and socio-economic status of these groups of households. Such similarities are important for our empirical approach since the "control groups" we define are meant to correct for seasonal and other time-varying aggregate predictors of children's schooling and nutrition. Moreover, retrospective data from patients' medical records show that the two groups of ARV recipients had similar health status (as

Table 2
Relationship between ARV treatment and adult health.

	(1)	(2)	(3)
Dependent variable	Weight (kg) of adult patient		
	All kids	Boys	Girls
ARVHH <100 days*ROUND2	6.385	6.402	7.728
	(1.012)***	(1.611)***	(1.289)***
Constant	64.859	56.429	63.100
	(7.190)***	(1.550)***	(9.043)***
Observations	251	120	131
R-squared	0.95	0.94	0.97

Notes: Standard errors in parentheses are clustered at the household level in each round (** significant at 5%; *** significant at 1%). The table reports results from estimating Eq. (4) in the paper. All regressions include individual fixed effects, as well as month-of-interview indicators. Observations for which school attendance was reported to be below normal because of school holidays during the past week are excluded from the sample.

measured by body weight) at the time of treatment initiation, providing additional support for one of the identifying assumptions underlying Eqs. (1) and (2).

Identification in Eqs. (1) and (2) also depends upon variation in the amount of health improvement in ARV households between survey rounds. Summary statistics in Table 1 reveal much larger gains in body weight for early-stage ARV recipients and modest gains for those in the later stages of treatment. This is further evident in the results from estimating Eq. (4). Table 2 shows that, consistent with findings in the medical literature, there are significantly larger weight gains during the early stages of ARV therapy. On average, adults on treatment for 100 or fewer days in round 1 gain an additional 6–7 kg between rounds than do adults on treatment for more than 100 days in round 1. This large point estimate of 6.4 kg — a greater than 10% weight increase — is highly consistent with the dramatic health improvements during the first three months of ARV therapy that have been documented elsewhere (e.g. Wools-Kaloustian et al., 2006). This health improvement also translates into increased labor supply for adults in the early stages of treatment, as our earlier work has shown. The remainder of this section tests whether schooling and health outcomes of children also improve as a result of these changes in adult health.

4.1. Effect of treatment on children's schooling

The summary statistics in Table 3 show that in round 1, children in early-stage ARV households have the lowest level of school attendance. Their weekly hours of schooling averaged about 28 h, significantly fewer than the roughly 34 h of weekly schooling for children in the random sample and later-stage ARV households.[8] While merely cross-sectional comparisons, these round 1 statistics suggest that children are worst off in the very early stages of treatment, but that over time they catch up to others in their community. When we consider the changes between rounds 1 and 2 for children in each group of households, it appears that relative to children in random sample and later-stage ARV households, children in early-stage ARV households are better off. Although there is a secular decline in weekly hours of schooling between round 1 and round 2, the advantage of our empirical strategy is that it controls for such secular trends — which could be due to the fact that the agricultural harvest occurs during round 2. Table 3 also reveals that the market labor supply of children in both types of ARV households declines considerably between rounds, whereas it is largely unchanged for children in random sample households.

Our main results come from implementing the three empirical strategies discussed in Section 3, which take advantage of the longitudinal data by using child fixed effects and also make use of linked information on the health status of adult patients in the ARV households. The first

Table 3
Summary statistics for children's schooling outcomes.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Random sample		<100 days on ARVs in round 1			>100 days on ARVs in round 1			
	Mean	SD	Mean	SD		Mean	SD		
N (children 8–18 in round 1)	352		64			64			
Hours of school attended in past week									
Round 1	34.0	15.8	28.2	16.3	*	33.4	18.6		*
Round 2	28.0	15.8	26.4	17.0		28.3	17.1		
Did any work in past week									
Round 1	69%		68%			70%			
Round 2	78%		71%			68%		*	
Hours worked in past week (includes farm labor)									
Round 1	9.2	12.2	13.4	23.4	*	12.9	12.2	*	
Round 2	8.9	11.3	8.0	15.6		6.8	8.1		

Notes: Statistics are reported for only for children (a) between the ages of 8–18 years; (b) who live in households that were interviewed in both rounds on dates that did not contain any school holidays in the past week. Columns 1 and 2 present summary statistics for children in the random sample of households. Columns 3 and 4 present summary statistics for children in households where the adult ARV recipient had been on treatment for less than 100 days (or was about to initiate treatment) as of round 1. An asterisk in column 5 indicates a *p*-value<0.10 from a *t*-test for equality of means for the random sample and the $ARVHH_{<100}$ sample. Columns 6 and 7 present summary statistics for children in households where the adult ARV receipient had been on treatment for more than 100 days as of round 1. An asterisk in column 8 indicates a *p*-value <0.10 from a *t*-test for equality of means for the random sample and the $ARVHH_{>100}$ sample. An asterisk in column 9 indicates a *p*-value <0.10 from a *t*-test for equality of means for the $ARVHH_{<100}$ and $ARVHH_{>100}$ samples.

panel of Table 4 reports results obtained when boys and girls are both included in the regressions, whereas Panels B and C report the results for boys and girls separately. The first two columns of Panel A show a similar increase over time in school attendance for children in early-stage ARV households, relative to children in later-stage ARV households (column 1) as well as random sample households (column 2). Our results indicate that children in early-stage ARV households experience a gain of 6 h in weekly school attendance, roughly an entire school day and an amount equivalent to more than 20% of their average round 1 attendance levels. The fact that children in early-stage ARV households have a similar improvement relative to children in both later-stage ARV households and random sample households suggests that the latter two groups have similar schooling trends during the survey period, and that the random sample households are not necessarily an imperfect control group for seasonal trends. This is further verified by the result in column 2 of Panel A, which shows that compared to the random sample, children in later-stage ARV households do not experience any significant change in school attendance. The result is consistent with the fact that in later-stage ARV households much of the improvement in the treated adult's health has already occurred by round 1, and it provides added evidence that the estimated improvements in schooling for children in early-stage ARV households are primarily due to health improvements of the treated adults in their households. Furthermore, it should be noted that the pattern in column 2 of large increases in the early stages of treatment followed by no significant changes beyond 6–9 months of treatment is very similar what we observed in the treated adults' health status (Table 2) and labor supply (see Thirumurthy et al., 2008).[9]

The third column in Table 4 reports results from implementing the instrumental variables strategy described by Eqs. (3) and (4). This is meant to verify whether increases in children's school attendance occur in the same households that also experience improvements in adult

[8] A full day of school will typically last 6–8 h, with the longer school days being more common at higher school levels. Perfect school attendance is therefore in the range of 30–40 h, depending on the child's school level.

[9] We also performed tests for the equality of the two coefficients β_1 and β_2 in Eq. (2). When we pool all children (panel A), we cannot reject the hypothesis that the coefficients are equal. However, for girls (panel C), the coefficient for $ARVHH_{<100}*Round2$ is significantly different, at the 10% level, from the coefficient for $ARVHH_{>100}*Round2$.

health. The first stage results from the IV strategy (Table 2) underscored the distinction between the two types of ARV households in our sample. The second stage results, in column 3 of Table 4, indicate a positive and significant relationship between adult weight and children's school attendance. For the sample of all children in ARV households, a 1 kg increase in the weight of the adult patient leads to an increase of almost 0.9 h in weekly school attendance. A direct association can therefore be made between the treatment-induced improvements in adult health and the school attendance patterns of children.

Table 4 also shows the results from estimating separate treatment effects for boys and girls. The most notable finding here is that schooling increases for girls are more concentrated during the early stages of treatment, whereas for boys there is less direct evidence that school attendance closely tracks adult health improvements. In column 1 of Panel B, we show that relative to boys in later-stage ARV households, there is a positive but statistically insignificant treatment effect for boys in early-stage ARV households. Column 2 suggests that the absence of a treatment effect for boys in newly treated households is largely due to the fact that those in later-stage ARV households also have rising school attendance (relative to boys in random sample households). While our results in panel B cast doubt on the hypothesis that ARV therapy alone results in higher school attendance for boys, an alternative possibility that we cannot explicitly test for is that the treatment effect on school attendance takes longer to fully manifest for boys. Finally, while the IV results in column 3 of Panel B indicate a positive effect of adult health on boys' school attendance, the estimated coefficient is not statistically significant.

The treatment effect for girls, on the other hand, is large and significant during the early stages of ARV therapy for treated adults. Compared to children in later-stage ARV households, girls in early-stage ARV households have a significant increase of 8.9 h in weekly school attendance. The results are similar when we make comparisons to girls in the random sample. The estimated treatments effect for girls in early-stage ARV household is large and significant (6.5 h), but not significantly different from zero for girls in later-stage ARV households. Moreover, we find that under the IV strategy, the treated adults' weight has a large and significant effect on the school attendance of girls. These results indicate a strong relationship between the provision of treatment to adults and the school attendance of girls in particular.[10]

To further explore how the schooling effects relate to households' time allocation decisions more generally, we also examined the effect of treatment on children's weekly hours of market labor supply. The

Table 4
ARV treatment and children's school attendance.

	(1)	(2)	(3)
Dependent variable	Hours of school attended in past week		
Sample and specification	Comparison within ARV households (Eq. (1))	Comparison between ARV and random s ample households (Eq. (2))	Instrumental variables estimates with ARV households only (Eq. (3))
Panel A: All children			
ARVHH (<100 days)* ROUND2	6.033 (2.934)**	6.393 (2.792)**	
ARVHH (>100 days)* ROUND2		1.893 (2.548)	
Weight of adult patient (instrumented)			0.889 (0.408)**
Observations	256	964	251
R-squared	0.88	0.83	
Panel B: Boys			
ARVHH (<100 days)* ROUND2	6.089 (3.772)	8.673 (3.854)**	
ARVHH (>100 days)* ROUND2		4.902 (2.770)*	
Weight of adult patient (instrumented)			0.851 (0.596)
Observations	124	522	120
R-squared	0.88	0.83	
Panel C: Girls			
ARVHH (<100 days)* ROUND2	8.908 (4.229)**	6.513 (3.241)**	
ARVHH (>100 days)* ROUND2		−1.035 (3.941)	
Weight of adult patient (instrumented)			1.147 (0.515)**
Observations	132	442	131
R-squared	0.89	0.85	

Notes: Standard errors in parentheses are clustered at the household level in each round (* significant at 10%; ** significant at 5%; *** significant at 1%). The dependent variable is the total number of hours the child spent in school during the week prior to interview. Column 1 reports results from estimating Eq. (1) in the paper; column 2 reports results from estimating Eq. (2); and column 3 reports results from estimating Eq. (3). All regressions include child fixed effects and month-of-interview indicators. Panel A reports results for samples containing boys and girls; panel B reports results for samples of boys only; and Panel C reports results from samples of girls only. Observations for which school attendance was reported to be below normal due to school holidays during the past week are excluded from the sample.

Table 5
ARV treatment and children's market labor supply.

	(1)	(2)	(3)
Dependent variable	Hours worked in past week		
Sample and specification	Comparison within ARV households (Eq. (1))	Comparison between ARV and random sample households (Eq. (2))	Instrumental variables estimates with ARV households only (Eq. (3))
Panel A: All children			
ARVHH (<100 days)* ROUND2	−1.915 (3.542)	−4.576 (2.040)**	
ARVHH (>100 days)* ROUND 2		−3.305 (1.995)*	
Weight of adult patient (instrumented)			−0.289 (0.497)
Observations	256	916	233
R-squared	0.88	0.78	
Panel B: Boys			
ARVHH (<100 days)* ROUND2	−1.958 (4.893)	−7.606 (3.181)**	
ARVHH (>100 days)* ROUND2		−7.593 (2.896)***	
Weight of adult patient (instrumented)			−0.441 (0.742)
Observations	114	502	110
R-squared	0.90	0.82	
Panel C: Girls			
ARVHH (<100 days)* ROUND2	−0.921 (4.908)	−0.793 (2.734)	
ARVHH (>100 days)* ROUND2		1.200 (2.835)	
Weight of adult patient (instrumented)			−0.129 (0.645)
Observations	124	414	123
R-squared	0.71	0.68	

Notes: Standard errors in parentheses are clustered at the household level in each round (* significant at 10%; ** significant at 5%; *** significant at 1%). The dependent variable is the total number of hours devoted to income-generating activities in the past week. Column 1 reports results from estimating Eq. (1) in the paper; column 2 reports results from estimating Eq. (2); and column 3 reports results from estimating Eq. (3). All regressions include child fixed effects and month-of-interview indicators. Panel A reports results for samples containing boys and girls; panel B reports results for samples of boys only; and Panel C reports results from samples of girls only. Observations for which school attendance was reported to be below normal due to school holidays during the past week are excluded from the sample. The number of observations is slightly smaller than the number of observations in Table 4 because labor supply information is missing for 44 children.

[10] In our empirical work we also tested whether treatment effects differ for boys and girls of different age groups, such as primary school age children (8–14 in round 1) and older children (14–18 in round 1). Our results, while not reported here, suggest that young boys and girls experience the bulk of the attendance increases stemming from treatment provision.

Table 6
Summary statistics of children's anthropometric status.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Random sample		<100 days on ARVs in round 1			>100 days on ARVs in round 1			
	Mean	SD	Mean	SD		Mean	SD		
N (children 0–5 years in round 1)	349		16			25			
Weight-for-height *Z*-score									
Round 1	−0.08	1.34	−0.14	1.88		−0.55	1.71	*	
Round 2	0.03	1.20	0.38	1.70		−0.44	1.16	*	*
Percent with Weight-for-height Z< −2 (wasting)									
Round 1	4%		19%		*	8%			
Round 2	2%		13%		*	0%			
Height-for-age *Z*-score									
Round 1	−0.58	1.56	−1.16	1.75		−1.31	1.52	*	
Round 2	−0.76	1.27	−2.01	1.69	*	−1.34	1.51	*	
Mean Weight-for-height Z-scores (random sample in round 1)									
0–6 months	0.72	1.47							
6–12 months	0.60	1.79							
1–2 years	0.26	1.53							
2–3 years	−0.21	0.92							
3–4 years	−0.32	0.91							
4–5 years	−0.67	0.97							

Notes: Statistics are reported for only those children who were measured in both rounds. Columns 1 and 2 present summary statistics for children in the random sample of households. Columns 3 and 4 present summary statistics for children in households where the adult ARV recipient had been on treatment for less than 100 days (or was about to initiate treatment) as of round 1. An asterisk in column 5 indicates a *p*-value<0.10 from a *t*-test for equality of means for the random sample and the ARVHH<100 sample. Columns 6 and 7 present summary statistics for children in households where the adult ARV recipient had been on treatment for more than 100 days as of round 1. An asterisk in column 8 indicates a *p*-value<0.10 from a *t*-test for equality of means for the random sample and the $ARVHH_{>100}$ sample. An asterisk in column 9 indicates a *p*-value<0.10 from a *t*-test for equality of means for the $ARVHH_{<100}$ and $ARVHH_{>100}$ samples.

dependent variable in this case is the reported number of hours in the past week that a child spent working on income-generating activities. In Panel A of Table 5, we find only limited evidence that treatment provision to adults with AIDS leads to reductions in children's labor supply. This average effect seems to mask heterogeneity by gender. In Panel B, we show that compared to boys in later-stage ARV households, those in early-stage households do not experience significantly different trends in labor supply. But compared to boys in random sample households, boys in both types of ARV households experience a significant decline in labor supply. This is similar to the pattern for boys' school attendance, with significant increases for both groups of ARV households. Consistent with the first two sets of results for boys, the instrumental variables strategy (in column 3 of Table 5) reveals a negative but statistically insignificant relationship between adult health and labor supply. Panel C shows that there are no significant effects of treatment on the market labor supply of girls either. In summary, these results do not provide strong evidence that the provision of ARV therapy to adults goes on to influence — through income and substitution effects — children's market labor supply.[11]

Thus, the schooling gains due to treatment must be primarily the result of reductions in non-market labor (including caring for sick adults) and/or leisure. Indeed, in another paper that examines the association between treatment provision and time allocation to various household tasks (using a third round of follow-up data since the second round did not include comprehensive time allocation information), we find a significant reduction in the time that girls spend fetching water, as well as an effect on housework for boys (D'Adda et al., 2009).

[11] The results presented here differ from those in Thirumurthy et al. (2008), as our analysis here is restricted to children in households that were interviewed during non-holiday periods.

Table 7
ARV treatment and children's anthropometric status.

	(1)	(2)
Dependent variable	Weight-for-height *Z*-score	
Sample and specification	Comparison within ARV households (Eq. (1))	Comparison between ARV and random sample households (Eq. (2))
All children		
ARVHH (<100 days)*ROUND2	0.374	0.598
	(0.784)	(0.279)**
ARVHH (>100 days)*ROUND2		0.078
		(0.258)
Observations	81	773
R-squared	0.92	0.87

Notes: Standard errors in parentheses are clustered at the household level in each round (** significant at 5%; *** significant at 1%). The dependent variable is the Weight-for-Height *Z*-score, which is calculated from the measured weights and heights of children and based on comparison to a well-nourished reference population of children in the U.S. Column 1 reports results from estimating Eq. (1) in the paper and column 2 reports results from estimating Eq. (2). All regressions include child fixed effects, fixed effects for the interviewer who measured the child, month-of-interview indicators, and age controls. Observations with weight-for-height *Z*-score or height-for-age *Z*-score larger than 6 or smaller than −6 are excluded from the analysis.

4.2. Effect of treatment on children's nutritional status

As ARV therapy improves the health and productivity of HIV-infected adults, income effects may allow treated households to consume more food. This could in turn improve the nutritional status of household members, particularly children. We explore this possibility by examining the nutritional status of very young children (aged 0–5 years) residing in ARV households.

Table 6 presents summary statistics for the anthropometric status of children measured in both rounds of the survey. The most striking pattern here is that children in the early stages have a large increase in their weight-for-height *Z*-score between rounds 1 and 2, relative to the changes for children in random sample and later-stage ARV households. To establish whether these changes in the nutritional status of children are related to the provision of ARV treatment to adults and not to other factors such as seasonality and aggregate shocks, we use the longitudinal data to estimate Eqs. (1) and (2).[12] As column 1 of Table 7 indicates, relative to children in later-stage ARV households, those in early-stage ARV households do not experience a significant change in their *Z*-score. The small number of observations is a major limitation in making such a comparison, however. Relative to children in random sample households, we do find that a significant increase in *Z*-scores for children in early-stage ARV households. Weight-for-height of children in the latter households increases by 0.60 standard deviations in the 6 months between survey rounds, representing a substantial improvement in nutritional status.[13] Children in later-stage ARV households, on the other hand, have no significant change in *Z*-scores relative to children in random sample households. The estimated treatment effect for them is close to being significantly lower than the effect for children in early stage ARV households (*p*-value of 0.14). The different trends for children in the two types of ARV households provide suggestive evidence that the increased height-for-age *Z*-score of children in the early-stage ARV

[12] We also include interviewer fixed effects because the measurement of heights in small children is challenging and can vary with individual skills and experience. In addition, following the recommendations in WHO (1995), the 9 observations with weight-for-height *Z*-score or height-for-age *Z*-score larger than 6 or smaller than −6 are excluded from the analysis. We also include age controls because the interval between measurements is not exactly 6 months for all children. Finally, due to the small size of the ARV sample, we do not estimate regressions separately for boys and girls.

[13] Since height-for-age is an anthropometric index that changes slowly, children are unlikely to experience large changes over the course of 6 months. When examined as an outcome variable, it is reassuring that we find no significant changes in the height-for-age *Z*-scores of children living with ARV recipients.

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households are indeed due to the improving economic conditions in these households. However, the lack of a treatment effect in column 1 means that the effects in column 2 may be driven by differential trends among children in the random sample, and this leads us qualify our conclusions about the effect of treatment on children's nutritional status.

5. Discussion and policy implications

The results in this paper suggest that the provision of ARV therapy to adults with AIDS generates benefits often overlooked in the existing literature. After controlling for confounding factors, we find that children in households of treated adults attend more school. We also find suggestive evidence that young children in such households are better nourished. Particularly noteworthy is the consistency in the timing of these impacts with the health and labor impacts experienced by adults — most changes occur within 6 to 9 months after treatment is initiated.

To identify the various economic factors that drive our results it is worth noting that the most immediate impacts of ARV therapy are on treated patients, who experience large and immediate restorations in their health, functional capacity, and labor supply. These dramatic changes in the health and labor supply of working-age adults could affect their household members in several ways. First, the *income effect* from increased adult labor supply will result in higher food consumption, greater ability to pay school-related expenses, and reduced need for children and other household members to work. Second, since the relative productivity of treated patients' children will be lower, the *substitution effect* will reduce the labor supply of children. Third, children and other household members will have to provide less home-based care for treated adults. All of these factors should directly improve the educational status of children, and the income effect should directly improve their nutritional status. Moreover, the treatment of adults may also affect children's schooling *indirectly* through its effects of children's health (Miguel and Kremer, 2004).[14] While we cannot establish the size of each of these effects independently, our instrumental variables results link adult health to schooling outcomes and show that — at the very least — the improvements in adult health due to ARV therapy are a central part of the reason why children's school attendance increases.

Taken as a whole, our results have important implications for how one should generally value public expenditures on HIV/AIDS or other large-scale health interventions. Most research in this area denominates the returns to these programs in some metric of health, measures that are focused on morbidity and mortality impacts for patients. Even the use of quality- (or disability-) adjusted-life-years saved, which under certain conditions can capture patient income effects, still misses the important non-patient impacts described in this paper. Given the high returns to children's human capital, our results suggest that a more careful cost–benefit analysis of treatment is necessary.

Future work should extend our analysis to include a range of other household level outcomes that may be influenced by treatment, including investment in natural capital and physical assets. Two limitations of our study — the relatively small sample size of treated patients, and the single study site — could be overcome by larger studies conducted across multiple treatment sites that would provide insights on the generalizability of our findings. The HIV/AIDS epidemic and our response to it appear to influence household investment decisions that create an inextricable link between the welfare of current and future generations in countries heavily impacted by the disease. As further public investments are considered or re-considered, deepening our understanding of these linkages should be a priority.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jpubeco.2009.03.003.

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[14] There is also the possibility that treated parents expect that they and their children will live longer due to treatment availability, and therefore invest more in their children's education.

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