Antiretroviral therapy coverage associated with increased co-residence between elderly people and prime-age adults in Africa.

Short title: Antiretroviral therapy coverage and elderly living arrangements.

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Abstract

Objectives: To determine whether national antiretroviral therapy (ART) coverage is associated with changes in elderly living arrangements.

Design: Retrospective analysis using 103 nationally representative surveys from 28 African countries between 1991 and 2015.

Methods: The sample consisted of individuals aged at least 60 years old. We investigated how three measures of living arrangements of older people have changed with ART coverage: (i) the number of older individuals living without prime-age adults; (ii) the number of older individuals living with only dependent children (i.e., "missing generation" households); and (iii) the number of prime-age adults per household where an elderly individual lives.

Results: Sample size was 297,331 elderly individuals. An increase in ART coverage of 1% was associated with a 0.7 percentage point ($p < .001$) reduction in the probability of an elderly individual living without prime-age adult and a 0.2 percentage point ($p = .005$) reduction in the probability of an elderly individual living in a "missing generation" household in HIV endemic countries. Increases in ART coverage were also associated with more prime-age adults in households with at least one older person. In our study countries, representing 75% (749 million) of the sub-Saharan population, an additional 103,000 – 358,000 elderly individuals could be living with prime-age adults as a result of increased ART coverage (1%).

Conclusions: The scale up of ART is linked to substantial changes in the living arrangements of elderly people in Africa. Estimates of the returns to investments in HIV treatment may be inaccurate without taking into account these larger societal consequences.

Keywords: HIV; AIDS; Antiretroviral Therapy; Households; Family Characteristics; sub-Saharan Africa; Intergenerational Support

Introduction

The toll of the HIV epidemic is changing demographic and household structures in sub-Saharan Africa [1]. The HIV epidemic causes deaths among working age adults in particular, who often serve as primary caregivers of children and elderly family members—thereby decreasing the supply of family caregivers [2, 3]. Their need, however, could not be greater. More than 17 million children are orphaned as a result of AIDS [4] and the number of adults over age 60 is expected to rise by 60% between 2015 and 2030 [5]. These changes will further increase the demand for support by family members [6]. Unlike middle- and high-income settings, where a public welfare system provides for the elderly, the elderly in lower resource settings typically rely on within-family wealth transfers such as "upward" intergenerational transfers from adult offspring to their elderly parents [7-11]. In the absence of public wealth transfers, families in lower resource settings function as de facto social institutions to replace market or government institutions [12], and smooth consumption across the life cycle [13].

Global health policies have focused on rapidly expanding HIV treatment or antiretroviral therapy (ART) to curb the HIV epidemic by 2020 [14]. As a result, ART coverage is increasing dramatically in sub-Saharan Africa, from on average <1% in the early 2000s to currently over 50% (Figures S1-S2 in the Appendix) [15]. ART has been linked to improvements in the treated individual's outcomes, such as increased life expectancy [14], labor force participation [16, 17], and recovery of employment [18-20]. Relatively little is known, however, on the effect of large scale ART expansion on household outcomes [21]. ART coverage is likely to increase the number and productivity of prime-age individuals with possibly large spillovers to co-resident family members who depend on their support

[22]. While a few studies have assessed the consequences of ART for offspring [22, 23], little is known about the extent to which ART coverage has affected the household arrangements of the preceding generation. This topic differs substantially from the mainstream focus of medicine on treatment effects in the *treated* individual, and assesses the meaning of HIV treatment in prime-age adults for their co-residing household members who may or may not be on HIV treatment themselves.

In this paper, we analyze the largest available, nationally representative, and mutually comparable repeated cross-sectional samples from 103 surveys in 28 countries to examine the quantitative relationship between ART coverage and co-residence between elderly people and prime-age (age 18-59) adults. The overarching research question is important, both scientifically and for policy – how does HIV treatment in a prime-age adult affect the health, economic and social outcomes of older adults? Our specific research questions are three-fold: (i) to determine the relationship between AIDS mortality and elderly living arrangements in sub-Saharan Africa; (ii) to determine whether ART coverage is associated with changes in elderly living arrangements; and (iii) to determine the impact of increased ART coverage on the number of elderly people living with prime-age household members.

Methods

Data source

Our data on the characteristics of the elderly population and on living arrangements came from the Demographic and Health Surveys, AIDS Indicator Surveys, and Malaria Indicator Surveys conducted by Macro International, Calverton, MD [24]. These surveys are nationally representative household-level surveys and are typically performed at least

once every five years. AIDS Indicator Surveys and Malaria Indicator Surveys are performed intermittently between Demographic and Health Surveys. The standard survey includes questions about household composition and living arrangements such as age and educational attainment of each member of the household. While the Demographic and Health Surveys typically focus on children and prime-age adults, the basic household roster includes data on all household members, including elderly persons. We included all sub-Saharan countries where multiple surveys had been conducted between 1990 and 2015. Our final sample included 297,331 older individuals (age 60 or older) surveyed during 103 survey waves in 28 countries: Benin, Burkina Faso, Burundi, Cameroon, Chad, Côte d'Ivoire, Democratic Republic of Congo, Gabon, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Rwanda, Togo, Senegal, Sierra Leone, Tanzania, Uganda, Zambia, and Zimbabwe. We show the complete list of countries and survey years in Table S1 in the Appendix.

Outcome measures

We investigated three measures of living arrangements of older people: (i) the number of older individuals living without prime-age adults; (ii) the number of older individuals living with only dependent children (i.e., also described in the literature as "missing generation" or "skip generation" households [2, 3]); and (iii) the number of prime-age adults per household where an elderly individual lives. Elderly people may be harmed by living without prime-age adults (e.g., by being 'unattended' or 'unaccompanied'), incurring the burden of child support (in addition to the hardships of caring for themselves without adult support), or by living with fewer prime-age adults. We defined an elderly person to be 60 years of age or older, a prime-age adult to be between the ages of 18 and 59, and a

dependent child to be under the age of 10. The age criterion of 60 years or older was used because it captures the oldest 5% of the sub-Saharan African population, who may require financial and physical support (by comparison, the oldest 5% of the population in the United States comprise people who are more than 75 years old) [5]. These three measures of elderly living arrangements are documented in detail elsewhere [2].

Exposure

ART coverage was defined as the percentage of all people living with HIV who are receiving ART. We used the annual estimates of ART coverage by country from UNAIDS [15] and matched these estimates to our 103 surveys based on country and year.

Statistical analyses

Our analysis proceeded in three steps. First, we graphically assessed the naïve relationship between AIDS mortality rates and the proportion of elderly people living without prime-age adult in sub-Saharan Africa [2]. We also graphically assessed how ART coverage relates to elderly living arrangements. Second, for binary dependent variables (elderly people living without prime-age adults and elderly in missing generation households), we estimated the importance of ART coverage at the time of the survey by using probit models. For the number of prime-age adults living in households with older people, we used ordinary least squares (OLS) regressions. Where we used probit models, we report marginal effects, which represent the change in likelihood of the outcome given a one point change in the predictor variable. We estimated probit models of the form:

$$P[y_{ij} = 1 \mid B_{ij}, ARTcoverage_j] = \Phi\,(\alpha + x\,B_{ij} + \gamma\,ARTcoverage_j) \qquad (1)$$

We estimated a separate model for each of the binary outcome variables (elderly people living without prime-age adults and elderly in missing generation households). Our main parameter of interest is γ which represents the relationship between national ART coverage at the time of survey year j (at the aggregate level), and the outcome y_{ij} for senior i in survey year j (at the individual level). B_{ij} is a vector of parameters, including controls for age (years), sex, area of residence (urban vs. rural), education (years), measures of household socioeconomic status (electricity, radio, and bicycle), and indicators for country and survey year to adjust for unobserved differences between countries and account for common linear changes over time (i.e., country and year fixed effects). Our identifying assumption is that unobservable factors that might simultaneously affect ART coverage and our measures of elderly living arrangements are time-invariant. We clustered standard errors at the country and survey-specific primary sampling unit level to account for spatial correlation. We assessed the relationship between ART coverage and elderly living arrangements using pooled data from all countries, when stratifying by country HIV prevalence [25], and when stratifying by sex of the elderly individual [26].

Third, we used our regression results to estimate the potential (positive) impact in the number of elderly people living with prime-age adults associated with increased ART coverage in countries where the HIV epidemic is generalized or hyperendemic (Lesotho, Kenya, Malawi, Mozambique, Namibia, Tanzania, Uganda, Zambia, and Zimbabwe). To do so, we multiplied the estimated marginal effects of ART coverage by the number of older people (ages 60+), yielding the estimated number of elderly people living with prime-age adults resulting from increased ART coverage (1%). We calculated estimates of

the number of elderly people living with prime-age adults associated with ART coverage separately by country. These calculations assume that the same parametric relationship between the probability of an elderly individual living without prime-age adult and ART coverage within our study sample holds for each country.

Sensitivity analyses

We conducted a number of sensitivity analyses to generate additional confidence in our regression results. First, we used alternative functions for age to model the non-linear relationship between age and elderly living arrangements in our analytical sample (Figure S3 in the Appendix). Second, we modelled our outcomes with a log link function in Poisson regression models. Third, to investigate the potential role of outliers and the robustness of our results to the exclusion of individual countries in our sample, we re-estimated our main equations omitting each individual country from our sample. Fourth, we reweighted the observations with the population size of the country using the country population over 60 years old at the time of the survey. Fifth, we excluded surveys conducted prior to 2000, when ART coverage was very low. Finally, we used alternative definitions for the age cut-off of defining older age. We used ages 50 and 70 years old to define an elderly individual (as opposed to 60 years old), which capture the oldest 10% and 2% of the sub-Saharan African population, respectively [5].

Stata (version 15.0) was used for all statistical analyses.

Results

Descriptive statistics

Table 1 shows summary statistics. Our analytical sample included 297,331 elderly individuals. The proportion of elderly people living without a prime-age adult largely remained similar between the 1991-2000 surveys (25.9%) and 2011-2015 surveys (26.3%). In countries where HIV is highly endemic (5% or higher), the proportion of elderly increased from 31.8% to 33.5% over the same period. Compared with older individuals who lived with prime-age adults, elderly people living without prime-age adults were more likely to be female, to live in rural areas, and have completed fewer years of schooling. They were also less likely to have assets at home such as a radio. These findings suggest that, on average, elderly living without prime-age adults live in poorer socio-economic conditions relative to those living with prime-age adults.

Figure 1 illustrates the relationship between elderly living arrangements and AIDS mortality rates in sub-Saharan Africa. As expected, we find that higher AIDS mortality is associated with higher fractions of elderly living without prime-age adults. In Figure S4 in the Appendix, we show the naïve correlation between ART coverage and the proportion of elderly individuals living without prime-age adults using the most recent survey for each country included in our study. Additional ART coverage appears slightly associated with reduced co-residence between elderly individuals and prime-age adults. When we stratify by HIV prevalence, however, the relationship reverses in countries where HIV is highly endemic ($\geq$ 5%). One empirical concern with these naïve correlations between ART coverage and elderly living arrangements is that countries with higher ART coverage are likely to have higher mortality among younger generations for a range of other country specific factors (such as increased mortality from tuberculosis [27]). We therefore turn to

multivariable models that allow us to control for country and survey year indicators, in addition to a range of demographic and socio-economic characteristics.

In Tables 2 and S2 in the Appendix, we present our main results. We show the marginal effects obtained from probit regression models and coefficient estimates from the OLS models. Among countries where HIV was highly prevalent, ART coverage was significantly associated with a decrease in the proportion of older people living alone. Adjusting for a senior's age, sex, area of residence (urban vs rural), education, measures of household wealth, as well as survey year and country, a one percentage point increase in national ART coverage at the time of the survey was associated with an absolute reduction of 0.7 percentage points ($p < .001$) in the proportion of older people living alone and a 0.2 percentage points reduction ($p = .005$) in the proportion of older people living in missing generation households. ART coverage was also associated with an increase in the number of prime-age adults in households where an elderly individual lives (0.023, $p < .001$). As expected, in non-HIV-endemic countries, where the national roll-out of ART is unlikely to have affected the living conditions of elderly individuals, we find no significant relationship across all three measures of elderly living arrangements. In Table S3, we show results when stratifying by sex of the elderly individual and find slightly larger effects overall among female elderly individuals. Our results were consistent across a range of robustness checks including when using alternative model and sample specifications, alternative definitions of an elderly individual (50 and 70 years old), as well as when weighting the results by country population size (Tables S4-S8).

In Table 3, we used our parametric estimates to assess the population impact of increased ART coverage on the living arrangements of elderly people. Our estimates suggest that in

the countries with an HIV prevalence of $\geq$ 5% included in our study an additional 103,000 – 358,000 elderly individuals are living with prime-age adults as a result of increased ART coverage (1%). These findings suggest that the scale up of ART is linked to substantial consequences for the living arrangements and well-being of elderly in the region.

Discussion

In this retrospective analysis, using data from nearly 300,000 elderly people in sub-Saharan Africa, we demonstrate that ART coverage is positively associated with three major changes in the living conditions of elderly people: (i) an increase in the number living with prime-age adults; (ii) a reduction in the number living by themselves in households with children under age 10 (i.e., "missing generation" households); and (iii) an increase in the number of prime-age adults living with elderly individuals in households where elderly and prime-age adults live together. In countries where HIV is highly endemic, an additional 103,000 – 358,000 elderly individuals could be living with prime-age adults as a result of increased ART coverage (1%). To our knowledge, this study is the first multi-country analysis assessing the role of ART in elderly well-being. Estimates of the returns to investments in a life-saving treatment for prime-age adults are likely to be inaccurate without considering the broader societal consequences and meaning among household members who depend on their support.

These results are consistent with previous research on the relationship between AIDS mortality and the well-being of elderly individuals in Africa [2, 3, 28]. Two cross-national retrospective analyses found that an increase in AIDS mortality rate was associated with an increase in the proportions of older people living alone and in missing generation

households [2, 3]. Our study reveals a similar relationship between AIDS mortality and elderly living arrangements using more recent data from Africa as well as additional data from the AIS and MIS surveys (Figure 1). Taken together, these findings suggest that improved ART coverage might reverse some of the burden induced by the HIV epidemic for older people who lose their support and provide for young children. In households where elderly individuals depend on co-residence with prime-age adults, the continued scale up of HIV treatment may have large positive spillovers for elderly people [9].

This analysis has a few limitations. First, causality cannot be determined with the current study design. Nevertheless, we controlled for known confounders which were available in the DHS, AIS, and MIS [24, 29, 30]. Second, in addition to improving life expectancy [14], ART coverage may lead to changes in labor migration which affect our outcomes of elderly living arrangements [31, 32]. Circular migration, in particular, is associated with temporary periods spent away earning wages and sending remittances with subsequent returns to the home community [33]. Prime-age adults may need to migrate for work which would be more common with increased ART coverage [18]. Increased migration, however, would likely bias our estimates downwards since it would lead to less co-residence between elderly individuals and prime-age adults—thereby reducing the magnitude of the coefficient on ART coverage in our models. Third, we did not directly compare the health outcomes of elderly people living without prime-age adults vis-à-vis elderly individuals who lived with (and may be supported by) prime-age family members. Elderly living arrangements, however, have been linked to substantial changes in health outcomes [34, 35]. Fourth, increased co-residence between elderly individuals and younger generations in sub-Saharan Africa does not necessarily imply improved support for the elderly. Older

adults may have accumulated assets or savings, or support themselves through subsistence agriculture [36]. The elderly may also benefit from state old age pensions in a number of the countries included in the study, such as Lesotho, Namibia, and more recently, Uganda [37, 38]. In many households, intergenerational wealth transfers may occur from elderly individuals to the younger generation, rather than the other way around [11]. Nevertheless, prior research suggests that, on average, elderly individuals living without prime-age adults and those in missing generation households are less well-off compared to other household compositions [30]. Fifth, probit models with fixed effects have been suggested to be biased because of the "incidental parameters problem" in nonlinear fixed-effects model [39]. However, we used a relatively limited number of dummy variable coefficients which minimizes this risk and found similar results using linear probability models.

Finally, to assist in explaining and interpreting our quantitative findings, we will conduct a qualitative analysis in a sequential explanatory study design [40]. Qualitative data will be collected in selected countries in Africa (e.g., Botswana, Mozambique, South Africa, and Swaziland) through interviews with elderly individuals (ages 60+). This mixed-methods data generation will generate a nuanced understanding of the features of HIV treatment for aging in Africa and how it is likely to contribute to the living arrangements of elderly individuals [36]. While the current study provides evidence as to *whether* ART coverage is associated with changes in elderly living arrangements, the qualitative component will allow us to make conclusions regarding *why* ART coverage had the observed effects.

Conclusions

The HIV epidemic is changing demographic and household structures in Africa. Increasing coverage of HIV treatment may provide substantial benefits to elderly individuals who otherwise lack support from co-residing adults and provide for children.

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Contributors

JWDN, OK, LC, HS, SVS, TB and SV conceived and designed the study. JWDN conducted the statistical analyses under the guidance of SV, TB, and SVS. JWDN and SV wrote the report. OK and SVS suggested improvements to the statistical analyses. OK, LC, HS, TB, SVS, and SV contributed important revisions to the report. All authors approved the final submitted version of the report. JWDN is the guarantor.

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Role of funding source

The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Declaration of interests

We declare that we have no competing interests.

Ethical clearance

This study was considered exempt from full review by the Harvard T.H. Chan School of Public Health Institutional Review Board as the analysis was based on an anonymous public use data set with no identifiable information on the survey participants.

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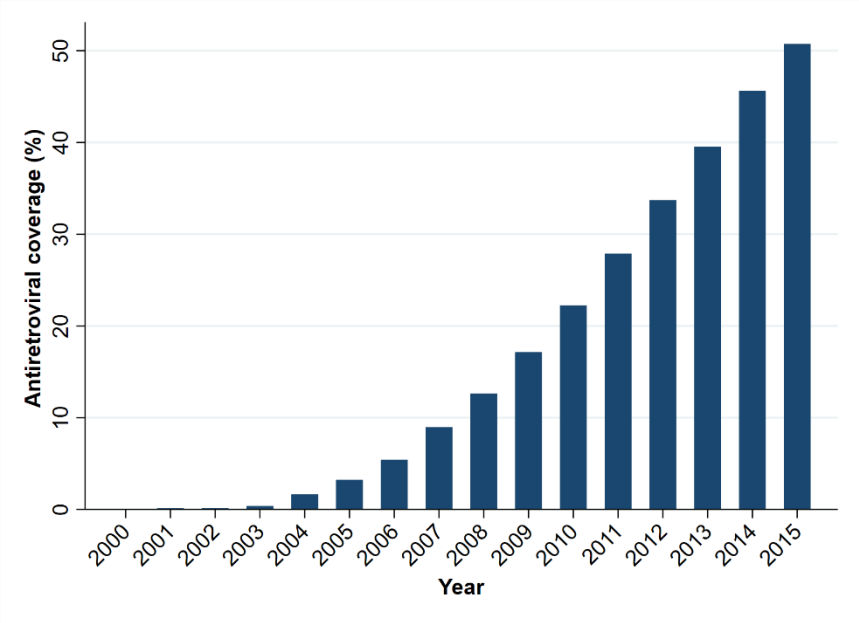
Appendix

In this appendix, we provide additional details related to our study, including:

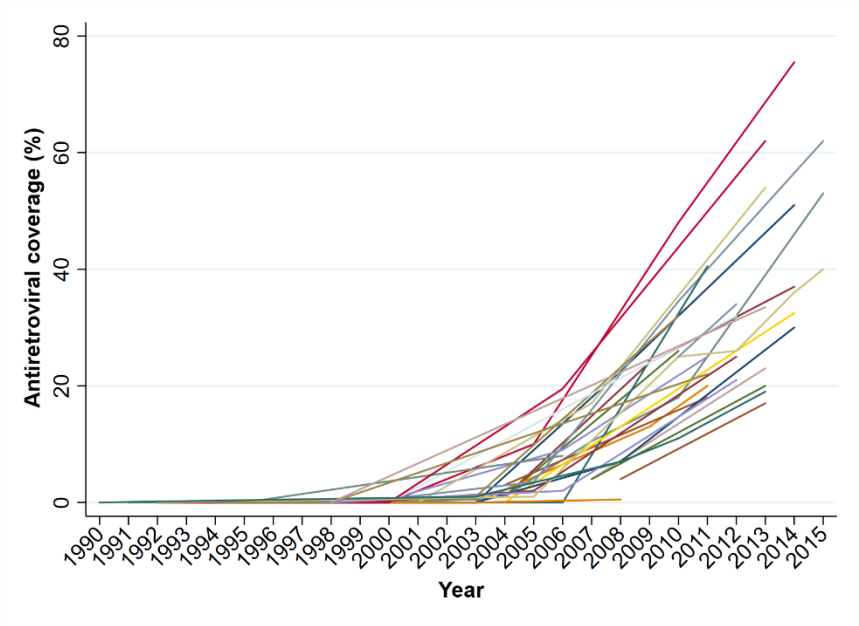
- **Figure S1**. Antiretroviral coverage in sub-Saharan Africa, by year
- **Figure S2**. Antiretroviral coverage in sub-Saharan Africa, by year and country
- **Figure S3.** Elderly living arrangements, by age
- **Figure S4**. Proportion of elderly living without prime-age adults, by ART coverage
- **Table S1**. ART coverage and elderly living arrangements, by study countries and years
- **Table S2**. Elderly living arrangements and ART coverage, full regression output
- **Table S3.** Elderly living arrangements and ART coverage, by sex
- **Table S4**. Elderly living arrangements and ART coverage, using Poisson models
- **Table S5.** Elderly living arrangements and ART coverage, post-2000 surveys
- **Table S6.** Elderly living arrangements and ART coverage, using quadratic in age
- **Table S7.** Elderly living arrangements and ART coverage, weighted by population
- **Table S8.** Using alternative definitions of elderly person (50 and 70 years old)

Figure S1. Antiretroviral coverage in sub-Saharan Africa, by year



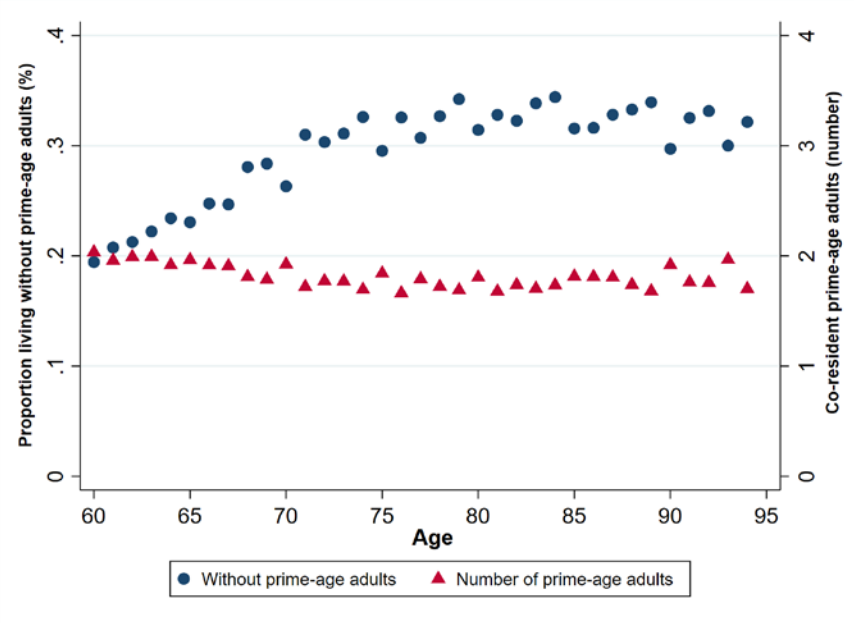
Notes: Figure shows average ART coverage in sub-Saharan Africa. ART coverage was defined as the percentage of all people living with HIV who are receiving antiretroviral therapy. ART coverage increased dramatically from the mid-2000s onwards. Source: annual UNAIDS estimates. Link: http://aidsinfo.unaids.org/.

Figure S2. Antiretroviral coverage in sub-Saharan Africa, by year and country



Notes: Figure shows ART coverage in the 28 sub-Saharan African countries included in our analysis in years when a Demographic and Health Survey, AIDS Indicator Survey, and/or Malaria Indicator Survey was conducted. ART coverage was defined as the percentage of all people living with HIV who are receiving antiretroviral therapy. ART coverage for each country-year observation is listed in Table S1. Source: annual UNAIDS estimates. Link: http://aidsinfo.unaids.org/.

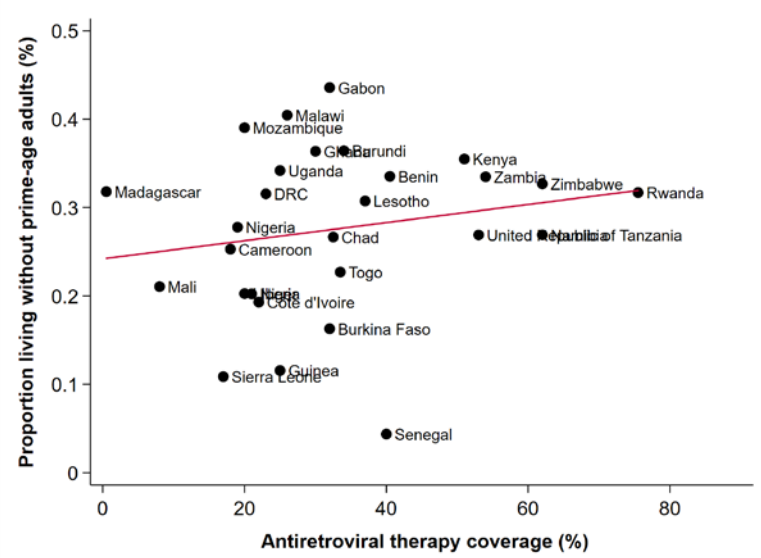
Figure S3. Elderly living arrangements, by age



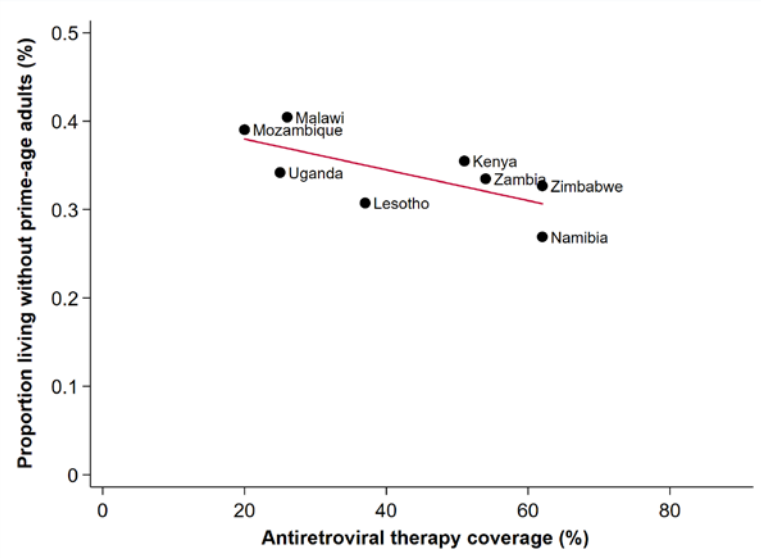
Notes: Figure shows (i) the proportion of older people (ages 60 or higher) living without prime-age adults (ages of 18 to 59) (blue circles) and (ii) the number of prime-age adults per household where an elderly individual lives (red triangles), by the age of respondents included in our analytical sample. Source: Demographic and Health Surveys, AIDS Indicator Surveys, and Malaria Indicator Surveys for 28 countries in sub-Saharan Africa, between 1991 – 2015.

Figure S4. Proportion of elderly living without prime-age adults and ART coverage

(a) pooled sample (*N* = 28 countries*)*



(b) country HIV prevalence ≥ 5% (*N* = 8 countries)



Notes: We used the most recently available Demographic and Health Survey, AIDS Indicator Survey, or Malaria Indicator Survey available for each country in our dataset to estimate the proportion of elderly living without prime-age adults. ART coverage was defined as the percentage of all people living with HIV who are receiving antiretroviral therapy. ART coverage relates to the year of the most recently available survey. Figure (a) includes all countries and figure (b) includes countries with an HIV prevalence of 5% or higher. Countries are categorized based on adult HIV prevalence (ages 15-49) in 2015 (UNAIDS 2015).

Table S1. ART coverage and elderly living arrangements, by study countries and years

Country	Survey year	ART coverage (%)	Lives without prime-age adults (%)	Lives in missing generation household (%)	Prime age adults in household (number)
Benin	1996	0.0	23.2	5.0	2.1
Benin	2001	0.0	24.8	5.0	1.8
Benin	2006	0.0	27.6	6.1	1.7
Benin	2011	40.5	33.7	9.6	1.4
Burkina Faso	1993	0.0	15.3	3.6	2.5
Burkina Faso	1998	0.0	13.6	3.2	2.4
Burkina Faso	2003	1.0	15.9	3.4	2.7
Burkina Faso	2010	32.0	16.9	4.0	2.1
Burundi	2010	25.0	37.3	8.2	1.1
Burundi	2012	34.0	36.5	10.2	1.1
Cameroon	2004	3.0	25.4	4.8	1.9
Cameroon	2011	18.0	24.3	5.7	2.0
Chad	2004	0.0	23.4	5.4	1.8
Chad	2014	32.5	26.8	9.1	1.7
Côte d'Ivoire	1994	0.0	11.0	2.4	3.6
Côte d'Ivoire	1998	0.0	8.7	1.3	3.7
Côte d'Ivoire	2011	22.0	19.2	4.6	2.3
Democatic Republic of Congo	2007	4.0	22.5	4.2	2.0
Democatic Republic of Congo	2013	23.0	30.2	6.6	1.6
Gabon	2000	0.0	31.3	3.4	1.9
Gabon	2012	32.0	34.0	2.8	1.5
Ghana	1993	0.0	43.4	10.8	1.1
Ghana	1998	0.0	41.6	8.2	1.1
Ghana	2003	0.0	33.3	7.3	1.4
Ghana	2008	7.0	33.8	6.2	1.3
Ghana	2014	30.0	39.7	7.5	1.1
Guinea	1999	0.0	10.8	4.0	2.7
Guinea	2005	2.0	13.9	4.4	2.4
Guinea	2012	25.0	11.0	4.2	2.6
Kenya	1993	0.0	34.5	6.1	1.4
Kenya	1998	0.0	40.4	5.8	1.2
Kenya	2003	0.0	33.6	5.1	1.4
Kenya	2008	22.5	33.5	6.3	1.3
Kenya	2014	51.0	35.0	7.9	1.2
Lesotho	2004	1.0	26.9	7.7	1.7
Lesotho	2009	24.0	26.0	7.7	1.8
Lesotho	2014	37.0	30.5	9.4	1.5
Liberia	2007	4.0	17.9	6.1	1.9
Liberia	2013	20.0	19.1	6.7	2.0
Madagascar	1992	0.0	26.9	7.1	1.7
Madagascar	1997	0.0	27.4	7.5	1.6
Madagascar	2003	0.0	30.3	6.3	1.4
Madagascar	2008	0.5	32.9	7.9	1.3
Malawi	1992	0.0	37.4	11.3	1.1
Malawi	2000	0.0	38.6	10.9	1.2
Malawi	2004	1.0	44.6	14.4	1.0
Malawi	2010	26.0	40.0	13.2	1.1
Mali	1995	0.0	19.2	4.5	2.4
Mali	2006	8.0	20.4	4.3	1.9

Mozambique	1997	0.0	34.1	5.2	1.4
Mozambique	2003	0.0	32.4	7.0	1.5
Mozambique	2009	13.0	50.5	10.5	0.8
Mozambique	2011	20.0	41.5	9.0	1.1
Namibia	1992	0.0	19.3	6.8	2.5
Namibia	2000	0.0	21.9	8.7	1.9
Namibia	2006	19.5	22.3	6.2	1.9
Namibia	2013	62.0	24.0	8.0	1.8
Niger	1998	0.0	17.5	7.9	2.3
Niger	2006	2.0	16.5	6.9	2.1
Niger	2012	21.0	21.8	8.5	1.6
Nigeria	1990	0.0	20.2	4.9	2.2
Nigeria	2003	1.0	19.5	3.1	2.1
Nigeria	2008	7.0	29.0	4.4	1.6
Nigeria	2010	11.0	24.2	6.5	1.8
Nigeria	2013	19.0	27.6	4.8	1.6
Rwanda	1992	0.0	29.4	11.2	1.4
Rwanda	2000	0.0	36.8	12.8	1.1
Rwanda	2005	10.0	31.8	10.2	1.2
Rwanda	2010	48.0	34.7	9.8	1.2
Rwanda	2014	75.5	32.3	8.0	1.3
Senegal	1992	0.0	5.5	1.7	4.0
Senegal	2005	1.0	4.1	1.1	4.6
Senegal	2010	25.0	2.8	0.9	4.9
Senegal	2012	26.0	2.7	0.2	5.1
Senegal	2014	36.0	3.4	0.5	4.8
Senegal	2015	40.0	4.4	1.1	4.5
Sierra Leone	2008	4.0	11.7	5.8	2.2
Sierra Leone	2013	17.0	11.1	5.3	2.4
Togo	1998	0.0	25.2	7.0	1.8
Togo	2013	33.5	20.1	5.8	2.2
Uganda	1995	0.0	38.6	12.6	1.2
Uganda	2000	0.5	40.0	12.0	1.2
Uganda	2006	9.0	35.6	13.1	1.3
Uganda	2011	25.0	35.0	12.6	1.3
United Republic of Tanzania	1991	0.0	20.4	4.7	2.1
United Republic of Tanzania	1996	0.0	26.2	4.9	1.7
United Republic of Tanzania	1999	0.0	21.4	4.3	1.9
United Republic of Tanzania	2003	0.5	26.1	7.3	1.8
United Republic of Tanzania	2004	1.0	25.4	5.0	1.9
United Republic of Tanzania	2007	10.5	26.2	6.7	1.7
United Republic of Tanzania	2010	18.0	27.2	6.9	1.7
United Republic of Tanzania	2011	25.0	24.5	7.1	1.8
United Republic of Tanzania	2015	53.0	27.7	7.5	1.7
Zambia	1992	0.0	25.2	4.5	1.8
Zambia	1996	0.0	25.7	6.2	1.8
Zambia	2001	0.0	27.4	7.1	1.6
Zambia	2007	17.0	35.7	10.1	1.3
Zambia	2013	54.0	33.3	8.5	1.4
Zimbabwe	1994	0.0	22.5	6.3	1.8
Zimbabwe	1999	0.0	30.7	8.7	1.4
Zimbabwe	2005	3.5	28.6	11.2	1.5
Zimbabwe	2010	34.5	30.7	10.8	1.4
Zimbabwe	2015	62.0	33.4	10.3	1.3

Notes: Sources: 103 Demographic and Health Surveys, AIDS Indicator Surveys, and Malaria Indicator Surveys for 28 countries in sub-Saharan Africa, between 1991 – 2015; annual UNAIDS estimates.

Table S2. Elderly living arrangements and ART coverage, full regression output

Subsample	**Country HIV prevalence > 5%**			**Country HIV prevalence ≥ 1 %**			**Country HIV prevalence < 1%**		
Dependent variable	**Lives without prime-age adults (1=yes, 0=no)**	**Lives in missing generation household (1=yes, 0=no)**	**Prime-age adults in household (number)**	**Lives without prime-age adults (1=yes, 0=no)**	**Lives in missing generation household (1=yes, 0=no)**	**Prime-age adults in household (number)**	**Lives without prime-age adults (1=yes, 0=no)**	**Lives in missing generation household (1=yes, 0=no)**	**Prime-age adults in household (number)**
Model	**Probit**	**Probit**	**OLS**	**Probit**	**Probit**	**OLS**	**Probit**	**Probit**	**OLS**
Predictor									
ART coverage (%)	-0.007***	-0.002***	0.023***	-0.001***	-0.001***	0.004*	0.002	-0.002	0.012
	(0.002)	(0.001)	(0.007)	(0.000)	(0.000)	(0.002)	(0.003)	(0.002)	(0.022)
Age (years)	0.004***	-0.001***	-0.008***	0.005***	-0.0002***	-0.007***	0.004***	0.001***	-0.002
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.002)
Female (1=yes, 0=no)	0.115***	0.059***	-0.228***	0.117***	0.053***	-0.218***	0.087***	0.035***	-0.197***
	(0.003)	(0.002)	(0.012)	(0.002)	(0.001)	(0.009)	(0.004)	(0.002)	(0.026)
Schooling (years)	0.003***	-0.002***	-0.014***	0.003***	-0.001***	-0.011***	0.004***	-0.0004	-0.059***
	(0.001)	(0.000)	(0.003)	(0.000)	(0.000)	(0.002)	(0.001)	(0.001)	(0.008)
Urban (1=yes, 0=no)	-0.044***	-0.032***	0.242***	-0.031***	-0.018***	0.277***	-0.008	-0.004	0.213***
	(0.009)	(0.005)	(0.032)	(0.005)	(0.003)	(0.023)	(0.007)	(0.004)	(0.078)
Electricity (1=yes, 0=no)	-0.009	-0.033***	0.257***	-0.033***	-0.019***	0.355***	-0.058***	-0.033***	1.392***
	(0.011)	(0.007)	(0.036)	(0.005)	(0.003)	(0.023)	(0.008)	(0.006)	(0.090)
Radio (1=yes, 0=no)	-0.128***	-0.024***	0.459***	-0.130***	-0.027***	0.559***	-0.090***	-0.030***	0.821***
	(0.005)	(0.003)	(0.017)	(0.003)	(0.002)	(0.013)	(0.005)	(0.003)	(0.041)
Bicycle (1=yes, 0=no)	-0.116***	-0.022***	0.412***	-0.143***	-0.030***	0.641***	-0.126***	-0.030***	0.931***
	(0.006)	(0.004)	(0.024)	(0.004)	(0.002)	(0.018)	(0.008)	(0.005)	(0.056)
Observations	92,474	92,474	92,474	234,321	234,321	234,321	54,096	54,096	54,096
R-squared			0.107			0.148			0.305

Multivariable probit and OLS models. Regression coefficients reflect the changes in outcome variable given an increase in national ART coverage of 1%. Values from the probit models are marginal effects estimates and those from the ordinary least squares regression are coefficient estimates. All models control for age, sex, residence (urban or rural), education, measures of household wealth, survey year indicators, and country indicators. Countries are categorized based on adult HIV prevalence (ages 15-49) in 2015 (UNAIDS). *** p<0.01, ** p<0.05, * p<0.1. Source: Demographic and Health Surveys, AIDS Indicator Surveys, and Malaria Indicator Surveys for 28 countries in sub-Saharan Africa, between 1991 – 2015.

Table S3. Elderly living arrangements and ART coverage, by sex

Dependent variable	**Lives without prime-age adults (1=yes, 0=no)**	**Lives in missing generation household (1=yes, 0=no)**	**Prime-age adults in household (number)**
Model	**Probit**	**Probit**	**OLS**
	Subsample: Female		
Predictor: ART coverage (%)			
Country HIV prevalence ≥ 5% (*N* = 50,076)	-0.006***	-0.003***	0.022***
	(0.002)	(0.001)	(0.007)
Country HIV prevalence ≥ 1 % (*N* = 123,836)	-0.002***	-0.001***	0.005**
	(0.001)	(0.000)	(0.002)
Country HIV prevalence < 1% (*N* = 26,255)	0.001	-0.003	0.011
	(0.004)	(0.002)	(0.023)
	Subsample: Male		
Predictor: ART coverage (%)			
Country HIV prevalence ≥ 5% (*N* = 42,671)	-0.007***	-0.001	0.021***
	(0.002)	(0.001)	(0.007)
Country HIV prevalence ≥ 1 % (*N* = 119,277)	-0.001	0.000	0.001
	(0.000)	(0.000)	(0.002)
Country HIV prevalence < 1% (*N* = 27,963)	0.003	-0.001	0.013
	(0.003)	(0.001)	(0.023)

Multivariable probit and OLS models. Regression coefficients reflect the changes in outcome variable given an increase in national ART coverage of 1%. Values from the probit models are marginal effects estimates and those from the ordinary least squares regression are coefficient estimates. All models control for age, residence (urban or rural), education, measures of household wealth, survey year indicators, and country indicators. Countries are categorized based on adult HIV prevalence (ages 15-49) in 2015 (UNAIDS). *** p<0.01, ** p<0.05, * p<0.1. Source: Demographic and Health Surveys, AIDS Indicator Surveys, and Malaria Indicator Surveys for 28 countries in sub-Saharan Africa, between 1991 – 2015.

Table S4. Elderly living arrangements and ART coverage, using Poisson models

Dependent variable	**Lives without prime-age adults (1=yes, 0=no)**	**Lives in missing generation household (1=yes, 0=no)**	**Prime-age adults in household (number)**
Model	**Poisson**	**Poisson**	**Poisson**
Predictor: ART coverage (%)			
Country HIV prevalence ≥ 5% (*N* =92,474)	-0.007***	-0.002***	0.018***
	(0.002)	(0.001)	(0.004)
Country HIV prevalence ≥ 1 % (*N* =234,321)	-0.001***	-0.001***	0.002
	(0.000)	(0.000)	(0.000)
Country HIV prevalence < 1% (*N* =54,096)	0.003	-0.002	0.010
	(0.004)	(0.002)	(0.010)

Multivariable poisson models. Regression coefficients reflect the changes in outcome variable given an increase in national ART coverage of 1%. Values are marginal effects estimates. All models control for age, sex, residence (urban or rural), education, measures of household wealth, survey year indicators, and country indicators. Countries are categorized based on adult HIV prevalence (ages 15-49) in 2015 (UNAIDS). *** p<0.01, ** p<0.05, * p<0.1. Source: Demographic and Health Surveys, AIDS Indicator Surveys, and Malaria Indicator Surveys for 28 countries in sub-Saharan Africa, between 1991 – 2015.

Table S5. Elderly living arrangements and ART coverage, using post-2000 surveys

Dependent variable	**Lives without prime-age adults (1=yes, 0=no)**	**Lives in missing generation household (1=yes, 0=no)**	**Prime-age adults in household (number)**
Model	**Probit**	**Probit**	**OLS**
Predictor: ART coverage (%)			
Country HIV prevalence ≥ 5% (*N* =74,061)	-0.007***	-0.002**	0.028***
	(0.002)	(0.001)	(0.006)
Country HIV prevalence ≥ 1 % (*N* =193,881)	-0.002***	-0.001***	0.008***
	(0.001)	(0.000)	(0.002)
Country HIV prevalence < 1 % (*N* =43,575)	n/a	n/a	n/a

Multivariable probit and OLS models. Regression coefficients reflect the changes in outcome variable given an increase in national ART coverage of 1%. Values from the probit models are marginal effects estimates and those from the ordinary least squares regression are coefficient estimates. All models control for age, sex, residence (urban or rural), education, measures of household wealth, survey year indicators, and country indicators. In the subsample of HIV prevalence < 1%, the country variable drops out because of collinearity with few country-year observations. Countries are categorized based on adult HIV prevalence (ages 15-49) in 2015 (UNAIDS). *** p<0.01, ** p<0.05, * p<0.1. Source: Demographic and Health Surveys, AIDS Indicator Surveys, and Malaria Indicator Surveys for 28 countries in sub-Saharan Africa, between 2000 – 2015.

Table S6. Elderly living arrangements and ART coverage, using quadratic in age

Dependent variable	**Lives without prime-age adults (1=yes, 0=no)**	**Lives in missing generation household (1=yes, 0=no)**	**Prime-age adults in household (number)**
Model	**Probit**	**Probit**	**OLS**
Predictor: ART coverage (%)			
Country HIV prevalence ≥ 5% (*N* =92,474)	-0.007***	-0.002***	0.023***
	(0.002)	(0.001)	(0.007)
Country HIV prevalence ≥ 1 % (*N* =234,321)	-0.001***	-0.001***	0.003*
	(0.000)	(0.000)	(0.002)
Country HIV prevalence < 1% (*N* =54,096)	0.002	-0.002	0.012
	(0.003)	(0.002)	(0.022)

Multivariable probit and OLS models. Regression coefficients reflect the changes in outcome variable given an increase in national ART coverage of 1%. Values from the probit models are marginal effects estimates and those from the ordinary least squares regression are coefficient estimates. All models control for age, age squared, sex, area of residence, education, measures of household wealth, survey year indicators, and country indicators. Countries are categorized based on adult HIV prevalence (ages 15-49) in 2015 (UNAIDS). *** p<0.01, ** p<0.05, * p<0.1. Source: Demographic and Health Surveys, AIDS Indicator Surveys, and Malaria Indicator Surveys for 28 countries in sub-Saharan Africa, between 1991 – 2015.

Table S7. Elderly living arrangements and ART coverage, weighted by population size

Dependent variable	**Lives without prime-age adults (1=yes, 0=no)**	**Lives in missing generation household (1=yes, 0=no)**	**Prime-age adults in household (number)**
Model	**Probit**	**Probit**	**OLS**
Predictor: ART coverage (%)			
Country HIV prevalence ≥ 5% (*N* =92,474)	-0.009***	-0.002**	0.031***
	(0.002)	(0.001)	(0.005)
Country HIV prevalence ≥ 1 % (*N* =234,321)	-0.002**	-0.000*	0.005*
	(0.001)	(0.000)	(0.003)
Country HIV prevalence < 1% (*N* =54,096)	0.001	-0.003*	0.025
	(0.004)	(0.002)	(0.022)

Multivariable probit and OLS models. Regression coefficients reflect the changes in outcome variable given an increase in national ART coverage of 1%. Values from the probit models are marginal effects estimates and those from the ordinary least squares regression are coefficient estimates. All models control for age, sex, residence (urban or rural), education, measures of household wealth, survey year indicators, and country indicators. Countries are categorized based on adult HIV prevalence (ages 15-49) in 2015 (UNAIDS). *** p<0.01, ** p<0.05, * p<0.1. Observations were reweighted with the country population size ages 60+ at the time of the survey. Source: Demographic and Health Surveys, AIDS Indicator Surveys, and Malaria Indicator Surveys for 28 countries in sub-Saharan Africa, between 1991 – 2015.

Table S8. Using alternative definitions of elderly person (50 and 70 years old)

Dependent variable	**Lives without prime-age adults (1=yes, 0=no)**	**Lives in missing generation household (1=yes, 0=no)**	**Prime-age adults in household (number)**
Model	**Probit**	**Probit**	**OLS**
Subsample: Elderly defined as ≥ 70 years old			
Predictor: ART coverage (%)			
Country HIV prevalence ≥ 5% (*N* =40,238)	-0.009***	-0.004***	0.032***
	(0.002)	(0.001)	(0.007)
Country HIV prevalence ≥ 1 % (*N* =99,967)	-0.001**	-0.001***	0.004*
	(0.001)	(0.000)	(0.002)
Country HIV prevalence < 1% (*N* =21,959)	0.002	-0.001	0.019
	(0.003)	(0.002)	(0.025)
Subsample: Elderly defined as ≥ 50 years old			
Predictor: ART coverage (%)			
Country HIV prevalence ≥ 5% (*N* =173,655)	-0.004***	-0.001*	0.014**
	(0.002)	(0.001)	(0.006)
Country HIV prevalence ≥ 1 % (*N* =442,938)	-0.001**	-0.001***	0.002
	(0.000)	(0.000)	(0.002)
Country HIV prevalence < 1% (*N* =107,638)	0.001	-0.003*	0.015
	(0.003)	(0.002)	(0.019)

Multivariable probit and OLS models. Regression coefficients reflect the changes in outcome variable given an increase in national ART coverage of 1%. Values from the probit models are marginal effects estimates and those from the ordinary least squares regression are coefficient estimates. All models control for age, sex, residence (urban or rural), education, measures of household wealth, survey year indicators, and country indicators. In Panel A, we defined an elderly person to be 70 years of age or older and a prime-age adult between the ages of 18 and 69. In Panel B, we defined an elderly person to be 50 years of age or older and a prime-age adult between the ages of 18 and 49. Countries are categorized based on adult HIV prevalence (ages 15-49) in 2015 (UNAIDS). *** p<0.01, ** p<0.05, * p<0.1. Source: Demographic and Health Surveys, AIDS Indicator Surveys, and Malaria Indicator Surveys for 28 countries in sub-Saharan Africa, between 1991 – 2015.