Age patterns and sex ratios of adult mortality in countries with high HIV prevalence

Bruno Masquelier[1], Jeff Eaton[2], Patrick Gerland [3], and François Pelletier[3]

[1]Louvain University, Belgium
[2]Imperial College London, UK
[3]Population Division of the United Nations, USA

Extended abstract for the 7th APC Conference - July 2015

Abstract

Adult mortality rates are poorly estimated in countries with high HIV prevalence due to the lack of comprehensive vital registration. A common approach consists in adding the number of AIDS-related deaths derived from epidemiological modeling on top of AIDS-free mortality rates. The latter are often obtained by anchoring model schedules of mortality to child survival. With such a counterfactual approach, age patterns and sex ratios of adult mortality are largely driven by model parameters. Here we compare UNAIDS all-cause mortality rates and orphanhood prevalence with survey and census data to detect significant deviations between empirical and model-based estimates. We also assess the sensitivity of model outputs to changes in the sex ratio of incidence and age patterns of infection. Both sibling and orphanhood data suggest larger sex ratios than in model-based estimates. Age patterns of mortality also have a larger AIDS hump in model outputs than in surveys and censuses.[1]

[1]This paper is a revised and updated version of a paper presented at the 6th African Population Conference in Ouagadougou. It focuses on countries with high HIV and also uses an extended set of data sources to compare with model-based estimates of mortality.

1 INTRODUCTION

All countries need timely and reliable estimates of mortality to monitor progress in the health of their populations. This need is especially acute in African countries highly affected by HIV/AIDS, where life expectancy at birth substantially declined in the 1990's and early 2000's before increasing again in the last decade. Yet, there is still considerable uncertainty as to mortality changes in these countries, and in Sub-Saharan Africa more generally. This is because vital registration systems operating in the region fail to provide full national coverage. Even in areas covered by registration offices, many vital events go unreported or local registers are not used to produce regular statistics. Overall, less than 50% of deaths are reported in official records at the national scale, with only few exceptions (e.g. South Africa). As a result, mortality trends and patterns are reconstructed from patchy and often discrepant estimates obtained from censuses and surveys.

The lack of reliable estimates is particularly egregious for adult mortality. More attention has historically been devoted to the measurement of child mortality, and methods to synthesize various estimates and account for data quality issues are now well established (Alkema et al. 2014). By contrast, the key developments in estimating adult mortality from incomplete or deficient vital statistics date back to the 1970's and early 1980's, before the onset of HIV/AIDS. The epidemic has since greatly complicated the estimation of mortality. For example, intercensal survival techniques have long been used to convert the cohort attrition between two censuses into measures of adult survival (Preston 1983, Preston and Bennett 1983). In countries suffering from large HIV epidemics, however, these techniques are now useless, because the attrition due to net migration and the excess mortality due to AIDS cannot be distinguished, since they are both concentrated in a narrow range of adult ages. Death distribution methods, designed to evaluate the completeness of death reporting, are also hazardous to apply because they assume that the completeness of death reporting is invariant by age (Hill 1987, Bennett and Horiuchi 1984). AIDS deaths among young adults could result in the dissolution of some households, which would violate this key assumption. The orphanhood technique, another widely used method, is based on survey and census reports on the survival of parents (Brass and Hill 1973, Blacker 1977). This method has been rendered obsolete in its original form because of the vertical transmission of the virus and atypical age patterns of mortality (Timæus and Nunn 1997). Lastly, data on the survival of siblings have been collected from women of reproductive age interviewed in Demographic and Health Surveys (DHS) since the early 1990's. Compared to other approaches, the sibling method is less affected by HIV-related biases, but there is accumulating evidence that deaths are omitted in sibling histories. Since the under-reporting of sibling deaths appears to be particularly pronounced in the more distant past (Masquelier et al. 2014), sibling histories could exaggerate the increase in adult mortality due to AIDS.

Overall, no method is fully satisfactory for estimating adult mortality in the absence of vital registration. In addition, the available estimates do not always provide time series needed to fully reconstruct past trends in mortality. They refer only to a few points in time, often outdated and sometimes ill-defined. In some cases, they correspond to probabilities

of surviving only for specific segments of the adult ages ($_{10}p_{25}$, $_{10}p_{35}$, etc.). In this context, estimates of adult mortality developed by the UN and others continue to be somewhat tied in with trends in child survival. Historically, the United Nations Population Division (UNPD) obtained age-specific death rates by indexing a standard age pattern of mortality to the probability $_5q_0$ for most African countries. Over past rounds of estimates, the UNPD has increasingly used a relational model to better reflect the observed relationship between adult and child survival, but this is not done for countries highly affected by HIV. In these countries, a counter-factual no-aids mortality scenario is first constructed, based on trends in child mortality. The excess mortality due to AIDS is then explicitly modeled using Spectrum/EPP, a program developed by the United Nations Programme on HIV/AIDS (UNAIDS) to estimate key HIV indicators. From surveillance and surveys, a smoothed trend in HIV incidence is generated and combined with age and sex patterns of infection to obtain the number of people living with HIV. These people progress over time to lower CD4 counts and are exposed to AIDS-related mortality. Those under ART benefit from extended survival. At any stage, infected individuals are also exposed to non-AIDS mortality rates, at a same rate as those not infected. On a country basis, UNPD analysts then check the resulting all-cause mortality rates against available empirical data. When important discrepancies are apparent with model outputs, the non-aids life expectancy is revised and the procedure is repeated until a "reasonable agreement" is achieved (United Nations 2005).

A different strategy was adopted in the Global Burden of Disease Study 2013, but still based on a counter-factual scenario. Risks of dying between the ages 15 and 60 were derived from all available empirical measurements, and then related to trends in child mortality in a regression framework including covariates (income per person, education and crude rates of death caused by AIDS). For countries affected by HIV/AIDS, these covariates were used to obtain counterfactual non-HIV values of mortality in children ($_5q_0$) and adults ($_{45}q_{15}$). These values served as entry parameters to generate a complete set of age-specific mortality rates. For this part, empirical life tables of the same country were used if available, or other countries with similar mortality profiles (GBD 2013 2014). The excess mortality due to AIDS was later added to the free age pattern of mortality, using a set of relative risks due to HIV by age and sex.

All model life-table systems used in the UNPD or the GBD thus refer to populations that have not been affected by HIV, and the mortality impact of the epidemic is taken into account in a second step. This is because changes in age patterns and sex ratios of mortality in generalized HIV epidemics are difficult to synthesize in a parsimonious model. However, more than 30 years after the onset of HIV/AIDS, this counter-factual approach has become highly problematic. First, the reliability of risks of dying net of AIDS inferred from the available surveys and censuses can be called into question, just as regression outputs from a limited set of covariates. In the case of the UN, the no-aids mortality rates are mostly derived from trends in child survival, but these estimates are biased by the vertical transmission of the virus (Walker et al. 2012). Even unbiased trends in child mortality may not necessarily reflect trends in mortality of the uninfected adult population. In several

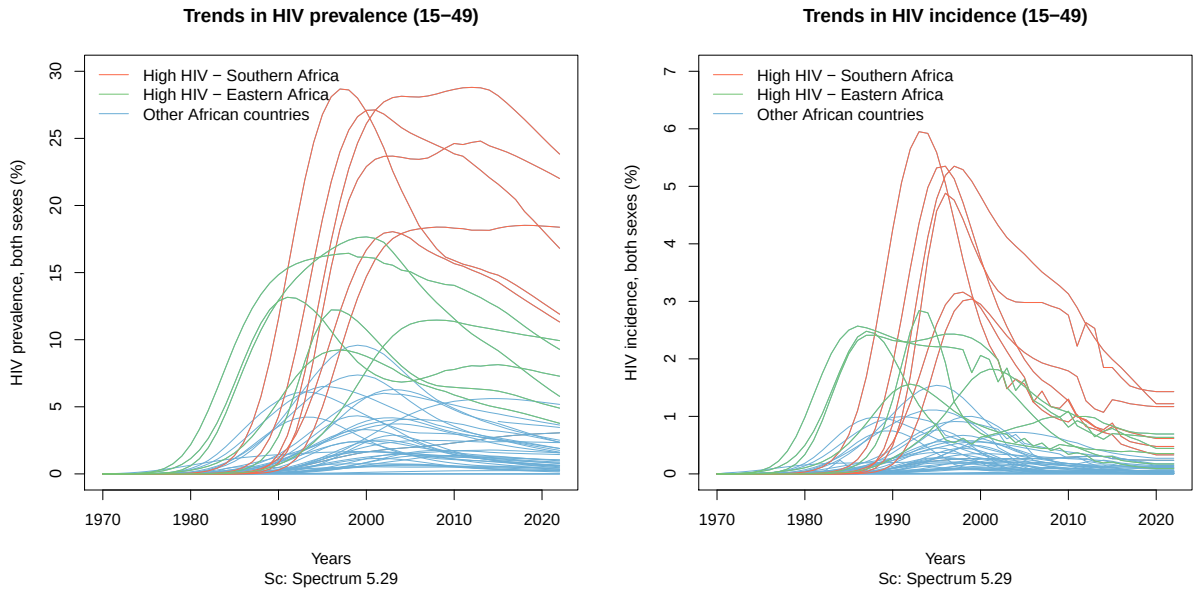

Figure 1 – *Trends in HIV prevalence and incidence for selected African countries*

African countries with small HIV epidemic, adult mortality has stagnated even though child mortality has dramatically declined (Masquelier et al. 2014). Second, there is some circularity in the estimation process. For example, non-aids mortality rates developed by the UNPD are key inputs of the modelling of the demographic impact of HIV/AIDS by Spectrum. However, they are also revised depending on all-cause mortality rates coming out of Spectrum. As for the GBD Study, it uses the UNAIDS estimates of crude rates of death caused by HIV/AIDS as a key covariate; these rates are also obtained from Spectrum, and therefore in part based on UNPD estimates.

Considering the strong assumptions about key parameters such as age and sex patterns of incidence over time in the modeling of AIDS-related deaths, there is a need for a more systematic evaluation of model-based estimates of adult mortality in high-prevalence countries. In this paper, we focus on countries where the peak in HIV prevalence was higher than 10%, plus the United Republic of Tanzania where HIV peaked at 9%. Because of differences in the timing and magnitude of the epidemics, the 12 countries are split into two groups: "high HIV -Eastern Africa" includes Kenya (KEN), Malawi (MWI), Mozambique (MOZ), Uganda (UGA), Tanzania (TZA) and Zambia (ZMB). "High HIV Southern Africa" includes Botswana (BWA), Lesotho (LSO), Namibia (NAM), South Africa (ZAF), Swaziland (SWZ), and Zimbabwe (ZWE). Trends in HIV prevalence and HIV incidence estimated by UNAIDS for these countries are presented in Figure 1.

First, we will present comparisons between model-based and empirical estimates of adult mortality. Mortality rates derived from DHS sibling histories and censuses will be evaluated against UNAIDS estimates of all-cause mortality. Secondly, proportions of orphaned children reported in household surveys and censuses will be compared with orphanhood prevalence estimated by Spectrum. Our working hypothesis is that empirical estimates

provide at best lower bounds, because of under-reporting of deaths and misreporting of orphanhood status. This extended abstract will present preliminary results for this first part. We also plan to use regression analysis to detect any systematic differences in the mortality levels and age/sex-patterns derived from different data sources (sibling data, recent household deaths, etc.). Second, we will explore the sensitivity of model outputs to different assumptions as regards the early sex ratios of incidence and age patterns of infection. This will be performed by generating different scenarios for a few countries in Spectrum and evaluating how they relate to empirical estimates. Parameters changing over time will also be explored.

2 DATA AND METHODS

2.1 UNAIDS ESTIMATES OF ALL-CAUSE MORTALITY

Our comparisons are based on the 2014 estimates of all-cause mortality developed by UNAIDS (extracted from Spectrum v5.29). These estimates are obtained by combining non-aids mortality rates from the 2012 Revision of the World Population Prospects (WPP) developed by the UNPD, with a complete modeling of the mortality impact of HIV/AIDS.

Non-aids mortality rates from the 2012 WPP are mainly derived from trends in child mortality (${}_5q_0$). Since 2004, several UN agencies[2] collaborate within the Inter-agency Group for Child Mortality Estimation (IGME) to obtain consistent and accurate child mortality rates from surveys and censuses (www.childmortality.org). In order to generate a complete no-AIDS life table that pertains to the uninfected population, trends in ${}_5q_0$ were combined with a uni-parametric model schedule in all the high prevalence countries considered here. The North model of Coale et al. (1983) was used for all countries classified in the "High HIV Eastern Africa" group, except Malawi, for which the South model was retained. By contrast, in Southern Africa, the West model of Coale-Demeny life tables was used for Botswana, Lesotho, Namibia and Swaziland. Estimates for Zimbabwe were based on the North Model, while the Far Eastern pattern from the United Nations (1982) life tables was used for South Africa.

It should be noted that a logit model, which has an additional parameter explicitly related to adult survival, was used in 22 African countries in the 2012 World Population Prospects. The UNPD has gradually moved away from one-parameter life tables and adopted a relational model (United Nations 2014). Various data series were considered to establish the level of adult mortality (${}_{45}q_{15}$), including reports on recent household deaths (adjusted for underregistration), orphanhood data, sibling estimates and intercensal survival ratios. However, this approach is not currently adopted for high HIV countries, because of the complexity of modeling mortality increases due to AIDS.

The non-aids life tables were then introduced into Spectrum. This program starts with country-specific estimates of HIV prevalence, obtained by fitting a smooth trend through past estimates from surveillance and survey data (Brown et al. 2006; 2008; 2010). From

[2]UNICEF, WHO, The World Bank and UNPD.

the reconstructed trends in prevalence, incidence rates and AIDS-related deaths are computed, based on assumptions about the age and sex patterns of infection, the patterns of survival after infection (Todd et al. 2007), and data on ART treatment. The number of children under five who contract the virus from their mother and will die of AIDS was then estimated from the number of HIV positive mothers, accounting for a reduced fertility of infected mothers, pediatric treatment, and interventions to prevent the vertical transmission (PMTCM).

This modelling of HIV/AIDS is the most important part of the mortality estimation for countries hardest hit by the epidemic. However, estimates are also sensitive to the choice of the age pattern used to infer background mortality. For a given level of child mortality, model schedules can exhibit very different chances of surviving in adulthood. For example, in the North model, the probability of a female surviving to age 5 ($_5p_0$) implied by a life expectancy at birth of 50 years corresponds to a probability of dying between ages 15 and 60 ($_{45}q_{15}$) of 0.337. With the South model, the same proportion of females surviving to age 5 corresponds to a life expectancy of 54 years and a probability $_{45}q_{15}$ that is 30% lower (0.243). The North and West models are closer to one another. For females, these two models have a roughly similar child mortality (for a same life expectancy at birth), but the West model encompasses a somewhat higher infant mortality. In adulthood, the West model corresponds to slightly higher mortality rates for females when the life expectancy is below 60. The ratio of North to West death rates increases steadily as the mortality decreases. The differences between the West and North models are more pronounced for males, as can be seen in Fig. 2 when life expectancy at birth reaches 65. Finally, the Far Eastern pattern, known to reflect high rates of mortality from tuberculosis, exhibits extreme levels of adult mortality for a given level of child survival. The reason why the North pattern has historically been preferred for tropical Africa is because it has one feature - low infant mortality relative to mortality at 1 to 5 - that is customary in African populations (Brass et al. 1968, Ekanem and Som 1984). It also displays high death rates from tuberculosis, though less extreme than the Far Eastern model. This second trait makes it attractive for Africa, because the age pattern of mortality from tuberculosis is close to the age pattern of mortality from malaria, a major cause of death in the region (Preston 1976).

2.1.1 Estimates of the number of orphans in childhood

UN agencies estimate the number of orphans from mathematical models relying on UNPD fertility and mortality rates (UNICEF 2006). The estimation method, developed by Grassly and Timaeus (2005), starts with the distribution of adult deaths by age and calendar year, and consists in estimating how many children were born to those adults, and whether these children are still alive and aged less than 18 years at the time of interest. To calculate the number of maternal orphans due to AIDS, the method accounts for the vertical transmission of the virus, the lower fertility of infected mothers, and the excess risks of mortality faced by orphans[3]. The HIV status of mothers in the years preceding their death is back-calculated,

[3]Using data from demographic surveillance sites, Zaba et al. (2005) showed that, in addition to higher death rates due to mother-to-child transmission, children under age 5 of both infected and uninfected

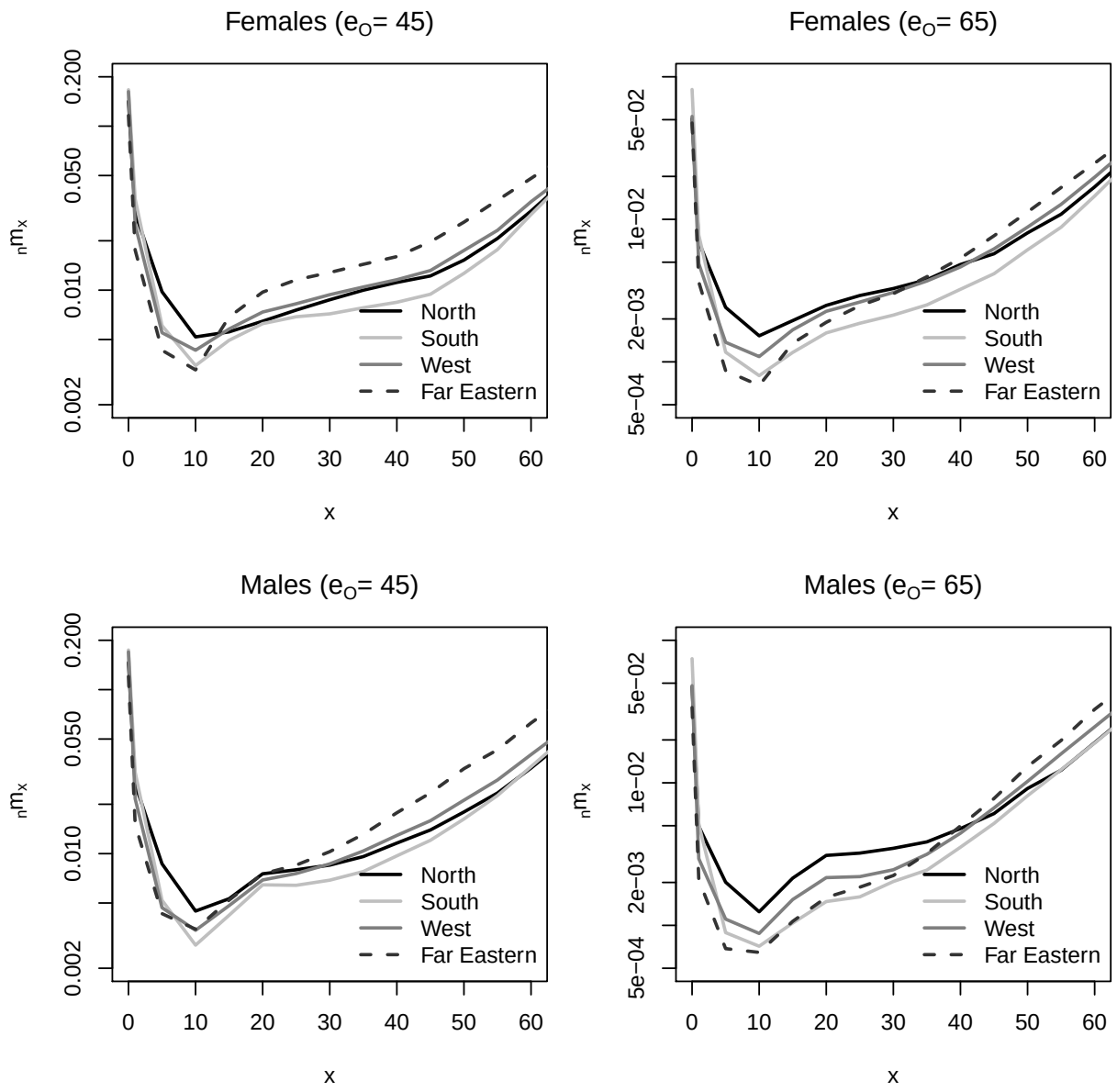

Figure 2 – *Mortality rates implied by different model age patterns for life expectancies at birth of 45 and 65 years*

using a standard pattern of disease progression. The number of maternal orphans due to other causes than AIDS is calculated in a similar way, assuming that their mothers remain uninfected. The estimation of paternal orphans is further complicated by the need to account for the effect on child survival of HIV transmission (from mother to child and between parents), as well as the reduced fertility of partners of infected men. This is done by using DHS data on concordance of HIV status amongst heterosexual partners. Because data on male fertility are seldom collected, a standard schedule is applied to estimate the number of children who were born by age of fathers (Paget and Timaeus 1994). Finally, since survival chances of both parents are not independent, the excess risk of dual orphanhood is predicted from a multi-level model fitted on proportions of maternal, paternal and dual orphans observed in DHS[4].This estimation method has been incorporated within Spectrum. In 2014, it has been revised to account for ART and PMTCT programmes (Stover et al. 2014).

2.2 EMPIRICAL ESTIMATES OF ALL CAUSE MORTALITY AND ORPHANHOOD

This study makes use of a variety of data sources. First, age-specific mortality estimates are obtained from 87 DHS with sibling histories collected in 36 countries (from 1992 to 2014)[5]. We complement these with mortality rates calculated from reports on recent household deaths in censuses and large-scale surveys, and with vital registration data when available. Secondly, proportions of orphaned children among 5- to 9-year olds are derived from DHS and MICS surveys, as well as census reports for 38 countries from 1965.

2.2.1 Sibling survival data from Demographic and Health Surveys

Sibling histories have been collected in a maternal mortality module included in DHS surveys since 1988. A standardized set of questions is used to elicit an exhaustive list of siblings born to the same mother by birth order. Information is collected about their gender and survival status. Current age is recorded for surviving siblings, while age at death and years since death are collected for the deceased. Some additional questions are aimed at identifying pregnancy-related deaths. In addition to interviews with women of reproductive ages, questions about sibling survival are included in the men's questionnaires of some DHS on a subsample of households. Sibling histories are also collected in other international survey programs, such as the World Health Surveys and MICS surveys (Obermeyer et al. 2008).

The main advantage of sibling histories is that they provide direct estimates, since the observed number of deaths can be divided by the corresponding person-years of exposure.

mothers experienced higher mortality risks in a 2-year period centered on the mother's death.

[4]The estimation of the excess risk of being double orphans has no bearing on this analysis, since we are only dealing with proportions of paternal or maternal orphans, irrespective of the survival status of the other parent.

[5]Several DHS surveys are discarded: the DHS conducted in Sudan in 1990 because the dataset is not standardized, the DHS for Nigeria 1999 because the data are not of very good quality (Pullum 2008), and the DHS conducted in 1995 in Eritrea because the data is not in public domain.

Indirect techniques are also available to convert proportions of surviving siblings into survival probabilities (Hill and Trussell 1977, Timaeus et al. 2001), but they tend to smooth out the trends in mortality. Sibling histories are also widely collected, they are standardized, readily available, and similar format to birth histories. A single survey can give a certain sense of past trends in mortality.

One limitation of the direct approach is that sample sizes do not allow for the calculation of annual age-specific death rates without introducing some modelling. Estimates presented in this paper are obtained after pooling surveys together within each country but fitting separate models for each country. We used penalized thin-plate regression splines for the trends. The age pattern and sex differences were allowed to change linearly with the duration of each country's HIV epidemic (starting 4 years after the onset of HIV/AIDS). We also adjusted mortality rates upwards to account for the underreporting of deceased children and siblings, based on a comparison of mortality rates obtained from successive surveys for a fixed reference period. Further details on the methodology are provided elsewhere (Masquelier et al. 2014).

Owing to poor quality of recall, the general consensus is that sibling histories generally provide lower bound estimates. For instance, using 14 DHS conducted between 1989 and 1995, Stanton et al. (2000) evaluated unadjusted probabilities of dying between ages 15 and 50 ($_{35}q_{15}$) derived from sibling histories against life expectancies estimated in the 1994 Revision of the WPP. Then they compared the relationship between the two indexes of mortality with the corresponding relationship embodied in Princeton life tables. This assessment revealed that several sibling estimates fell well below the level that would be expected if the age pattern of mortality conformed to one of the mortality schedules. Supplementing this analysis with additional comparisons with independent estimates deemed to be of good quality, Stanton et al. (2000) concluded that sibling histories understated mortality, especially in sub-Saharan Africa.

2.2.2 Recent household deaths

To complement sibling histories, we used reports on deaths that occurred in households in the 12 months prior to a series of censuses and surveys, as well as data from vital registration available in the Demographic Yearbook. Here we use raw mortality rates, without adjusting for incompleteness of death reporting. Estimates should therefore be considered as lower bounds. The database now covers 51 censuses, surveys or years of vital registration for the 12 countries considered.

2.2.3 Orphanhood data in censuses and surveys

Questions about orphanhood were first included in retrospective surveys organized in Chad, West Cameroon and Mauritania in 1964-65, as well as in the mortality module administered in some of the World Fertility Surveys. They were aimed at allowing the indirect estimation of adult mortality through the orphanhood technique, a method originally proposed by Henry (1960) and refined, among others, by Brass and Hill (1973) and Timaeus (1986), Timæus (1991;?), Timaeus (1991), Timæus (1992). In the early 1990s, questions on orphanhood appeared in the DHS and MICS rosters of household membersHowever,

these questions were restricted to children under 15 (or 18), which indicates the focus had moved to the vulnerability of orphans and vulnerable children (OVCs).

Many African countries have also included these questions in their census schedule since the 1960s. Some countries have collected data on parental loss at each census round (e.g. Gambia, Kenya, Sierra Leone), while other countries have never done so (e.g. Guinea or Nigeria). As is the case of sample surveys, the primary purpose of these questions was to allow the estimation of adult mortality. Later on, the HIV-TB epidemic spurred a renewed interest in the number of orphans, their schooling attainments and living arrangements. In a few countries, questions on parental survival were then restricted to people under a certain age (18, 20 or 25).

This study draws on proportions of orphaned children under age 15 as observed in 61 censuses, 112 DHS, 43 MICS, and 18 additional surveys (such as *Sexual Behavior Surveys* in Zambia or *October Household Surveys* in South Africa). Maternal orphans are defined as children whose mother is dead, regardless of the survival status of their father. Paternal orphans are defined in a similar way. Because causes of death of parents are not recorded, it is not possible to distinguish between AIDS- and non-AIDS orphans.

It is widely recognized that observed proportions of orphans underestimate by a large extent the true orphan prevalence. The most pervasive problem is the "adoption effect", which refers to the fact that some fostered orphans are misclassified as non-orphans. In the presence of adults, interviewers may not probe whether they are the biological parents of children observed in the household (Blacker 1984). Foster parents may also deliberately or inadvertently claim adopted orphans as their own offspring. Often cited as a source of confusion is the usage of terms pertaining to biological parents to refer to larger circles of kins or to show respect to elders. In addition, many children in sub-Saharan Africa do not cohabit with their parents but are fostered in the extended family (Renata 2009).

In the late 1980s and early 1990s, the adoption effect was identified as the main reason for the implausibly low levels of mortality calculated from young orphans, compared to those derived from older respondents (Blacker and Mukiza-Gapere 1988, Timaeus 1991). The adoption effect is supposed to be more pronounced in reports relative to children, because they are less likely to know that they have been adopted, and because at older ages, both biological and foster parents are more likely to be dead. Methods were later developed to estimate mortality from orphanhood in adulthood or before and since marriage (Timæus 1991;?).

Robertson et al. (2008) analyzed the consistency of reporting of orphanhood status across successive rounds of a cohort study in Manicaland (Zimbabwe). They found that, out of 198 children reported as maternal orphans in the first round (and followed up to the third round), 33% were reported as non-orphans at least once in the next two rounds (with 95% confidence intervals ranging from 26.7 to 39.9). In contrast with what was observed in Senegal, the reports on paternal survival appeared to be more consistent, as only 13.4% (10.9 - 15.9) of paternal orphans were later reported as having a living father. Higher

consistency of reports on paternal orphanhood status could be explained by a higher likelihood of paternal orphans to live with their surviving mother (as compared with maternal orphans with their surviving father), as well as by higher remarriage rates among widowers.

In addition to the adoption effect, orphan prevalence can be biased by non-responses and age misreporting. Proportions of missing responses on orphanhood status are usually rather low, but they are of the same order of magnitude as proportions of orphans. Here, missing or unknown responses are simply discarded, under the assumption that ignorance of orphanhood status is not associated with the risk of being orphan (Beegle et al. 2010).

The first systematic comparison between Spectrum-based and observed orphan prevalence was conducted by Grassly et al. (2004). The proportions of maternal orphans in MICS and DHS were consistently lower than model predictions (by 40% on average), irrespective of the HIV prevalence. Paternal orphan prevalence was more in agreement with model outputs, with a closer congruence in countries with high HIV prevalence. Grassly et al. (2004) ascribed these discrepancies to a combination of (1) overestimation of background adult mortality by the United Nations and (2) underreporting of orphanhood status because of the adoption effect. Grassly et al. (2004) concluded that the North and West model were inappropriate, and showed that reducing adult mortality from causes other than AIDS would produce a closer agreement with survey data[6].

More recently, Robertson et al. (2008) presented ratios of Spectrum orphan prevalences over DHS estimates, for various countries of sub-Saharan Africa. Important discrepancies were again noted with the 2006 revision of the WPP, albeit less pronounced than observed with the 2000 revision. The proportions of fatherless children accorded closely with Spectrum estimates.

3 RESULTS

Descriptive statistics will be presented in this extended abstract. In the full paper, results from linear-mixed effects models will be available.

Figure 3 compares the prevalence of orphanhood among 5- to 9-year olds observed in surveys and censuses (y-axis) with Spectrum estimates (x-axis). On average, proportions of maternal orphans obtained from Spectrum are higher than those derived from surveys and censuses. The average ratios of model to observed proportions are 1.7 for low HIV countries, 1.6 for Eastern Africa, and 1.5 for Southern Africa. There is a better agreement for fathers, with average ratios of 1.5 for low HIV countries, 1.3 for Eastern Africa, and 0.85 for Southern Africa. However, it is difficult to explain why empirical proportions of paternal orphans are *higher* than modeled by Spectrum in countries in Southern Africa with high HIV prevalence. Ratios of paternal to maternal orphans should increase with

[6]At that time, model projections were based on the West pattern of Princeton life tables (UNAIDS 2002), in conjunction with life expectancies of the 2000 revision of the WPP. These life expectancies were themselves mostly obtained by indexing the North model with levels of child mortality.

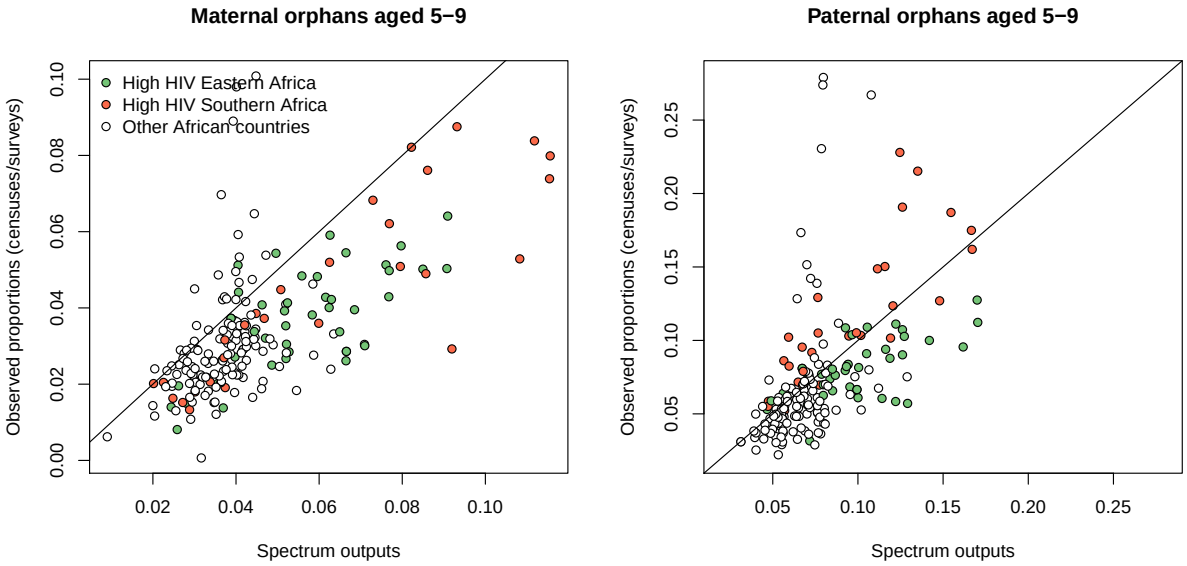

Figure 3 – *Comparison of prevalence of orphanhood among 5- to 9-year olds observed in surveys and censuses (y-axis) with UNAIDS estimates (x-axis)*

the magnitude of the epidemic; they tend to decline in model-based estimates. Figure **??** also indicates that the deviations from empirical estimates vary across countries.

When looking at probabilities ${}_{45}q_{15}$ obtained from sibling histories, we can observe a pattern consistent with what is apparent with orphanhood data (Figure 5). Overall, the values of ${}_{45}q_{15}$ from Spectrum (and WPP estimates) are higher than in DHS, especially for female mortality. The mean ratios of UNAIDS to DHS estimates are 1.19 for females and 1.14 for males. However, in countries in Southern Africa with high HIV, many empirical measurements are *higher* than modeled by Spectrum/WPP. This indicates that sex differentials of adult mortality observed in surveys and censuses are larger than those embodied in model-based estimates.

For orphan prevalence, this pattern can be ascribed to more pervasive misreports when information is elicited about the survival of mothers, owing to the adoption effect. But in the case of siblings, this cannot be readily explained by differential underreporting of deaths by sex. Completeness of death reporting declines more rapidly for brothers as the reference period extends further back in time, denoting a lower level of recall.

Figure 6 presents six country-specific trends. According to DHS, there does not seem to be a reduction of the female advantage in adult mortality over time, and in the case of Malawi, the sex ratio of mortality has even widened in the 2000s, compared to previous decades. Yet, in UNAIDS estimates, the female probability ${}_{45}q_{15}$ tend to be closer to that of men, and even higher for some time in Zimbabwe, Namibia, and Malawi.

In addition, there is a large variation in the congruence of UNAIDS estimates with DHS data when the ratios are broken down by age group and periods. Fig. 7 and 8 indicate that UNAIDS estimates were much higher than DHS in the period 1980 to 1994 for countries

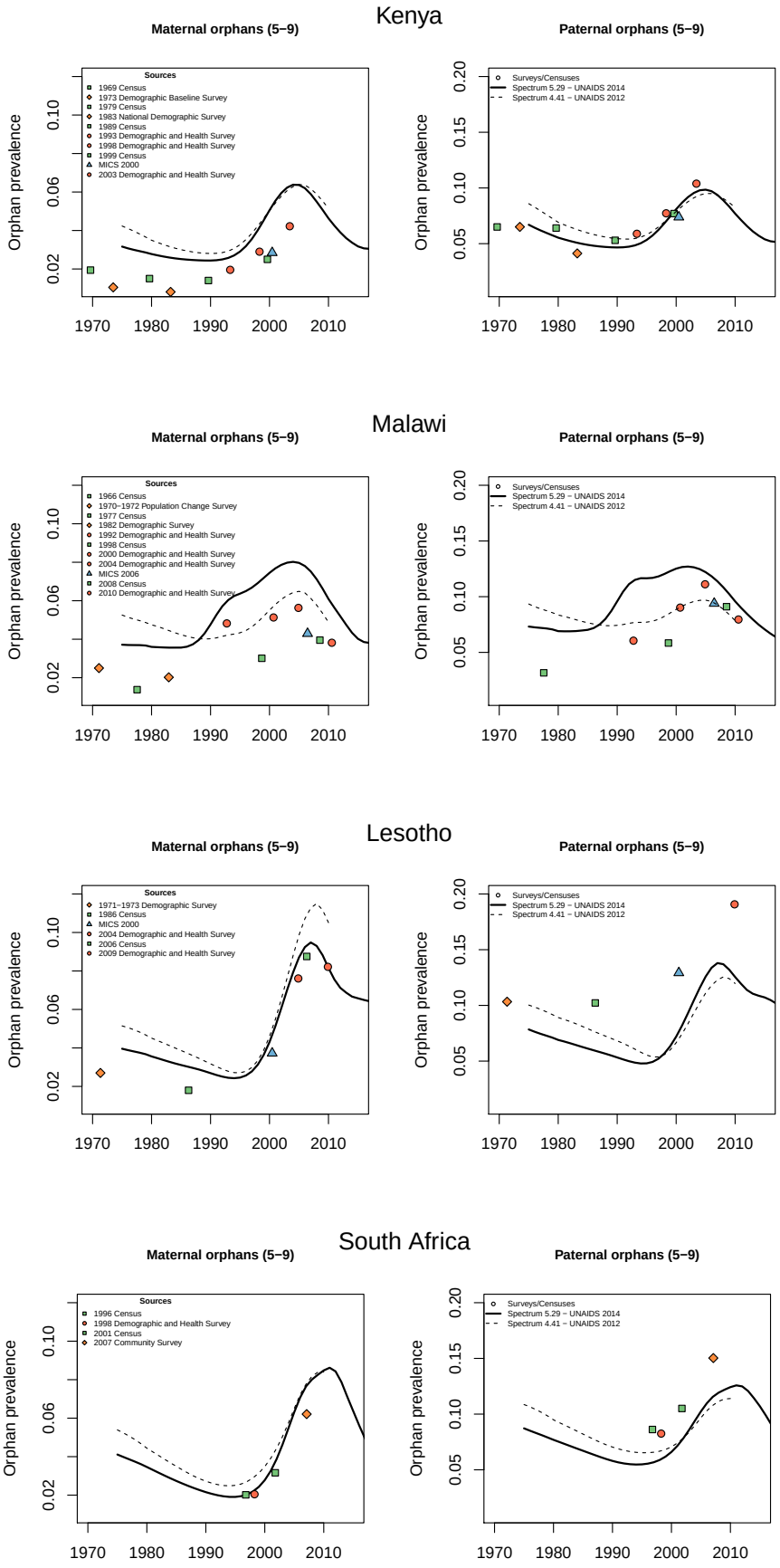

Figure 4 – *Comparison of prevalence of orphanhood among 5- to 9-year olds observed in surveys and censuses (point estimates) with Spectrum estimates (lines) for selected countries*

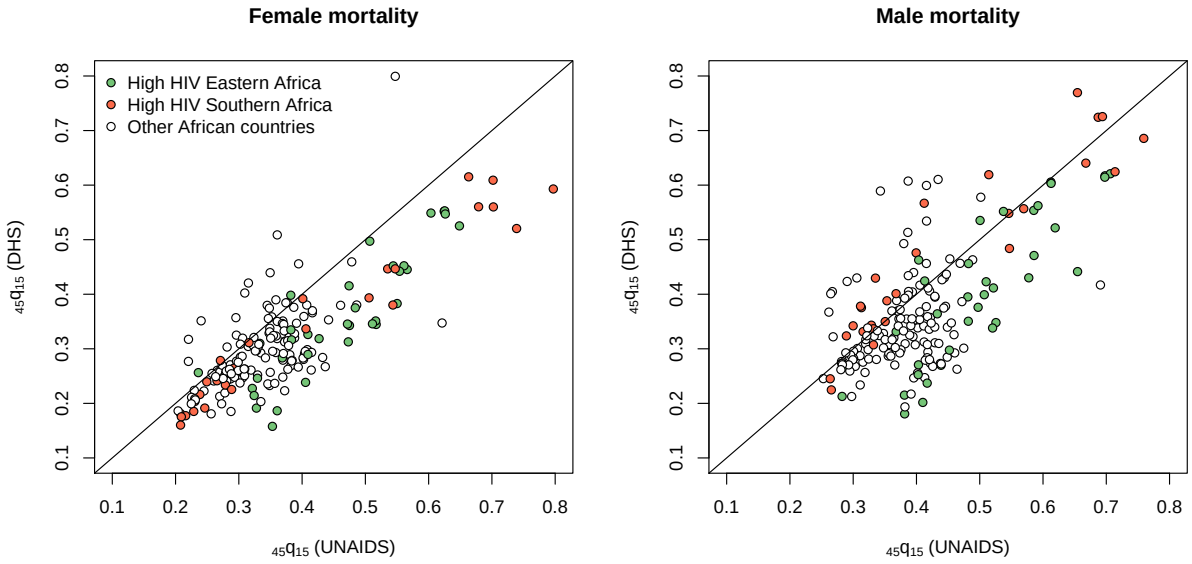

Figure 5 – *Comparison of estimates of ${}_{45}q_{15}$ obtained from DHS (y-axis) with UNAIDS estimates (x-axis)*

in Eastern Africa with high HIV prevalence. The age patterns of mortality were fairly comparable across series in this first period. The ratios then reduced, especially for males. For the period 1995-2004, the age patterns of mortality increases due to AIDS were also quite distinct in UNAIDS and DHS estimates. They tend to be lower for 15- to 19-year-olds and 20- to 24-year-olds, then increase and decline again with age after the 35- to 39-year-olds. This cannot be attributed entirely to misstatements of siblings' age, because this pattern should then be apparent in the previous period (1980-1994) as well. Rather, this suggests that age patterns of mortality increases due to AIDS derived from sibling histories differ from those embodied in UNAIDS estimates. According to sibling data, the "AIDS hump" is wider; women aged 15-24 and women aged 45-59 experience higher mortality rates than currently assumed in countries with generalized HIV epidemic, while mortality rates faced by 25- to 35-year-olds are lower. The AIDS-hump in male mortality rates also appears to be less concentrated at ages 25-39 than implied by model-based estimates, with higher death rates among middle-aged adults. These observations also apply to Southern Africa, albeit to a lesser extent. It is also worth noting that in this region, DHS estimates were on average higher than UNAIDS estimates even before HIV had a very clear impact on mortality levels.

4 CONCLUSION

The agreement between model-based and survey/census-based estimates varies greatly with the region, and possibly the life expectancy of the non-aids scenario and/or HIV prevalence. Both sibling and orphanhood data suggest larger sex ratios of adult mortality than in model-based estimates in Southern Africa. In this region, mortality rates of adult males

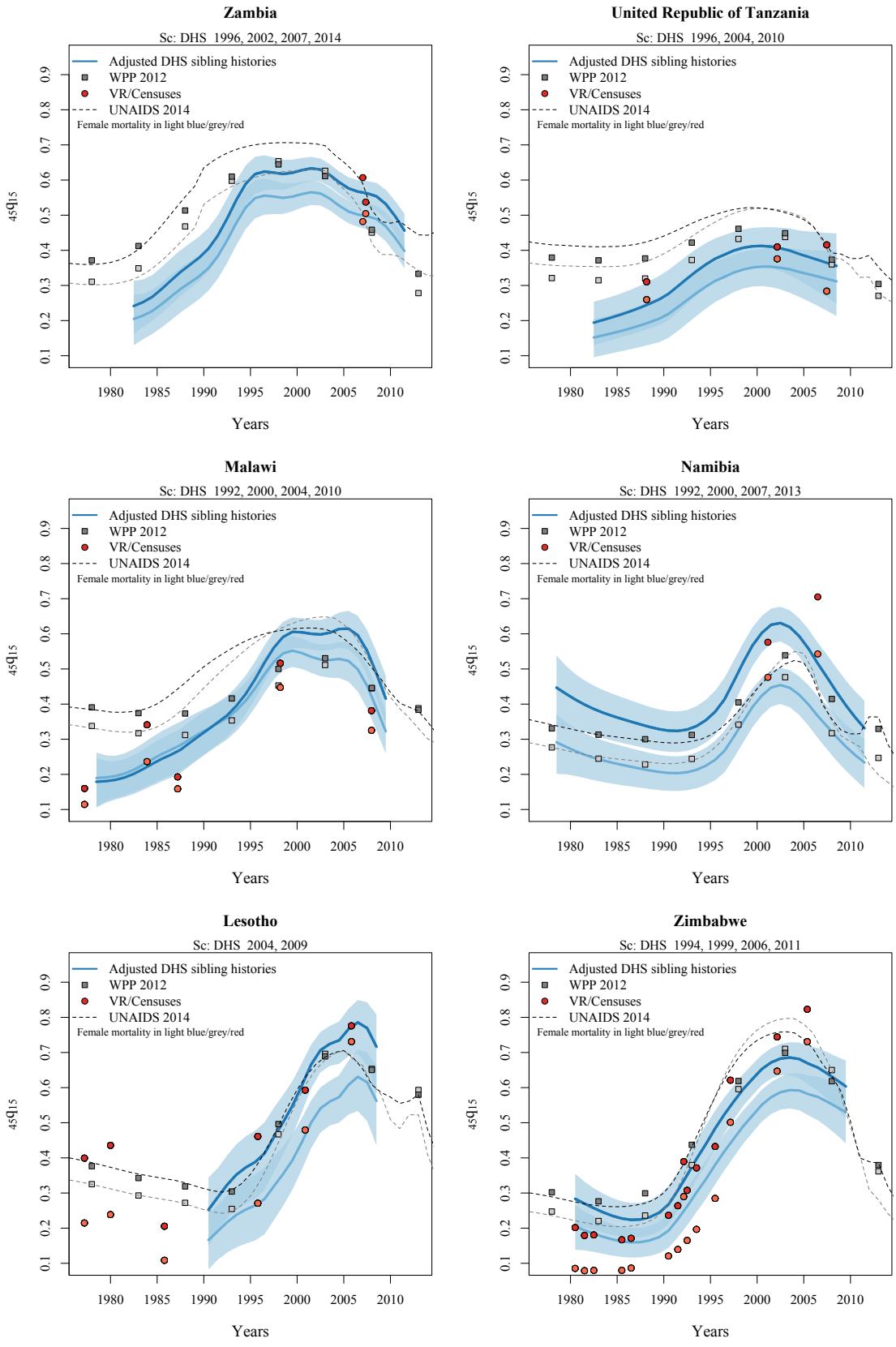

Figure 6 – *Comparison of estimates of* ${}_{45}q_{15}$ *obtained from DHS (blue lines) with UNAIDS estimates (dotted grey lines). Estimates from recent household deaths or vital registration are presented in red/orange.*

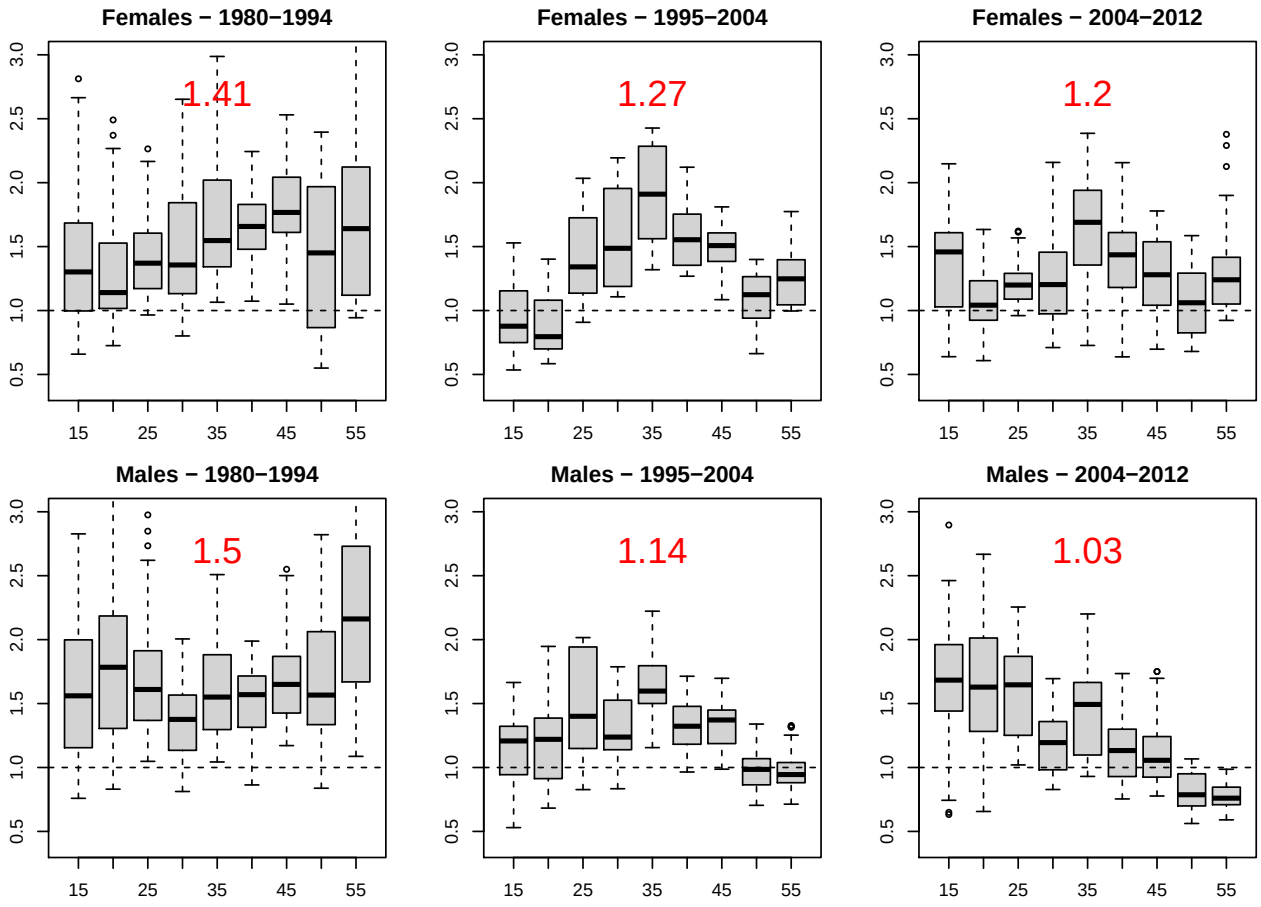

Figure 7 – *Ratios of UNAIDS probabilities of dying to DHS estimates derived from sibling histories, by sex, age group and period : high HIV Eastern Africa*

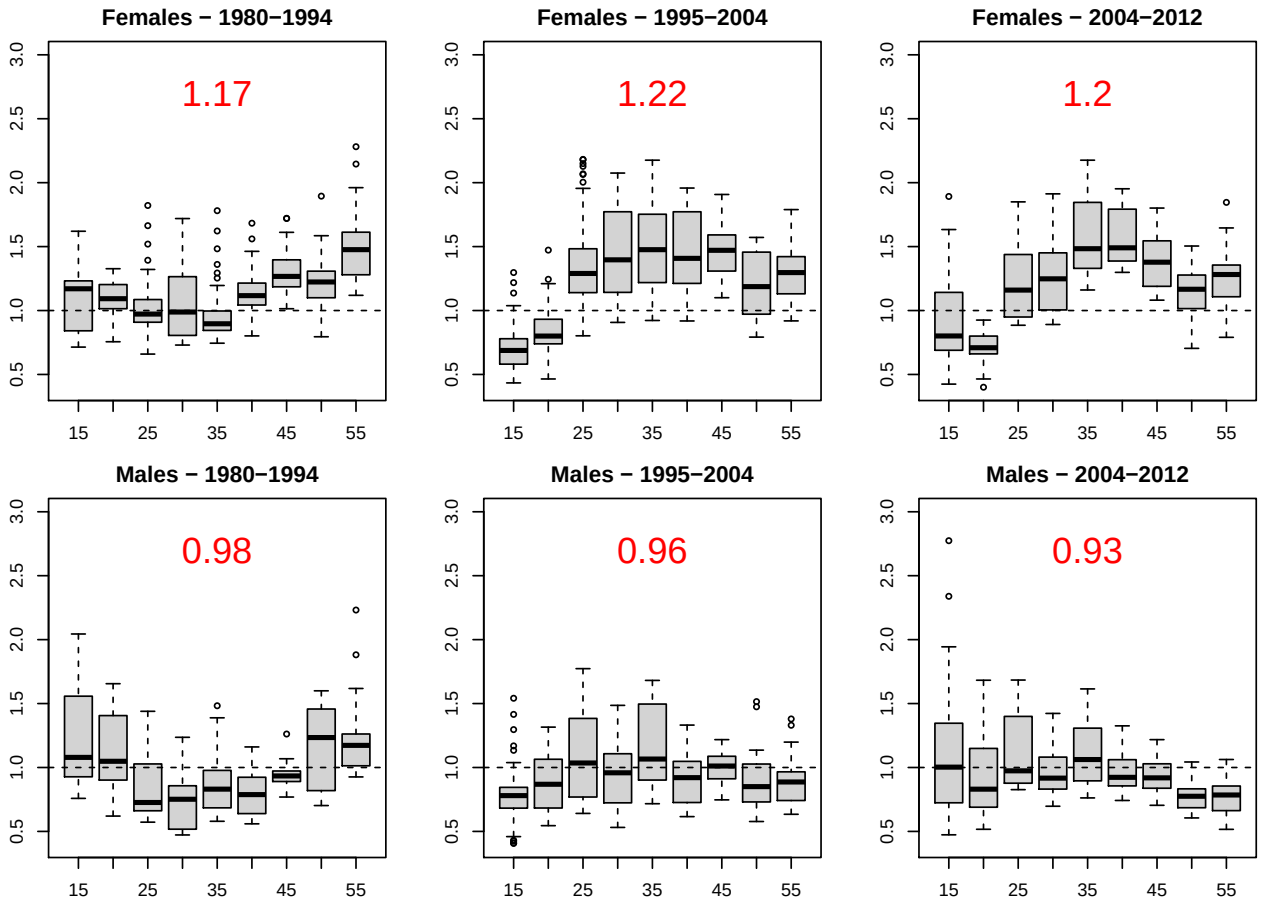

Figure 8 – *Ratios of UNAIDS probabilities of dying to DHS estimates derived from sibling histories, by sex, age group and period : high HIV Southern Africa*

are underestimated in WPP/UNAIDS estimates, either because of erroneous sex ratios of incidence/prevalence, or because the mortality of the uninfected population is too low.

Further research is required to better pinpoint the sources of these discrepancies. We also plan to perform simulations with varying sex ratios of incidence and age patterns of infection to assess the sensitivity of model-based estimates to these key parameters.

During the course of the HIV epidemic, the "AIDS hump" of mortality is expected to broaden and gradually shift towards older ages (Sharrow and Clark 2010). In the coming years, this shift will be mainly driven by a reduction of mortality following the increasing availability of antiretroviral treatments, and the aging of the infected population, which are both taken into account in models. But even prior to ART, such changes can be steered by modifications in the age profile of HIV incidence. Little literature exists on the possible modifications in the age profile of new infections as the epidemic matures.

References

L. Alkema, J. R. New, J. Pedersen, D. You, D. You, P. Bastian, J. Wu, T. Wardlaw, C. Mathers, T. Boerma, J. Ho, E. Suzuki, F. Pelletier, K. Andreev, P. Gerland, D. Gu, N. Li, C. Sawyer, T. Spoorenberg, J. Wilmoth, K. Hill, L. Alkema, S. Cousens, T. Croft, G. Jones, M. Guillot, J. Pedersen, and N. Walker. Child mortality estimation 2013: an overview of updates in estimation methods by the United Nations Inter-agency Group for Child Mortality Estimation. *PLoS ONE*, 9(7):e101112, 2014.

K. Beegle, D. Filmer, A. Stokes, and L. Tiererova. Orphanhood and the Living Arrangements of Children in Sub-Saharan Africa. *World Development*, 38(12):1727–1746, 2010.

N. Bennett and S. Horiuchi. Mortality estimation from registered deaths in less developed countries. *Demography*, 21(2):217–234, 1984.

J. Blacker. The Estimation of Adult Mortality in Africa from Data on Orphanhood. *Population Studies*, 31 (1):107–128, 1977.

J. Blacker. Experience in the use of special mortality questions in multipurpose surveys: the single-round approach. In United Nations, editor, *Data bases for mortality measurement*, chapter IX, pages 79–89. United Nations, New York, 1984.

J. Blacker and J. Mukiza-Gapere. The indirect measurement of adult mortality in Africa: results and prospects. In International Union for the Scientific Study of Population, editor, *African Population Conference, Dakar, Senegal, November 7-12, 1988*, pages 23–38. IUSSP, 1988.

W. Brass and K. Hill. Estimating adult mortality from orphanhood. In International Union for the Scientific Study of Population, editor, *Proceedings of the International Population Conference: LiÃ¨ge*, volume 3, pages 111–123, 1973.

W. Brass, A. Coale, P. Demeny, D. Heisel, F. Lorimer, A. Romaniuk, and E. van de Walle. *The Demography of tropical Africa*. Princeton University Press, 1968.

T. Brown, N. Grassly, G. Garnett, and K. Stanecki. Improving projections at the country level: the UNAIDS Estimation and Projection Package 2005. *Sexually Transmitted Infections*, 82:iii34–iii40, 2006.

T. Brown, J. Salomon, L. Alkema, A. Raftery, and E. Gouws. Progress and challenges in modelling country-level HIV/AIDS epidemics: the UNAIDS Estimation and Projection Package 2007. *Sexually Transmitted Infections*, 84 (S1):i5–i–10, 2008.

T. Brown, L. Bao, A. Raftery, J. Salomon, R. Baggaley, J. Stover, and P. Gerland. Modelling HIV epidemics in the antiretroviral era: the UNAIDS Estimation and Projection package 2009. *Sexually Transmitted Infections*, 86(Suppl 2):ii3–ii10, 2010.

A. Coale, P. Demeny, and B. Vaughn. *Regional model life tables and stable populations (2nd ed.)*. New York: Academic Press, 1983.

I. Ekanem and R. Som. The problem of choosing model life tables for African countries. *Genus*, 40(1-2): 57–70, 1984.

GBD 2013. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*, Dec 2014.

N. Grassly and I. Timaeus. Methods to estimate the number of orphans as a result of AIDS and other causes in sub-Saharan Africa. *JAIDS Journal of Acquired Immune Deficiency Syndromes*, 39:635–75, 2005.

N. Grassly, J. Lewis, M. Mahy, N. Walker, and I. Timaeus. Comparison of household-survey estimates with projections of mortality and orphan numbers in sub-Saharan Africa in the era of HIV/AIDS. *Population Studies*, 58:2:207–217, 2004.

L. Henry. Mesure indirecte de la mortalité des adultes. *Population*, 15, 3: 457–466, 1960.

K. Hill. Estimating Census and Death Registration Completeness. *Asian and Pacific Population Forum*, 1(3): 8–13, 1987.

K. Hill and J. Trussell. Further developments in indirect mortality estimation. *Population Studies*, 31(2):313–334, 1977.

B. Masquelier, G. Reniers, and G. Pison. Divergences in mortality trends in sub-Saharan Africa: survey evidence on the survival of children and siblings. *Population Studies*, 68(2): 161–177, 2014.

Z. Obermeyer, C. Murray, and E. Gakidou. Fifty years of violent war deaths from Vietnam to Bosnia: analysis of data from the world health survey programme. *BMJ*, 336:1482–1486, 2008.

W. Paget and I. Timaeus. A Relational Gompertz Model of Male Fertility: Development and Assessment. *Population Studies*, Vol. 48, No. 2.:333–340, 1994.

S. Preston. *Mortality patterns in national populations: with special reference to recorded causes of death*. Studies in Population. Academic Press, 1976.

S. Preston and N. Bennett. A census-based method for estimating adult mortality. *Population Studies*, 37(1): 91–104, 1983.

Samuel H. Preston. An Integrated System for Demographic Estimation from Two Age Distributions. *Demography*, 20(2):pp. 213–226, 1983. ISSN 00703370.

Th. Pullum. An Assessment of the Quality of Data on Health and Nutrition in the DHS Surveys, 1993-2003. DHS Methodological Reports No. 6., Calverton, Maryland: Macro International Inc., 2008.

S. Renata. Child fostering in Africa: When labor and schooling motives may coexist. *Journal of Development Economics*, 88(1):157 – 170, 2009.

L. Robertson, S. Gregson, C. Madanhire, N. Walker, P. Mushati, G. Garnett, and C. Nyamukapa. Discrepancies between UN models and DHS survey estimates of maternal orphan prevalence: insights from analyses of survey data from Zimbabwe. *Sexually Transmitted Infections*, 84 S(1): 57–62, 2008.

D. Sharrow and S. Clark. A parametric investigation of mortality at all ages in a rural, south african population, paper presented at the 2010 annual meeting of the population association of america. 2010.

C. Stanton, A. Noureddine, and K. Hill. DHS Maternal Mortality Indicators: an assessment of data quality and implications for Data Use. *Studies in Family planning*, 31,2:111–123, 2000.

J. Stover, K. Andreev, E. Slaymaker, C. Gopalappa, K. Sabin, C. Velasquez, J. Nakiyingi-Miiro, A. Crampin, T. Lutalo, K. Herbst, S. Gregson, and M. Urassa. Updates to the spectrum model to estimate key HIV indicators for adults and children. *AIDS*, 28 Suppl 4:S427–434, Nov 2014.

I. Timaeus. An Assessment of Methods for Estimating Adult Mortality from Two Sets of Data on Maternal Orphanhood. *Demography*, 23, 3:435–450, 1986.

I. Timæus. Estimation of Mortality from Orphanhood in Adulthood. *Demography*, 28 (2):213–227, 1991.

I. Timaeus. Measurement of adult mortality in less developed countries: A comparative review. *Population Index*, 57(4):pp. 552–568, 1991.

I. Timæus. Estimation of Adult Mortality from Orphanhood Before and Since Marriage. *Population Studies*, 45(3):455–472, 1991.

I. Timaeus. New estimates of adult mortality from DHS data on the timing of orphanhood relative to marriage. Proceedings of the Demographic and Health Surveys World Conference, Washington D.C., 1991. Vol. II. Columbia, Md.: Institute for Resource Development/Macro International, Inc.

I. Timæus. Estimation of adult mortality from paternal orphanhood: a reassessment and a new approach. *Population Bulletin of the United Nations*, 33:47–63, 1992.

I. Timæus and A. Nunn. Measurement of adult mortality in populations affected by AIDS: an assessment of the orphanhood method. *Health transition Review*, 7(2):23–43, 1997.

I. Timaeus, B. Zaba, and M. Ali. Estimation of adult mortality from data on adult siblings. In B. Zaba and J. Blacker, editors, *Brass tacks: essays in medical demography*, pages 43–66. Athlone Press, Londres, 2001.

J. Todd, J. Glynn, M. Marston, T. Lutalo, S. Biraro, W. Mwita, V. Suriyanon, R. Rangsin, K. Nelson, P. Sonnenberg, D. Fitzgerald, E. Karita, and B. Zaba. Time from HIV seroconversion to death: a collaborative analysis of eight studies in six low and middle-income countries before highly active antiretroviral therapy. *AIDS*, 21:S55–63, 2007.

USAID UNAIDS, UNICEF. *Children on the Brink 2002 : A Joint Report on Orphan Estimates and Program Strategies*. UNAIDS, UNICEF, USAID, Washington DC, 2002.

UNICEF. *Africa's Orphaned and Vulnerable Generations: Children Affected by AIDS*. UNICEF, UNAIDS and PEPFAR, 2006.

United Nations. *Model Life Tables for Developing Countries*. United Nations publication, Sales No. E.81.XIII.7, 1982.

United Nations. *World Population Prospects: The 2004 Revision*, volume III: Analytical Report. Population Division, Dept. of International Economic and Social Affairs, United Nations, New York, 2005.

United Nations. World Population Prospects: The 2012 Revision, Methodology of the United Nations Population Estimates and Projections. Working Paper No. ESA/P/WP.235, 2014.

N. Walker, K. Hill, and F. Zhao. Child Mortality Estimation: Methods Used to Adjust for Bias due to AIDS in Estimating Trends in Under-Five Mortality. *PLoS Med*, 9 (8):e1001298, 08 2012.

B. Zaba, J. Whitworth, M. Marston, J. Nakiyingi, A. Ruberantwari, M. Urassa, R.i Issingo, G. Mwaluko, S. Floyd, A. Nyondo, and A. Crampin. HIV and Mortality of Mothers and Children: Evidence From Cohort Studies in Uganda, Tanzania, and Malawi. *Epidemiology*, 16(3):–, 2005.