Is fertility in sub-Saharan Africa that high, or is it an artefact of survey eligibility criteria?

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Introduction

Measures of fertility are typically derived from censuses and surveys in sub-Saharan Africa (SSA). Censuses are not widespread in SSA, with countries in turmoil unable to manage them, or the cost too high for most countries to hold them regularly (every ten years), or are not valued. Household surveys are more frequently relied on instead. Surveys are a cornerstone in the production of demographic knowledge – requiring substantial efforts to reach: from questionnaire preparation, ethical considerations, training of interviewers, moving around to find the respondents (if in-person), data entry and harmonisation. In the process, surveys are shaped by multiple decisions, and are socially constructed (Biruk 2018). Part of this construction derives from seemingly simple decisions: Who are the respondents? Who is eligible to be surveyed? Moreover, "behind-the-scene" decisions in enforcing the eligibility criteria can determine the quality of the data. For instance, a fieldworker may enquire about level of education, and if the respondent is hesitant, the interviewer may intervene, asking whether they finished primary school or not (leaving it at that, rather than counting the years of schooling as desired in questionnaire). The interviewer may also sometimes draws data from the respondent, by making them think differently to get a response to their questions (Randall et al. 2013). Additionally, interviewers may manipulate responses at the time of enumeration, defining who is included in the survey sample, and who is excluded, or whether they require further interviews or not. In this article, we assess whether survey eligibility criteria, the age range of respondents, affects fertility estimates through such manipulation. With the recent dramatic changes in funding and in survey design, including withdrawal of US funding from the Demographic and Health Surveys (DHS), an increase in mobile phone surveys, and desire to have shorter surveys, it is important to consider how survey eligibility may affect demographic outcomes like fertility, to improve and incorporate in future surveys.

Estimating Fertility in Africa

Efforts to document fertility in SSA countries with large surveys are not novel. From the early 1970s, the World Fertility Survey (WFS) in particular offered high quality, internationally comparable, and accessible data, and the findings were important for policymakers and researchers (Sprehe 1974).

Moreover, the WFS served as a shining model of standardized demographic surveys (Cornelius 1985). With fertility being of primary interest, the WFS's main reason for surveying households was to identify women eligible for interview: ever married women under age 50, or all women aged 15-49 (Verma et al. 1980). Such survey design, and eligibility criteria have remained acceptable in contemporary surveys.

Fertility estimated using household surveys, primarily with the DHS and the Multiple Indicator Cluster Surveys (MICS), has been documented to stall in the last two decades after earlier declines in many African countries (Ezeh et al. 2009; Garenne 2013; Kebede et al. 2019; Schoumaker 2019; Shapiro and Gebreselassie 2008). These findings of fertility stalls are also corroborated with fertility estimated in surveillance sites (Moultrie et al. 2008), and in censuses, though overall census-based estimates are somewhat lower than those based on surveys (Schoumaker 2019). In censuses, all females above a certain age are asked about their births, though this age varies from age 10 to 18, and in some countries, there is also an upper age limit. For example, in Liberia women aged 12-54 were asked about their fertility. However, being infrequent, and typically relying on summary birth histories (asking about the total number of children ever born), censuses are less suitable for monitoring fertility trends. With household surveys remaining the central source of fertility data in Africa, it is imperative to ensure that the survey design does not mislead what we know of fertility declines and stalls in the region.

Household surveys and eligibility

Households are generally the key unit approached in demographic surveys, considered a bounded and clearly defined entity – even though they often aren't (Randall et al. 2011). Household surveys typically start by identifying the enumerated household, and then listing all the individuals attached to the household. This listing, the household roster, includes characteristics of each individual, their age, sex, educational attainment, marital status etc. The roster is used to identify eligible household members for individual interviews. Enumeration of a household is never neutral or straightforward, depending on who is doing this and for what purposes (Biruk 2018). This is evident for example with what could seemingly be assumed as simple, the identification of parents to children, which can actually be complicated when the children are orphaned or fostered (Grassly et al. 2004; Timaeus and Nunn 1997).

When household survey questionnaires are long, with extra modules (questions or measures) required depending on the household member characteristics, it is possible that interviewers try to reduce their workload and change the member's characteristics. Such displacements, like omitting births from a

reference period, have been studied in the Demographic and Health Surveys (DHS), and appear to be relatively rare (in birth histories, roughly 2% of births and 5% of deaths were omitted) (Pullum and Becker 2014). However, truncated birth histories are more prone to omissions and displacement of births outside of the reference period. These misreporting errors have not been found to be systematically associated with interviewers, but rather with respondent characteristics (Masquelier et al. 2023).

An important feature of household surveys is that they are representative of the population they aim to study. A larger sample is more representative, and can reduce error, but it is costlier and takes longer to collect the data. As a means to cut back on costs and on fieldworker burden, while still capturing the information desired (and having quality data), survey design often considers eligibility of respondents by age and sex. For instance, it is not necessary to interview under-40 year olds about retirement. In addition to the topic of the survey, eligible ages are also determined by ethical considerations, like interviewing minors which requires parental/guardian consent. Survey eligibility can eventually shape the data, and even distort demographic outcomes like fertility estimates.

Interviewer effects and manipulation

Characteristics of interviewer, like their gender, can potentially affect how respondents reply to questions. These effects may not be evident at the country level. For example, in a cosmopolitan capital city respondents are more open to female interviewers, but in more conservative areas respondents react differently (Flores-Macias and Lawson 2008). Moreover, these effects may depend on the questions asked. Interviewer effects occur especially when respondents are asked about sensitive behaviours like drug use, or about attitudes (Davis et al. 2010). In some cases, respondents are more reluctant to share details with outsiders (Sana et al. 2013), though there is little evidence that the quality of data with a local interviewer, who has some relationship to respondent is inferior to data from outsider interviewers (Weinreb et al. 2018).

At its extreme, interviewer effects may be “intentional”. Some interviewers fabricate data, which can substantially affect data quality (Finn and Ranchhod 2017). Fabrication is not intentionally malicious, but often a reflection of waning morale, poor management and inadequate institutional support (Kingori and Gerrets 2016). With quotas to fill, or a salary dependent on productivity, interviewers may try to speed up interviews, fabricating some responses. For instance, although the purpose of filter questions is to reduce respondent burden, this can be exploited by interviewers to cut interviews short, when they change answers, thus manipulating and distorting the data (Kosyakova et al. 2015).

Nonetheless, it is often *plausible* responses that are fabricated, and while still erroneous, may not threaten data quality (Castorena et al. 2023).

One type of interviewer manipulation is “age displacement”, in contrast to “age misreporting” which is done by the respondent.[1] Displacement in ages or in the timing of events across eligibility boundaries are typically attributed to interviewers trying to reduce their workload (though if respondents are aware of the boundaries, it is possible they may similarly aim to have a shorter interview). Such displacement is evident for example in birth histories, whereby the number of births reported just within the reference window is low, and just before, outside the window, the number of births is high. In some surveys, an excess of over 20% of births is evident just before the window (Pullum and Becker 2014).

Here we examine age displacement related to eligibility criteria of household surveys. To what extent does age eligibility shape fertility measures? We focus on fertility since surveys typically aim to interview *all* women in households rostered, and not in a sub-sample of households. Indeed, the DHS was initially designed to collect fertility and family planning data (Corsi et al. 2012), resulting in a strong focus on women of reproductive ages. With all women interviewed, we are required to compare eligibility *across* surveys. We examine household roster-based and female interview-based fertility in two sets of surveys which have different eligibility criteria, across five countries in sub-Saharan Africa. We hypothesize that with stricter eligibility criteria, reported ages are manipulated (by interviewers), and therefore:

a) In surveys with stricter criteria: where individuals are eligible for additional data collection, there are fewer individuals in ages within the lower and upper boundaries of these age criteria.

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[1] Age misreporting in surveys is pervasive in low- and middle-income countries, confounding the measurement of demographic indicators in countries where data is already limited.[1] Although missing data on ages has become rare, systematic over- or under-statement of ages persists (Pullum and Staveteig 2017). Age displacement is often measured through heaping around ages ending in 5 and 10, which is typically attributed to respondents rounding up/down ages, or displacing their age due to poorer education (Dechter and Preston 1991). Age misreporting is especially problematic since age is one of the most important and relied on characteristics of respondents. Inaccurate ages, can affect multiple demographic estimates, such as mortality rates in older ages (Coale and Li 1991; Dechter and Preston 1991). Moreover, errors in age are correlated with observable characteristics of the respondents. Respondents are more likely to report on ages ending in five or zero when they are less educated and do not have a birth certificate, and are rural, male, poorer, and older (Rosenzweig 2021).

b) In surveys with stricter criteria: fertility is lower especially among 15-19 year olds and 45-49 year olds, because women were transferred out of eligible ages.

Data and Methods

To assess whether and to what extent survey eligibility can distort demographic estimates in household surveys, we rely on two surveys run in multiple countries in sub-Saharan Africa. The first is the Demographic and Health Surveys (DHS), and the second, the Population-Based HIV Impact Assessment (PHIA). Both surveys are publicly available, after registration.[2] Both the DHS and PHIA are nationally-representative household surveys managed, at least until recently, by large U.S. funders, U.S. Agency for International Development (USAID) and the U.S. President's Emergency Plan for AIDS Relief (PEPFAR), respectively. However their purposes are different: the DHS is first and foremost meant to monitor vital statistics and population health indicators (Corsi et al. 2012), while the purpose of PHIA is more focused, aimed to estimate HIV prevalence and viral load suppression (Rosenberg et al. 2023; Sachathep et al. 2021).

We selected the surveys closest in time to each other within each country, and end up with DHS and PHIA surveys in five countries: Cameroon (2017-2018), Malawi (2015-2016), Tanzania (2015-2017), Uganda (2016-2017), and Zimbabwe (2015-2016). We only use these surveys since fertility estimates should be similar to each other all else equal. As such, we can attribute the differences in the surveys to eligibility with more certainty, rather than to changes in these outcomes over time. The dates of data collection in the paired surveys overlap except for in Cameroon, where the PHIA survey finished six months before the DHS, and in Tanzania where PHIA data collection started nine months after the DHS (Appendix Table A1).

Eligibility is not exactly the same across the five countries, but follow similar criteria. For the DHS surveys, women are the key respondents and are interviewed between ages 15 to 49. In Cameroon, in half of the households surveyed, women aged 50-64 are also interviewed. In the DHS men are also generally interviewed in a sub-set of households, covering different age ranges. Women in the DHS typically have to report on all their children, answering a full birth history module. For under-five year old children, additional information is asked, and anthropometric measures and biomarkers (anaemia, vitamin A, malaria) are taken. In Zimbabwe and Tanzania, all children under 60 months were eligible

[2] For the DHS, we use the "household member recode" and the "individual recode" files. For the PHIA, we combine household, adult and child datasets.

for these health measures. In Uganda and Malawi, only children in households which were eligible for the men's survey were eligible for biomarkers and anthropometry. In Cameroon, children were eligible in households where men were not interviewed.

Unlike the DHS, the PHIA relies on a wider age range: interviewing adolescents from age 10-14, collecting biomarkers and anthropometric measures for children under age 15, and interviewing both men and women in the household in older ages. In Cameroon, Malawi and Uganda, adults from age 15 to 64 in all households were eligible for interview. In Tanzania and Zimbabwe, there was no upper age limit for adult surveys. As in the DHS, children eligible for biomarkers and anthropometric measures were only from a subset of either a third or a half of households.[3]

Our analysis evaluates population structure and fertility according to eligibility criteria across surveys, comparing them according to DHS eligibility criteria as opposed to with PHIA eligibility criteria. Both the household questionnaire and women's interviews rely to some extent or another on age reporting. First, we consider the population structure, and calculate the proportion of the de facto population in each five-year age group of women. In both the PHIA and DHS surveys, this relies on the household rosters. Second, we use the women's interviews to directly estimate fertility using reports on births over the last twelve months over mother's five-year age group.

Fertility measurement

We estimate fertility directly using birth histories. We compute age-specific fertility rates (ASFR) and total fertility rates (TFR) (Schoumaker 2013), based on the date of the interview, date of birth of the mother,[4] and date of birth in the last year (using a one-year reference period).[5] In PHIA surveys women were asked if they had given birth in the three-years preceding the survey and to how many children, and whether there was a birth in the 12 months preceding the survey. Then they were asked additional questions about the last pregnancy that resulted in a live birth, such as about visits to antenatal clinics, survival status of the child, and date of death. Thus, in PHIA we have all required information on only one child – the most recently born in the preceding three years.[6] Even though women in older ages were interviewed, we restrict TFR computation up to age 49 only – for comparability, and because the female reproductive period is typically up to this age. In the DHS, full birth histories were available, with information about all births provided, including child's survival status, age, age at death and twin

[3] See Appendix Figure A1 for schematic depiction of eligibility criteria across the surveys.
[4] Mother's date of birth is not available in the PHIA so we rely on the women's ages to approximate their dates of birth.
[5] For missing months of birth (or death) we assume the births occurred mid-year.
[6] In Malawi, information was recorded for up to three births, but we only use the most recent.

status. To be comparable to PHIA, we consider only one birth in the last twelve months (though it is possible to have two births) in the DHS. The proportion of women birthing two children within 12 months is minor (Table 1). Similarly, we do not account for twin births in both PHIA and DHS. To ensure our analysis is not biased by excluding two or twin births in the last twelve months, we use the DHS to compare the total fertility rates based on births in the last year with those based on births in the last three years (as typically done by the DHS programme (Rutstein and Rojas 2006)), and find that TFR is only slightly higher when computed for the three years before survey (Appendix Figure A2).

Table 1: Proportion of women giving birth twice in last 12 months in the DHS

Country	**Proportion out of all women, including those with no births**	**Proportion out of women who gave birth**
Cameroon	0.37%	2.30%
Malawi	0.27%	1.77%
Tanzania	0.31%	1.79%
Uganda	0.34%	1.83%
Zimbabwe	0.28%	2.16%

For all of our analysis, we use the survey-provided sample weights. We estimate the PHIA-to-DHS ratio of the outcomes, to evaluate whether estimates are higher in PHIA or in DHS. A value over one (or when the ratio is logged, a value over zero) indicates that estimates are higher in PHIA.

Robustness tests

To ensure our results are robust, we run three checks: firstly we estimate fertility indirectly using the population age structure, secondly we examine fertility in a sub-set of women, and thirdly, we compare directly measured fertility from two other surveys for a subset of countries. For indirect estimation of fertility, we use an alternative method based solely on the population age structure (Hauer and Schmertmann 2020). The inferred TFR (iTFR) relies on the number of children under age 5 and the number of women in reproductive ages. The extended total fertility rate (xTFR) further includes on the proportion of women aged 25-34 of those aged 15-49 to account for the age distribution of fertility. These fertility rates are adjusted for child mortality using the probability of dying till age 5 (q_5), resulting in the iTFR+ and xTFR+. We estimate under-five mortality from the DHS and PHIA surveys based on reports of the survival status of recent births, and timing of death, of the most recent birth (in last 12 months). These alterative indicators of TFR are useful gauges of fertility where data is lacking. Essentially, surveys with household rosters, and no birth histories, can provide estimates of fertility.

However, since they rely on accurate age structures, they may be affected by distorting of ages to fit (or not) eligibility criteria. Using these indirect estimates of fertility, we eliminate the possibility of the difference in questions asked in the DHS and PHIA (full birth histories and recent births respectively).

Our second robustness test relies on estimating fertility in the DHS and PHIA surveys amongst urban secondary or higher educated women, since omission and displacement of births tends to be more common amongst lower-educated and rural women (Jensen et al. 2025; Masquelier et al. 2023). This robustness check reduces under-reporting on births that may bias our main results. If the differences in fertility between the surveys is related to the abridged fertility question used in PHIA (last birth only), then we would expect the fertility estimates to be closer to those of the DHS in this sub-group of women.

Finally, since it is possible that the DHS methodology is somewhat particular in other ways, in a final test, we also consider other surveys which were held in the same countries around the same time. We directly estimate fertility from the Multiple Indicator Cluster Surveys (MICS) and the Performance Monitoring and Accountability (PMA) surveys. MICS focus on generating data on wellbeing of children, and their mothers, interviewing women aged 15-49. We use MICS from Cameroon, Malawi and Zimbabwe, all in 2014,[7] slightly earlier than the DHS and PHIA surveys. PMA surveys are high-frequency surveys meant to monitor health indicators, and also interview women aged 15-49. We use two PMA surveys from Uganda, from 2016 and 2017 (Makerere University, School of Public Health at the College of Health Sciences and Bill & Melinda Gates Institute for Population and Reproductive Health at the Johns Hopkins Bloomberg School of Public Health 2024).[8] Both PMA and MICS are nationally representative, and include full birth histories. By comparing these surveys, we ensure that our results are not an artefact of DHS survey design unrelated to the age eligibility criteria. Unfortunately, we are not aware of other surveys where different age eligibility criteria, like those in the PHIA surveys, are used in sub-Saharan Africa.

Population projections

To assess the potential consequences of discrepancies between the PHIA and DHS surveys in their fertility estimates, we use population projections. We rely on Leslie matrices, assuming stable populations, to examine the long-term consequences of the different fertility measures from the two

[7] In the 2014 MICS, 24,230 women were interviewed in Malawi (between November 2013 and April 2014), 9,861 women in Cameroon (between June to October), and 14,408 in Zimbabwe (between February and April).
[8] For the PMA in Uganda in 2016, data collection was between March and May, and the final sample included 4,191 completed households and 3,818 completed de facto female interviews. In 2017, data collection was conducted between April to May and the final sample included 4,503 households and 4,122 de facto females.

surveys, essentially reflecting the divergent eligibility criteria. We use mortality rates for women from the UN World Population Prospects (WPP) abridged life tables, for each country from the year of the survey (United Nations 2024). The ASFRs populating the matrices come from the directly estimated fertility derived from the DHS and PHIA surveys. The initial population structure is based on the number of women in each country by five-year age group, estimated using census samples (Steven Ruggles et al. 2024). We use the census closest in time to the dates of the surveys in each country: Cameroon 2005, Malawi 2018, Tanzania 2012, Uganda 2014, and Zimbabwe 2012. We use common initial population, and survival rates across the PHIA and DHS matrices, so that the only difference between the populations projected are in their fertility rates. Overall, we build ten matrices: two for each country we analyse, each reflecting the ASFR estimates obtained from the DHS or PHIA. Using the cohort component method, we project up to 50 years from the date of the survey.

Results

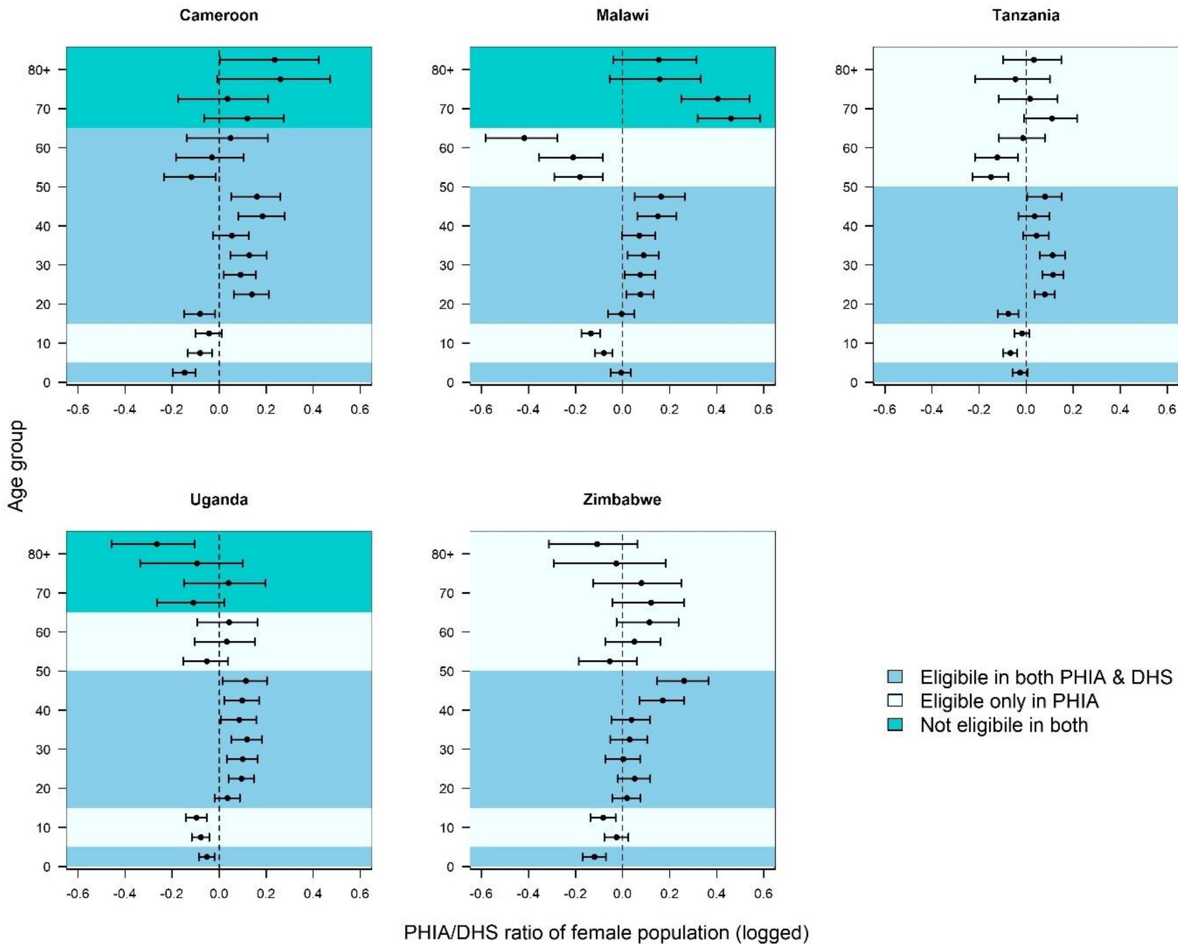
Population structure

Based on household rosters in the surveys, we examine the population structure in each country across the DHS and PHIA surveys, considering the PHIA-to-DHS ratio of the proportion of women by five-year age group (Figure 1). We find that in all countries, the DHS overestimates the proportion of girls under age 15 in the population. The ratios of under-five year olds, who are eligible for biomarkers and anthropometric measures in both PHIA and DHS, are closer to equity in Malawi and Tanzania. For girls aged 5-14, who are only eligible in the PHIA surveys, the distortion is particularly evident in Malawi and Uganda. The ratios for older-aged adult women (50-64) who are eligible only in PHIA in all countries except Cameroon, are also quite distorted. In Tanzania, and more so in Malawi, the ratios indicate a higher proportion of women aged 50-59 in the DHS. In Cameroon, 50-54 year old women are over-represented in the DHS despite half of the households eligible for interviews of women aged 50-64. When we compare the eligibility of women in this age group in the Cameroon DHS (Appendix Figure A3), we find that the proportion of women aged 50-64 is actually much higher in households selected (eligible) for this interview.

From Figure 1, it is also clear that in Malawi there is some interviewer manipulation of ages of women between ages 65-74 in the PHIA surveys, where the criteria for interview has an upper boundary of age 65 (Cameroon, Malawi and Uganda). The particularly high ratios for 65-74 year olds suggest that women were “aged” to fall outside of eligibility criteria in the PHIA, while the particularly low ratios for 50-64 suggest that women were “aged” in the DHS. We do not read much into the distorted ratios

in the highest age groups (75+), since the populations in each of these groups is very small.[9] Manipulation of ages among women between 20 to 49 years old – age groups covered by both PHIA and DHS – is also evident, especially closer to the upper age boundary of the DHS. The higher ratio indicates that in the DHS there are lower proportions of women in these ages.

Figure 1: The ratio of PHIA-to-DHS proportions of the female population within each five-year age group



Note: Error bars represent 95% confidence intervals. The x-axis uses a logarithmic scale, so a value over 0 represents a higher value in the PHIA surveys.

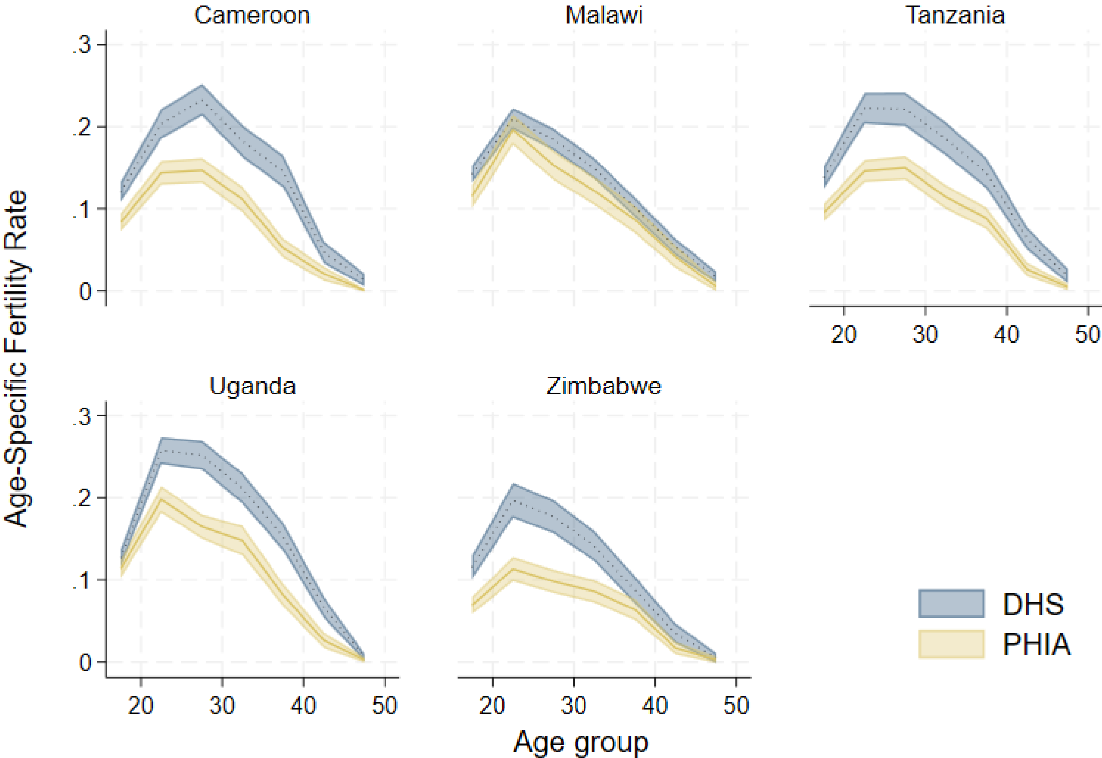
Directly estimated fertility (based on births in last year)

In both the DHS and PHIA, women are asked about births in the last 12 months,[10] allowing us to estimate the age-specific distribution of births and fertility. In Figure 2 we examine the age-specific fertility rates, based on the births over the last twelve months. We find that in both surveys a typical

[9] Less than 1% of the population, and on average fewer than 300 individuals (men and women combined) in all surveys.
[10] Although half of the households in the Cameroon DHS included interviews of women aged 50-64, they were not asked about births in last 12 months.

SSA age-pattern of fertility rates is evident in all countries, peaking between ages 20-29 (Bongaarts and Casterline 2013). However, the DHS estimates are higher than the PHIA ASFR at every age, though in Malawi confidence intervals overlap. The largest gap between the surveys is between ages 25-29. In Cameroon, Tanzania and Zimbabwe, the estimates of fertility for adolescents, aged 15-19, are notably lower in the PHIA surveys.

Figure 2: Age-specific fertility rates based on births in the last 12 months in PHIA and DHS

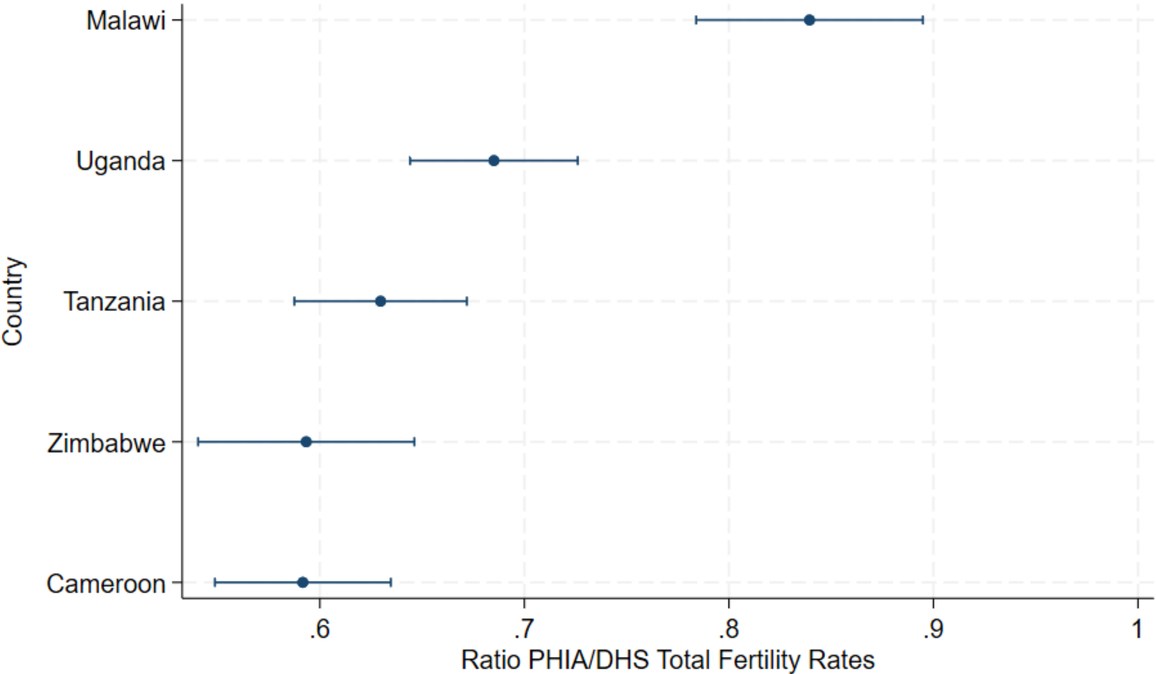


Evidently, with the ASFR being lower in the PHIA in all ages, we also find lower TFR in PHIA surveys than in DHS.[11] On average, the TFR in PHIA is 1.5 births lower than in the DHS. The PHIA-to-DHS ratio of TFR is closest to equity in Malawi (Figure 3), confirming the small gap seen in Figure 2. TFR in Uganda based on the PHIA survey is also lower than the TFR estimated in the PMA surveys (Appendix Figure A4). Indeed, the DHS-based estimate of TFR lies between the TFRs of 2016 and 2017 estimated from the PMA surveys. Similarly, when we compare to the fertility estimated in the MICS of 2014, expected

[11] The TFRs estimated in the DHS are quite similar to the UN WPP estimates of TFR in the same years (United Nations 2024). Although the WPP estimates are based in part on the DHS, the WPP modelled TFR is on average 0.03 children higher than the DHS estimates. The largest gap is in Uganda, where our DHS-based TFR estimate is 5.36, while according to the WPP it was 5.05.

to be slightly higher if we anticipate declining fertility, we find TFR to be slightly higher than those estimated using the DHS. In Cameroon, Malawi and Zimbabwe, MICS fertility is higher than PHIA fertility at all ages, though the gap is somewhat smaller in Malawi (Appendix Figure A5).

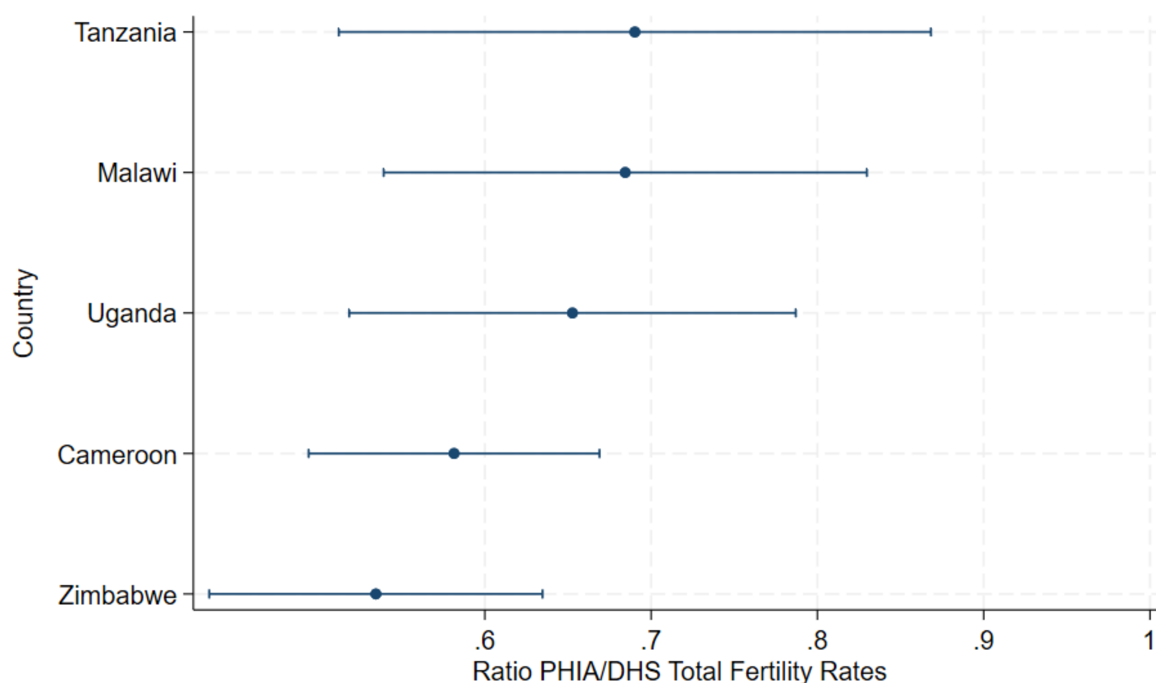
Figure 3: Ratio of PHIA to DHS total fertility rates based on births in the last 12 months



Are our results on the fertility gap reliable?

To ensure that the gap in fertility estimated in the PHIA and DHS does not derive from the type of questions asked in the survey, we consider an indirect method of obtaining TFR, and whether the truncated birth histories in the PHIA are driving lower fertility estimates. Since the truncation of birth histories in PHIA, whereby women provide details on recent births only, may be the reason we find lower fertility, we estimate fertility in both DHS and PHIA amongst women who have been found less likely to misreport or omit births. Even among higher educated and urban women, we find that the PHIA/DHS ratio of TFR is lower than equity across all five countries (Figure 4). The confidence intervals are wider due to the smaller number of women in this sub-sample. Moreover, TFR among urban educated women is lower than the national average (with cross-country means of 1.9 in PHIA and 3.0 in DHS), since fertility is typically lower in urban areas and among higher educated women (Adhikari et al. 2023). As with the TFR, the ASFR estimated from PHIA is lower than in those from the DHS, amongst urban educated women too, though the peak age of childbearing is slightly older, and there are no differences in fertility over age 40 between the surveys (Appendix Figure A6).

Figure 4: Ratio of PHIA to DHS total fertility rates based on births in the last 12 months among urban and secondary+ educated women

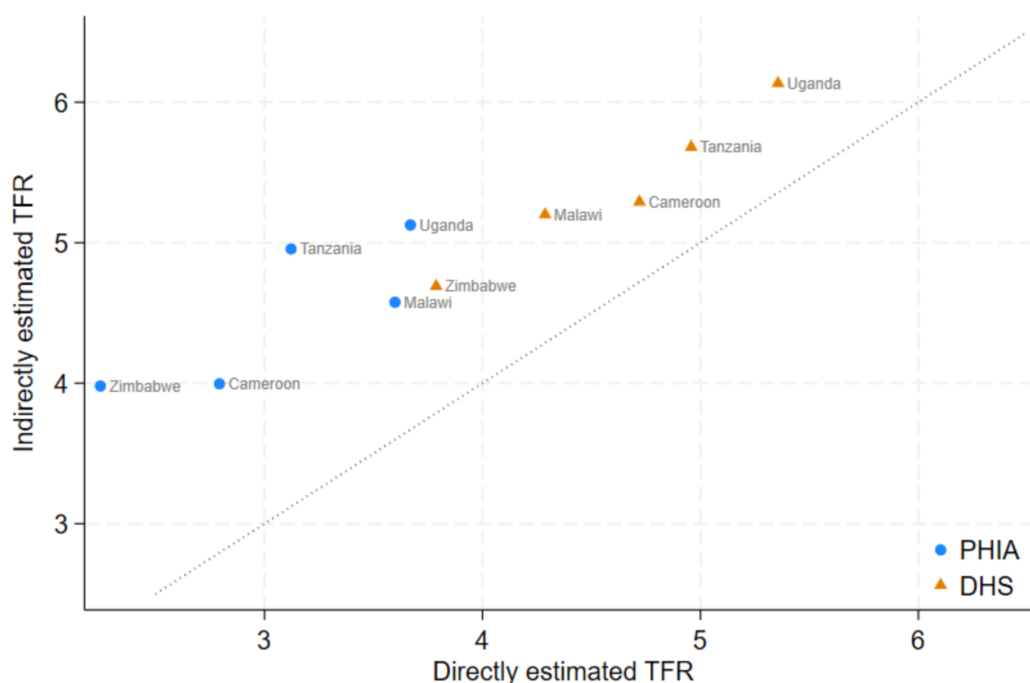


Rather than relying on birth reports in the survey, it is also possible to use the population structure, based on the household roster, to estimate fertility (Hauer and Schmertmann 2020). In doing so, we obtain TFR estimates (xTFR+ and iTFR+) that are in quite close range with the WPP TFR estimates, especially those based on the PHIA surveys (Appendix Figure A7).[12] In Figure 5, we compare the directly estimated TFR, based on the birth history questions, with indirectly estimated fertility, based on the population age structure. Whether using the DHS or the PHIA, the indirect estimates are higher than the direct estimates. Nonetheless, it appears that the gap between the age structure-based TFR and directly estimated TFR is greater in the PHIA surveys. As with the TFR estimated according to births in the last twelve months, the inferred TFR and the extended TFR, accounting for under-five mortality,[13] are higher based on the DHS than the PHIA surveys (Figure A8).

[12] The greatest difference is in Uganda, whereby the DHS estimate is over one birth higher than the WPP (while the difference with the PHIA is 0.07 births).

[13] DHS under-five mortality is estimated to be higher than that estimated based on PHIA (Appendix Figure A9).

Figure 5: Total fertility rates estimated indirectly based on the population rosters in PHIA and DHS, as compared to direct estimates

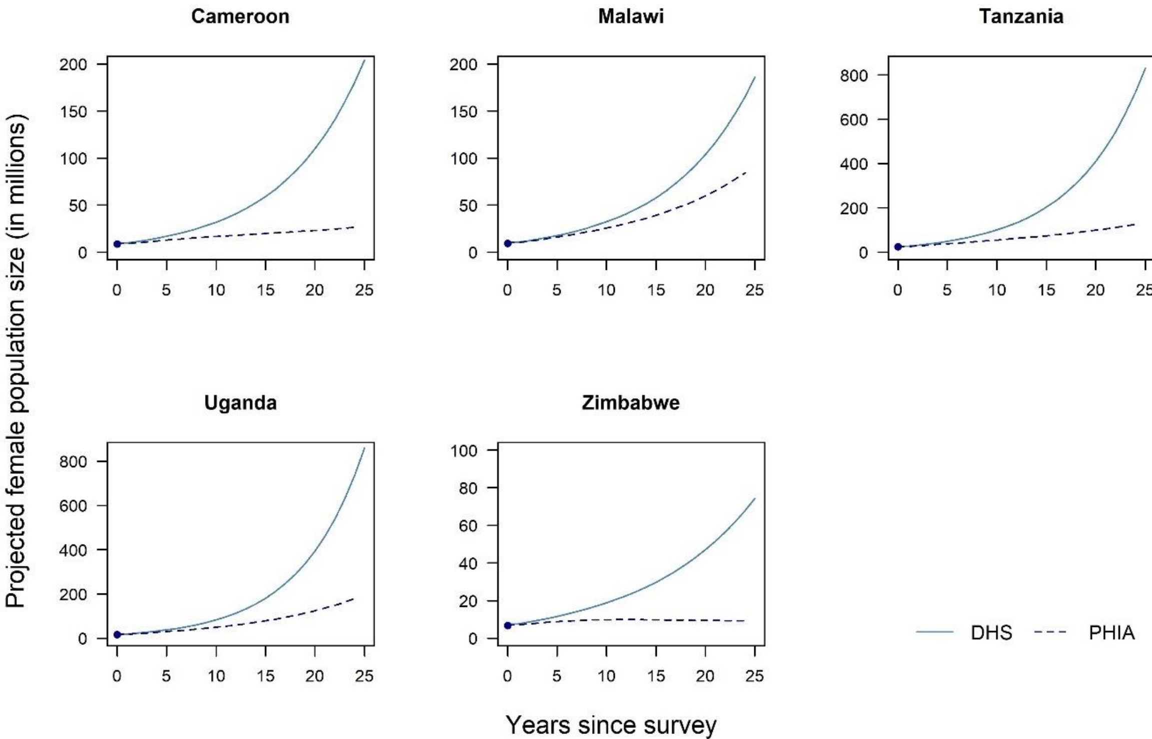


Note: The indirect measure of fertility is the extended TFR adjusting for child mortality, xTFR+ (Hauer and Schmertmann 2020)

Implications of differential fertility: Projected populations according to PHIA vs. DHS direct estimates of fertility

The differences in fertility between the PHIA and DHS surveys are captured in the forecasted population sizes in each country (Figure 6). Population growth is exponential based on the DHS fertility rates across countries, while the increases in population size based on the PHIA fertility rates are much more attenuated. In Zimbabwe and Cameroon, the female population size at the time of the survey is not expected to grow much over the next 25 years, assuming constant mortality and fertility.

<u>Figure 6</u>: Forecasted size of female population assuming constant mortality and fertility rates, according to DHS and PHIA age-specific fertility rates



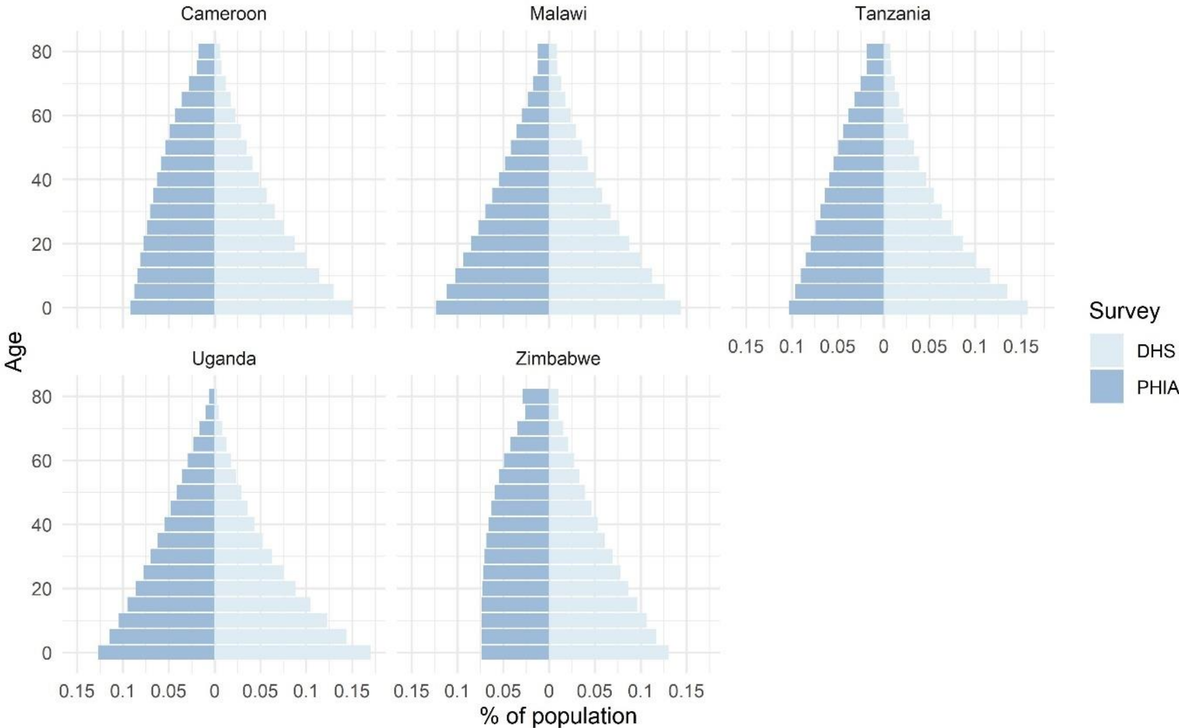
Note: Starting size of population (dot at time 0) is the size of the population at time of last census; the y-axis scale is unique to each country

The gap in population size between PHIA-based and DHS-based projections is dramatic, even within the short term, 10-15 years ahead. Looking even further ahead to when the populations are at stable state, we consider what the population structure of each country would be at 50 years after the survey (Figure 7). Across the five countries, a wide-based pyramid, reflecting a young population, and expansive state, is projected using the DHS measures. A typical pyramid shape is also seen in Malawi and Uganda with the PHIA projections. Nonetheless, when comparing the proportion of the population in the 80+ age group for example in Malawi, we find large discrepancies between the pyramids: in the DHS projection 0.85% is expected to be over age 80 in 50 years, compared to 1.2% in the PHIA projection. In the youngest age group too, we project a gap: 12.3% of the population under age 5 with the PHIA fertility estimates, and 14.4% using the DHS estimates.

The gap between the PHIA-projected and DHS-projected populations in Cameroon, Tanzania and Zimbabwe is even greater. In Tanzania and Cameroon, the base of the pyramid of the PHIA projections is narrower, essentially driving quite large differences in dependency ratios (the proportion of

under15s and over 65s to the working population) in comparison to the DHS-based projections. Moreover, in Zimbabwe, we project a pyramid of stationary state using the PHIA estimates. The proportion of under-five year olds based on the DHS estimates in 50 years from the date of the survey in Zimbabwe, 2065, is projected to be 13%, but based on the PHIA estimates almost half of this, only 7.4%. Since the mortality rates and initial population size we use in these projections are the same for both PHIA and DHS (from the WPP, and censuses respectively), we can directly attribute these gaps between the projected population structures to the different ASFR estimated from each survey.

Figure 7: Projected population age structure after 50 years, assuming constant mortality and fertility, based on age-specific fertility rates from DHS and PHIA



Discussion

We find strong evidence of eligibility criteria of household surveys, and the manipulation of ages to fit them, distorting fertility measures and age structures. In the surveys with stricter criteria, the DHS with upper age boundary of 49, we found that under-fifteen year olds and 50-64 year olds were over-represented in the population. At the same time, women aged 45-49, within the eligibility age range, were under-represented in the DHS, supporting our first hypothesis. Similarly, in the PHIA surveys where there was an upper age boundary (of 64) we also found some evidence of shifting of ages, with 65-74 year olds over-represented in the population. These findings suggest that at the time of the

household questionnaire, where all household members are first identified, there is some advance manipulation of ages, reducing the number of potential individual interviews to follow.

We further found that fertility was lower across countries based on the PHIA surveys, whether TFR was measured directly or indirectly. Moreover, in all maternal age groups we found higher fertility. The gap between the surveys in ASFR was especially large among 25-29 year olds. In three countries, we found lower fertility among 15-19 year olds in the PHIA surveys, refuting our hypothesis that stricter criteria (as in the DHS) is associated with lower fertility in these young ages. We also do not find a meaningful gap between the surveys in fertility among 45-49 year olds. The stricter age criteria in the DHS seems to push fertility estimates up. This is not only due to distortions amongst 15-19 and 45-49 year olds, since fertility is higher in the DHS across all age groups. This may be because when interviewers arrive to a household and fill in the household roster, they need to attribute all the children in the household to mothers. Women with no children or who are not married however are easier to "ignore". This selective exclusion of women reduces the burden on the interviewer while at the same time, does not raise problems with dealing with children in the household. Nonetheless, it is possible that other factors are at play here, in addition to age manipulation.

The lower fertility in the PHIA surveys among 15-19 year olds supports previous findings on adolescent fertility which has been shown to be higher in the DHS than in rural Health and Demographic Surveillance Sites in Africa where fertility is quite accurately measured (Rossier et al. 2020). It may be possible that in the DHS adolescent fertility is exaggerated because childless young women are commonly temporary migrants, and are excluded from cross-sectional surveys. Though if this is the case, these women would also be exaggerated in the PHIA data. An alternative explanation to the higher adolescent fertility in the DHS could be due to the eligibility of under-five year old children for anthropomorphic measures and biomarkers in the surveys. In both Tanzania and Zimbabwe where the gap between surveys is notable, all children are eligible; so moving adolescent girls with children out of the age range would not affect the requirement of these extra measures.

Considering the large gap we find in fertility across the countries between the DHS and PHIA surveys, it is not surprising that our projections are disparate. The implication of having higher ASFR from the DHS surveys is in exponential population growth (assuming constant reproduction and survival rates). Similar exponential growth is also seen in Malawi based on the PHIA estimates of fertility. The projected age structure in Malawi is also similar, where the PHIA-DHS difference between TFR estimates is smallest. In Zimbabwe and Cameroon where the PHIA estimates of fertility are lower (than the DHS, and compared to the other countries), the projected population size is quite stable, and the

population pyramids have narrow bases. The consequences of these projections are also slower population growth than expected.

Can we attribute the disparities in fertility, and age structure, to the variation in eligibility criteria? While we find clear evidence of stricter age criteria being associated with distorted age structures and higher fertility, we are not able to directly claim that it is due to age displacement. Other factors may be at play, even though we compare nationally representative surveys conducted around the same time, somewhat controlling for these other factors. Nonetheless, different characteristics of the survey, such as wording of the questions, timing of interviews, or who answers the household questionnaire could also be important factors in determining the differences we find between the surveys. We do not consider whether all interviewers engage in manipulation, or only some or none. Or whether selected households are already somehow distorted through eligibility criteria during survey design even before interviewers go into the field. Additional differences in survey implementation may also be important. For instance, training of interviewers in PHIA may be more focused on aspects related to HIV and less on accurate birth histories.

Our quasi-experiment compares two household surveys with different eligibility criteria, yet it is possible that both are equally inaccurate. We do not have the true ages of household members nor the true birth histories, lacking a "golden standard" to refer to (such as birth certificates). Indeed, truncated birth histories, where questions are asked only of recent births, similar to what we rely on in our analysis with PHIA, tend to produce lower fertility estimates because of the omission and displacement of births outside the reference period (Masquelier et al. 2023). Even with full birth histories, or routine monitoring of births as done in surveillance sites, birth and especially pregnancy reporting is not complete (Eilerts-Spinelli et al. 2022; Espeut and Becker 2015; Pullum and Becker 2014). Since higher educated and urban women do not omit or displace births as much as lower-educated and rural women (Jensen et al. 2025; Masquelier et al. 2023), we ran a robustness check comparing directly estimated fertility among urban, higher educated women in the DHS and PHIA surveys. Although the fertility estimates in PHIA were somewhat closer to those of the DHS in this sub-group of women, we still find lower fertility estimated from PHIA than from the DHS across all five countries. Moreover, our indirect estimates of TFR, based on age structures, also point to lower fertility estimates from PHIA, indicating that the differences in fertility between the surveys is not related to the different questions asked on births in the surveys. Rather, displacement of women's ages seems to be the key factor pushing DHS fertility rates up. Similarly, we find that in other surveys with similar age eligibility criteria, of upper boundary of 49 for women, MICS and PMA, fertility is estimated to be

higher than in PHIA. This finding does not necessarily mean that PHIA fertility estimates are correct, but that there is more uncertainty in fertility estimates than we previously thought.

Our analysis is not intended to call out respondents on misreporting, or to cast interviewers as unskilled or idle. Rather, we highlight how eligibility criteria can inadvertently lead to differential demographic outcomes, even regarding the most basic measures of population structure. Moreover, even after interviewers finish data collection, data is processed to ensure the data are consistent and harmonised (Sana and Weinreb 2008; Tichenor 2017; Waller 2013). During this “data cleaning”, raw data is also often manipulated, so that reported values crisply fit in the desired categories. It may be that this process also contributes to some variation between the surveys.

Future surveys aiming to measure fertility, whether directly with questions on births, or indirectly using household rosters, should consider how capping upper ages of eligibility can affect estimates. Moreover, such surveys should consider how to improve age measurement. For example, using innovative methods such as computer vision can help improve precision of age measurement (Helleringer et al. 2019), or comparing reported ages with birth certificates would result in more accurate reports and lower the likelihood of manipulation, though this is seldom possible in SSA countries.

Although we focused on the national level, there could also be greater differences sub-nationally, e.g. between rural and urban regions; age structures are known to differ by sector (Menashe-Oren and Stecklov 2018), as does fertility (Lerch 2018; Menashe-Oren and Sánchez-Páez 2023; Shapiro and Tambashe 1999). The effect of eligibility criteria should be examined sub-nationally too, to unpack whether this plays out differently in different populations.

Our findings of lower than expected fertility in SSA countries may shed new light on fertility declines in Africa. In particular, the commonly referred to fertility stalls (Bongaarts 2008; Bongaarts and Casterline 2013; Grimm et al. 2022; Schoumaker 2019) may be in part mis-guided by the household surveys relied on to describe these stalls. Our PHIA-based fertility estimates in Zimbabwe and Cameroon (TFR of 2.2 and 2.8 respectively) would suggest that fertility has declined considerably in these countries – in comparison to them being clearly identified as stalled (Grimm et al. 2022; Schoumaker 2019). Although we do not assess stalls per se, and indeed there may be stalls, the fertility levels we estimate in a relatively recent period seem to be already low. Additional national household surveys with wider age eligibility criteria are needed to confirm this.

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Appendix

Figure A1: Eligibility range of respondents by age in PHIA and DHS surveys in five SSA countries

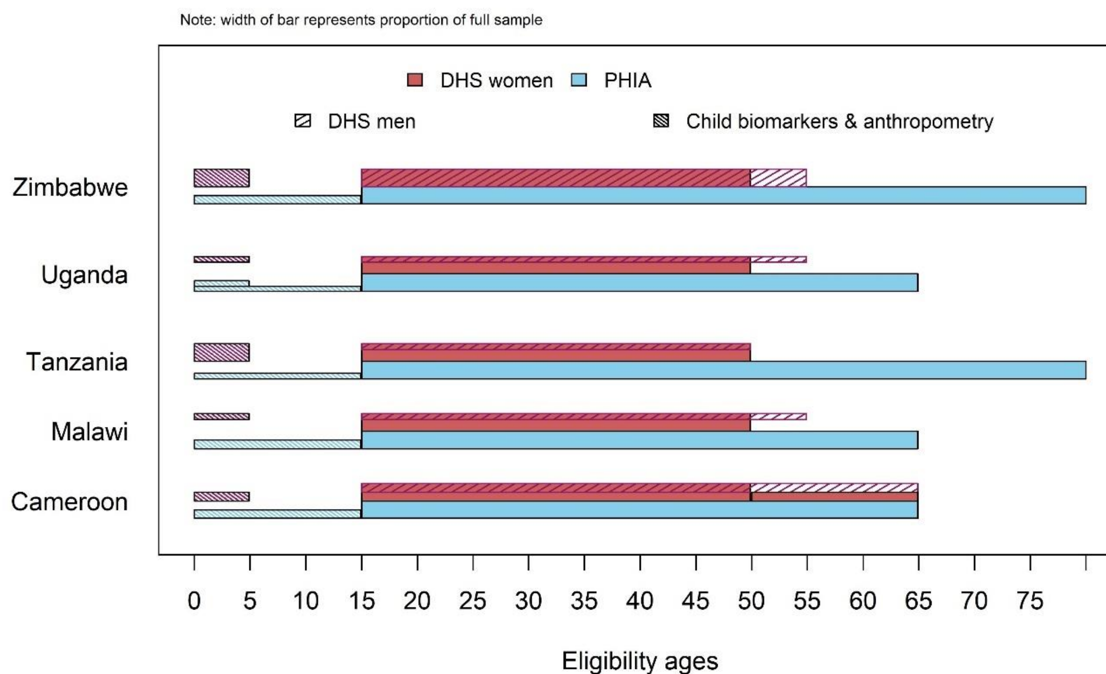
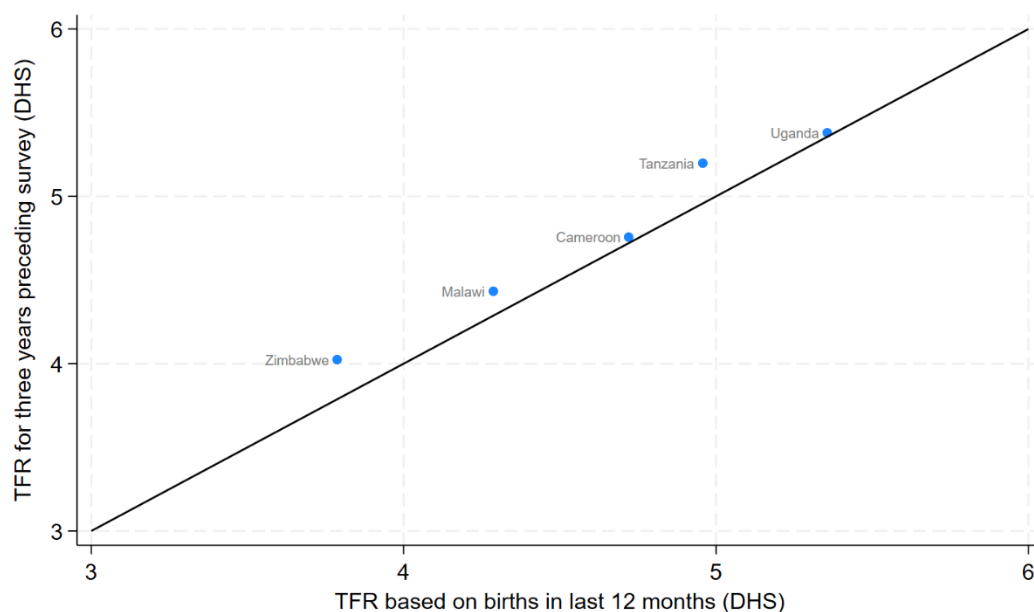


Figure A2: DHS comparison of total fertility rates estimated for three years preceding survey, and estimated for the 12 months preceding the survey



Note: TFR for the three years preceding survey includes twins

Figure A3: Proportion of female population in Cameroon DHS, in households where women aged 50-64 were eligible for survey as opposed to households where they were not eligible

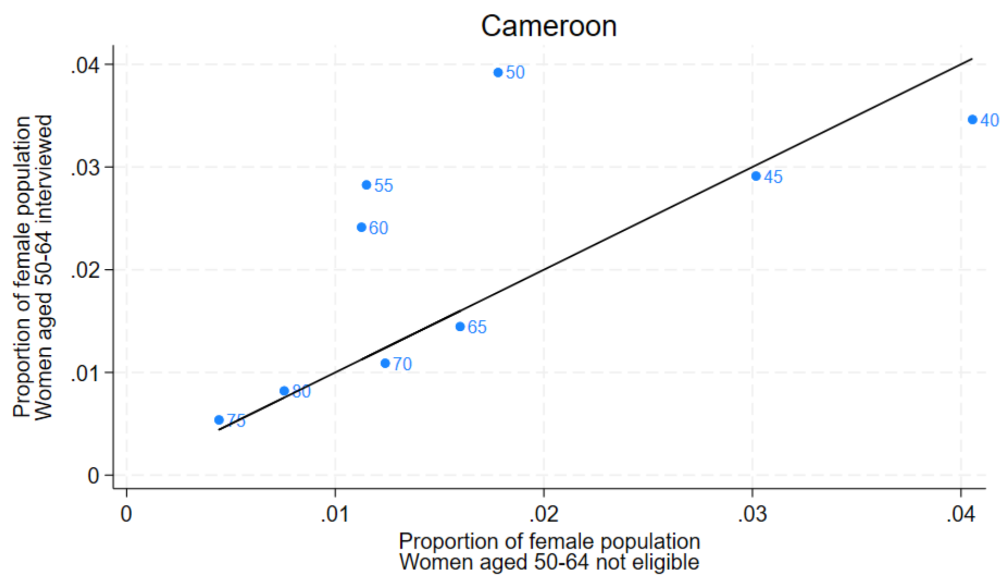


Figure A4: Directly estimated fertility in Uganda, comparison with PMA 2016 and PMA 2017 surveys

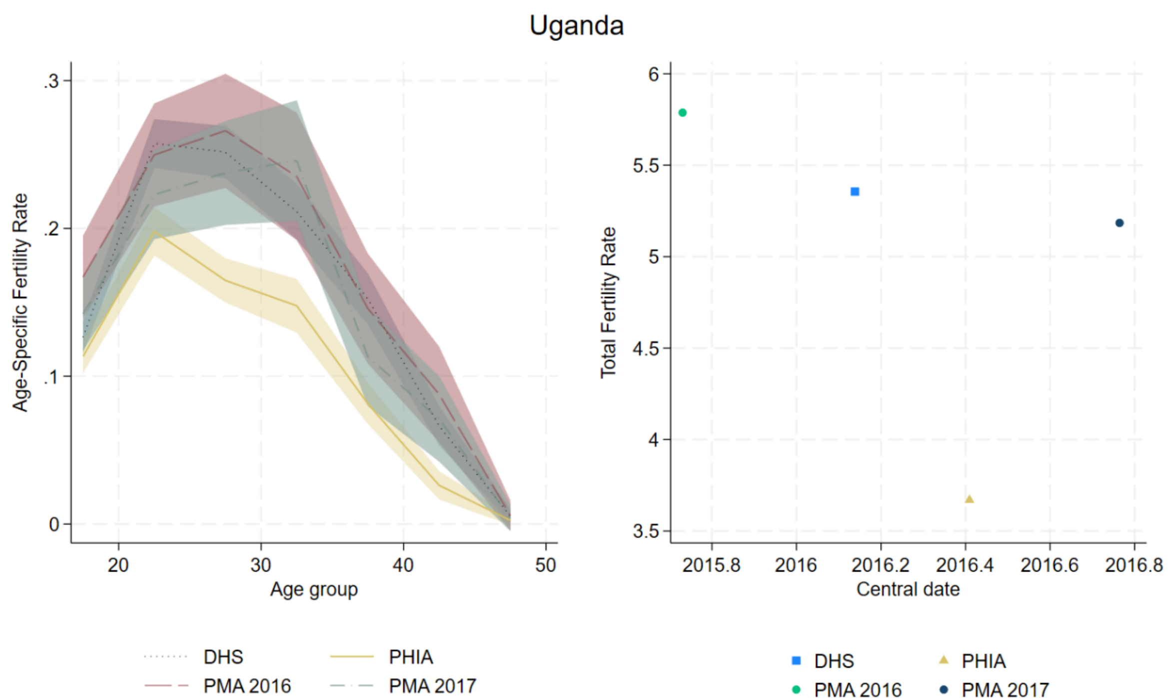


Figure A5: Directly estimated fertility in Cameroon, Malawi and Zimbabwe, comparison with MICS 2014 surveys

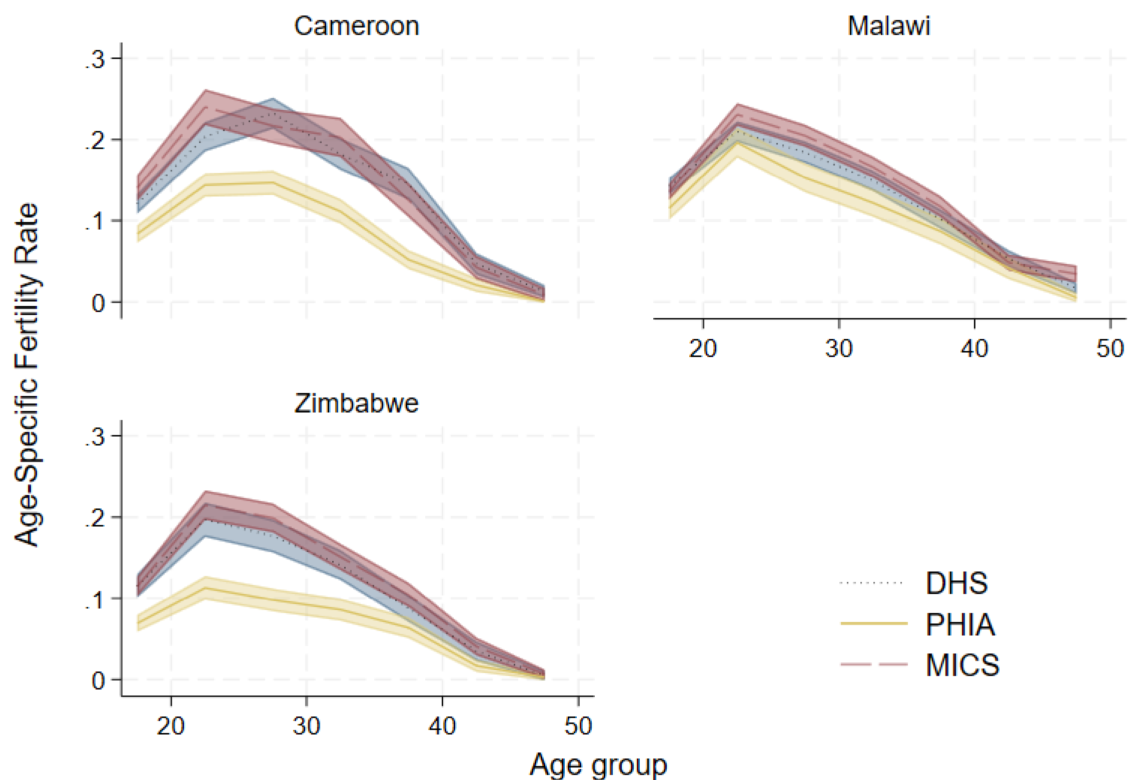


Figure A6: Age-specific fertility rate amongst urban women with higher education

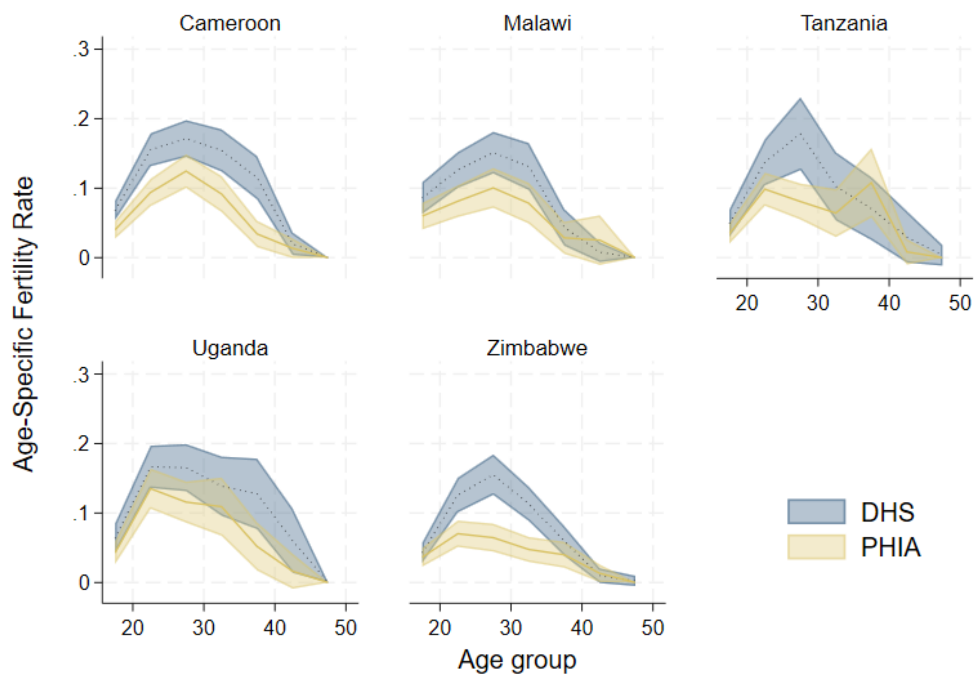


Figure A7: Comparison of extended TFR accounting for child mortality (xTFR+) in DHS and PHIA with UN WPP TFR

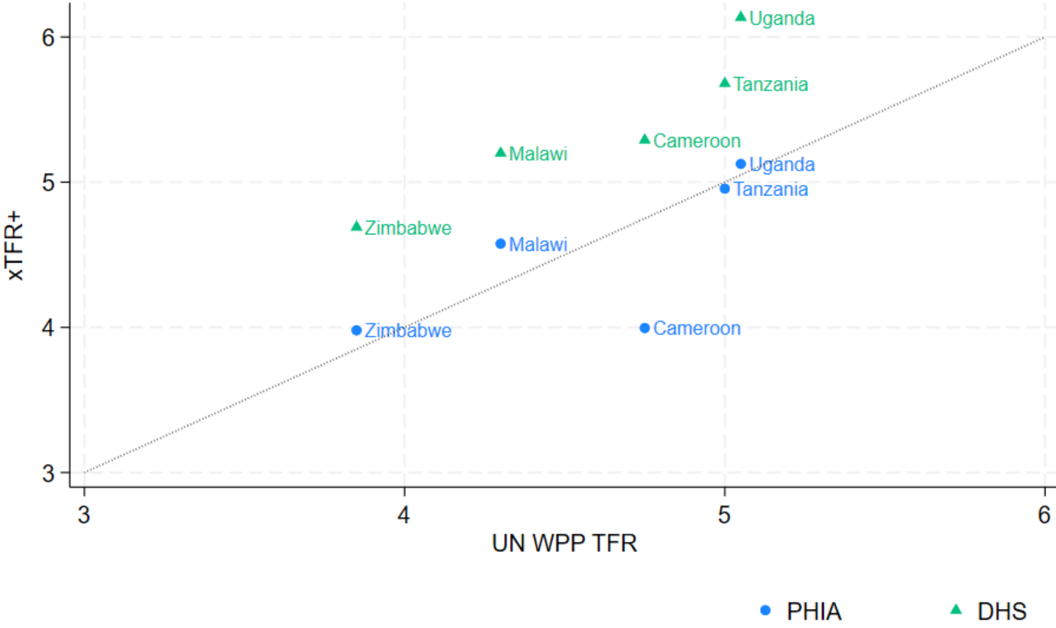
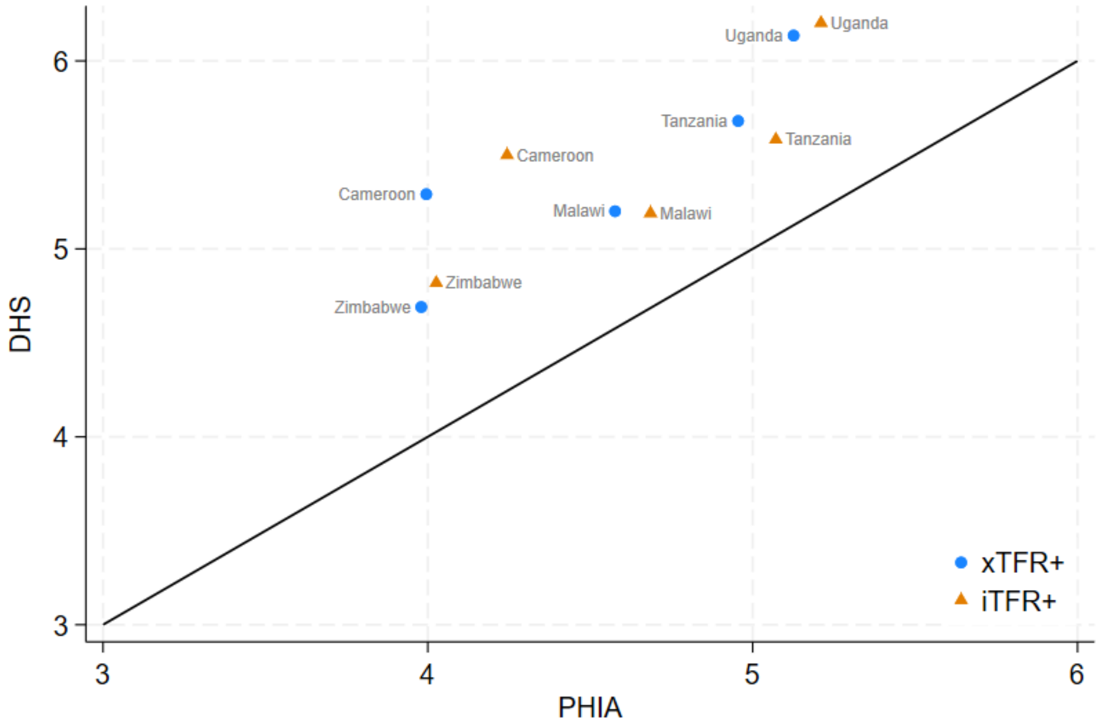


Figure A8: Total fertility rates estimated based on the population rosters in PHIA and DHS



Note: iTFR+= inferred TF adjusting for child mortality, xTFR+= extended TFR adjusting for child mortality (Hauer and Schmertmann 2020)

<u>Figure A9</u>: Under-five mortality rates estimated in PHIA and DHS using last birth only

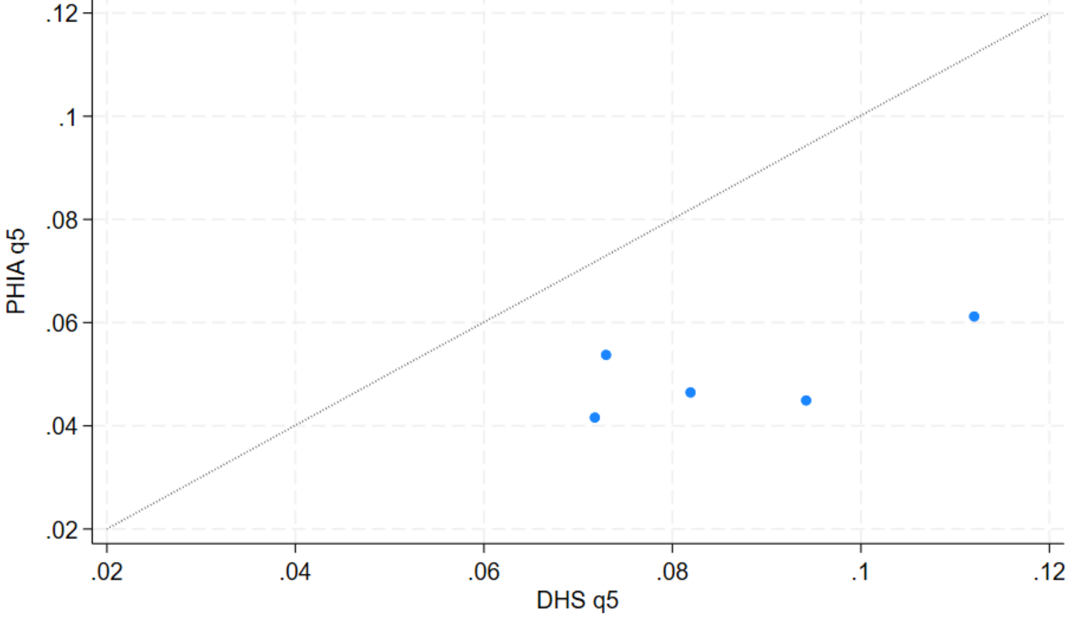


Table A1: Characteristics of the DHS and PHIA surveys

	Cameroon		Malawi		Tanzania		Uganda		Zimbabwe	
	PHIA	**DHS-7**	**PHIA**	**DHS-7**	**PHIA**	**DHS-7**	**PHIA**	**DHS-7**	**PHIA**	**DHS-7**
Dates of data collection	June 2017 – December 2017	June 2018 - December 2018	November 2015 – August 2016	October 2015 - February 2016	November 2016 – June 2017	August 2015 - February 2016	September 2016 - March 2017	June 2016 - December 2016	October 2015 – April 2016	July 2015 - December 2015
Sample design	Sampling frame: 2005 census. 490 PSUs	Sampling frame: 2005 census and 2014 4th Cameroon Household Survey. 470 PSUs	Sampling frame: 2008 census. 500 EAs	Sampling frame: 2008 census. 850 EAs	Sampling frame: 2012 census. 526 EAs	Sampling frame: 2012 census. 608 PSUs	Sampling frame: 2014 census. 523 PSUs	Sampling frame: 2014 census. 697 EAs	Sampling frame: 2012 census. 500 PSUs	Sampling frame: 2012 census. 400 EAs
Questionnaires	HH roster Adult (with child module) Adolescent	HH roster Women's (with reproduction and child health modules) Men's Biomarker	HH roster Adult (with child module)	HH roster Women's (with reproduction and child health modules) Men's Biomarker	HH roster Adult (with child module) Adolescent	HH roster Women's (with reproduction and child health modules) Men's Biomarker	HH roster Adult (with child module) Adolescent	HH roster Women's (with reproduction and child health modules) Men's Biomarker	HH roster Adult (with child module) Adolescent	HH roster Women's (with reproduction and child health modules) Men's Biomarker
Number households successfully interviewed	11,623	11,710	11,386	26,361	14,811	12,563	12,386	19,588	11,717	10,534
Number de facto individuals in HH	54,553	60,699	44,658	117,177	67,667	59,657	62,759	87,929	46,787	42,586
Number adult respondents	27,307 adults 15-64	13,527 women aged 15-49 1,150 women aged 50-64 6,978 men	19,652 adults aged 15-64	24,562 women 7,478 men	33,044 adults 15+	13,266 women 3,514 men	30,701 adults aged 15-64	18,506 women 5,336 men	24,723 adults 15+	9,955 women 8,396 men
Non-response amongst adult respondents	4.8% adults	1.8% women aged 15-49 1.5% women aged 50-64 2.5% men	12.3% adults	2.3% women 5.4% men	8.6% adults	2.7% women 8.1% men	3.32% overall 2.1% women 6% men	3% women 6% men	10.9% adults	3.8% women 8.1% men

Abbreviations: PSU= Primary sampling unit, EA= enumeration area, HH= household