

RESEARCH ARTICLE

On the empirical study of fertility transition: A case for application of age-adjusted measures in multivariable analysis

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Among studies of factors driving fertility transitions, the cumulative children ever born (CEB) has been treated as the dependent variable in multivariable models. Some of these studies have cited total fertility rates (TFRs) in their rationales for investigating the determinants of fertility transition. However, CEB and TFR (which are computed from age-specific fertility rates) are notably disparate measures of fertility. The aim of this study was to argue that where TFRs are cited as a basis for an investigation of driving factors of fertility transitions, the dependent variable in the multivariable modeling ought to be an adjusted measure of fertility. The study applied trend analysis to examine the extent to which CEB and age-specific marital fertility rates (ASMFR) reflected trajectories of the trends of total marital fertility rates (TMFRs) in Ghana, Kenya, Rwanda, and Zimbabwe. Multivariable analysis based on the two-fold Oaxaca-Blinder decomposition technique was applied to examine how using ASMFR compared to CEB impacts the understanding of factors of fertility change, using the case of Zimbabwe. Trend analysis showed that ASMFR was more effective in reflecting fertility trends and measuring the role of associated factors. The results from multivariable analyses show that a case can be made for the use of adjusted measures in the understanding of factors of fertility transition.

Keywords: Marital fertility; Children ever born; Age-specific marital fertility rate; Total marital fertility rate; Decomposition analysis

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1. Introduction

The interest in understanding fertility, the most studied of the demographic events, carries various purposes which include to understand the factors driving trends in birth rates, health implications of childbearing, and to predict future childbearing patterns based on prevailing fertility schedules (Ariho, *et al.*, 2018; Ariho & Nzabona, 2019; Colleran & Snopkowski, 2018; Liu & Raftery, 2020). In many cases, scholars have used the total fertility rate (TFR) to highlight the need for the investigation of the determinants of fertility, and conducted multivariable analyses using the cumulative children ever born (CEB) as the dependent variable (Adhikari, 2010; Al-Balushi, *et al.*, 2020). While many of these studies analyzed fertility at one point in time, those which compared two points in time with the aim of understanding drivers of fertility decline also relied on

CEB as the depended variable (Ariho, *et al.*, 2018; Ariho & Nzabona, 2019). However, some scholars have analyzed the TFR as the dependent variable, although such studies have been few (Liu & Raftery, 2020; Retherford, *et al.*, 2005; Retherford & Rele, 1989).

The use of CEB instead of TFR or its constituent parts, the age-specific fertility rate (ASFR), has several conceptual and technical advantages. Conceptually, the CEB is a measure of actual births that a woman has had. Technically, the CEB can be analyzed in its raw form without the need to transform it into a state that can be analyzed in a multivariable model. However, there are disadvantages associated with CEB, especially in multivariable analyses aimed at establishing the factors influencing trends in fertility rates. First, the CEB is not an age adjusted measure, and therefore, the change in its average estimate between two time points may contradict that of the TFR which one may have used to argue for the need to investigate determinants of fertility transition. Second, the CEB is an historical measure which may be ineffective in capturing short-term changes in fertility patterns. When a birth cohort has unusually high birth rate compared to those older and younger than them, its CEB estimate will potentially inflate the average CEB estimate for a country despite that the country may be experiencing a continuous decline in fertility rates. Due to its inability to capture short-term changes in fertility, it can be argued that the use of age adjusted measures may be preferable in studies seeking to understand the driving factors of fertility transition.

The age-adjusted measures, namely, the ASFR and age-specific marital fertility rate (ASMFR) in the case of marital fertility, present a viable alternative for the investigation of potential drivers of fertility transition in multivariable models. Conceptually, age-adjusted fertility rates are aligned to the TFR or total marital fertility rate (TMFR) when one is studying marital fertility as is the case in this study. The advantage of ASMFRs is that they reflect contemporary fertility patterns based on recent births and are thus more reflective of prevailing fertility determinants compared to historical fertility measures like CEB. However, the main criticism of ASMFRs is that they are a synthetic measure which does not reflect actual number of births that have been recorded. Nonetheless, the ability of ASMFRs to reflect short-term changes in fertility provides a better opportunity for investigating time-dependent drivers of fertility rates. The study of time-dependent drivers is important in understanding the changing profile of determinants of fertility rates, thus providing a platform for designing policy responses accordingly. This paper was conceived to comparatively test this property of ASMFRs

in comparison to the CEB using data from Ghana, Kenya, Rwanda, and Zimbabwe. The study explored a multivariable decomposition equation using the case of Zimbabwe to demonstrate the extent to which the choice of a fertility measure impacts the nature of the findings about driving forces of marital fertility trends.

2. Methods

2.1. Data

This study analyzed DHS data from Ghana, Kenya, Rwanda, and Zimbabwe collected between 1988 and 2015, focusing on women who reported that they were in a union at the time of data collection. This meant that women living with a male partner as husband and wife in cohabitation or living together arrangements were considered married. The sample sizes from each survey for each country are reported in [Table 1](#). Ghana and Kenya collected their first DHS surveys in 1988 and 1989, respectively, and thereafter in 1993, 1998, 2003, 2008, and 2014. Rwanda collected its DHS surveys 1992, 2000, 2005, 2010, 2014/15, and 2019/20, but the latest was not included in the study for comparison with other countries and Zimbabwe's surveys were collected in 1988, 1994, 1999, 2005/06, 2010/11, and 2015. The selection of the countries was based on three considerations: (1) to have one country from each of the four sub-regions of sub-Saharan Africa, (2) a country must have at least five rounds of DHS data, and (3) a country must have experienced significant fertility transition for at least one defined period between 1988 and 2015. All the DHS waves collected between 1988 and 2015 were analyzed.

The DHS surveys were collected with funding from the United States Agency for International Development (USAID) and implemented by host countries' statistical agencies with technical support from the Inner-City Fund (ICF) Macro International Inc., usually cited as ICF International (<https://dhsprogram.com/>). The DHS surveys collect data from nationally representative samples of households on a variety of socioeconomic indicators which include fertility, maternal and child health, mortality, and family planning among others (ICF International, 2016). The DHS uses a standardized instrument across all the countries that it is implemented. This makes the DHS datasets comparable across countries and over time. The surveys have been instrumental in the study of the demographic transitions of SSA countries, allowing for detailed investigations of the determinants of fertility rates and drivers of transitions, especially in the African countries, where there are unreliable and incomplete vital registration data (Be-Ofuriyua & Emima, 2002; Bongaarts, 2015; Cleland, *et al.*, 2011; Gould & Brown, 1996; Indongo

Table 1. Myer's Indices of age misreporting in the DHS data for women from Ghana, Kenya, Rwanda, and Zimbabwe

	DHS1988	DHS1993	GHS1998	GDHS2003	GDHS2008	DHS2014
Ghana						
n	3,156	3,204	3,229	3,694	2,950	5,456
MI	15.6	12.3	12.6	10.7	12.8	9.0
	DHS1989	DHS1993	DHS1998	KDHS2003	KDHS2008	DHS2014
Kenya						
n	4,778	4,583	4,847	4,876	5,041	19,036
MI	10.6	8.3	9.6	7.0	9.9	9.6
		DHS1992	DHS2000	RDHS2005	RDHS2010	DHS2014
Rwanda						
n		3,698	4,891	5,458	6,834	6,890
MI		6.8	6.8	6.8	6.8	6.8
	DHS1988	DHS1994	DHS1999	DHS2005/06	DHS2010/11	DHS2015
Zimbabwe						
n	2,973	3,469	4,203	6,154	6,543	6,015
MI	8.5	8.6	10.8	6.2	8.8	6.1

& Pazvakawambwa, 2012; Locoh, 2002; Potts & Marks, 2001; Upadhyay & Karasek, 2012). The DHS data are publicly available on Measure DHS portal.

2.1.1. Ethics requirements

This study did not require ethics clearance, because it was based on secondary data. The DHS data are collected with ethics clearance from each host country's relevant institutional review boards (IRBs). The data are publicly available on Measure DHS website <https://dhsprogram.com/data/available-datasets.cfm>. To access the data, researchers must register as a DHS data user. The access to the datasets is granted to legitimate research purposes.

2.2. Variables

The dependent variables for this study were ASMFRs and CEB. These two variables were used, because they represent age-adjusted and cumulative and non-adjusted measures of fertility, respectively. The ASMFRs constitute the constituents of the TMFR. Because the TMFR is derived from ASMFRs, it is defined as the total number of live births that a woman is expected to have by the end of her reproductive career if she remains married and experiences the given ASMFRs. The CEB measures that the cumulative total number of children a woman has given birth to in her lifetime, thus reflects actual achieved fertility.

The independent variables were age group and education. Age is the main demographic characteristic used as the basis for calculating fertility indicators, because it does not change its form from population to population

and has a predictable constant change over time. Socioeconomic variables such as household wealth status, rural-urban residence, and contraceptive which are widely used in fertility analysis do not have a constant rate of change over time and are, therefore, not reliable for basing fertility rates on. However, they are important factors for understating fertility transitions. We used education as one of the independent variables, because it has been widely shown to play a significant role in the onset and progress of fertility transition in sub-Saharan African countries.

2.3. Data quality analysis

The first consideration when conducting fertility analysis using DHS data is the quality of the data. The early surveys especially from the DHS Phases I and II from some SSA countries have been noted to have problems of data quality due to misreporting of dates and ages which adversely affect the accuracy of fertility rates for age. The adverse impact of poor quality in DHS data is that if subsequent surveys have improved quality, demographic trends may be erroneously shown to have occurred when in fact it was only improvements in the data. The previous assessments of quality issues in DHS data have indeed highlighted the problem of age heaping whereby respondents showed bias toward stating ages ending in digits zero and five (Pullum, 2006). In analyzing fertility rates, age misreporting can have an adverse effect on the resulting age distribution of fertility rates and can distort the results on the differences/similarities between two time points of the same country. Given that this study was designed to determine the accuracy of two types of measures of fertility levels which

can be used in multivariable analysis fertility transitions, it was important to make sure that the data were of acceptable level of quality. Consequently, we analyzed the quality of the age data for the 23 surveys used in this study using the Myer's Index (MI). The findings from this analysis are presented under results section and they show that the quality of the data from the four countries meets the minimum expected standards for this study.

2.4. Computation of fertility measures

The fertility measures used in this study have different computational demands. The CEB, because it measures achieved fertility, is obtained by finding the average number of children born to a defined birth cohort which can be single-year or 5-year. The CEB measure is computed by dividing the total number of CEB by a cohort of women by the total number of women as indicated in the formula below:

$$\overline{CEB}_{n-n+5} = \frac{C_{n-n+5}}{W_{n-n+5}} \quad (1)$$

Using this measure, the average number of CEB to the 45 – 49 age group, called completed family size, is the equivalent of the total fertility rate. The downside of this, however, is that one must wait for 45 years to obtain the total fertility rate of a birth cohort aged 15 – 19 years. To obtain a measure of the total fertility rate of a population without having to wait for 35 years, the age-adjusted measures, namely, TMFR and its widely cited equivalent, TFR, are often computed. It should, however, be acknowledged that data on marital fertility may not be easily accessible, especially in countries that do not collect DHS data and do not make marital status data publicly available from their censuses.

The estimation of the TMFR and its constituents ASMFRs, equations [2] and [3], take a different approach from that for CEB. When computing the TMFR and ASMFRs using the DHS data, the recommended approach is to use births occurring in the 3 years preceding the year of survey data collection (Croft, *et al.*, 2018). Despite producing a TMFR which is considered a synthetic measure, this approach provides a current picture of the age patterns of fertility at any given time. Calculating ASMFRs involve dividing the number of live births occurring to a cohort during a specified period by the total number of person-years of exposure for the women of the given age cohort. Schoumaker (2013) developed a Stata programme, *tfr2*, which computes fertility rates using this approach by applying a Poisson regression model on birth history data. This program first transforms birth history data into a person-period table such that births are counted for the

age group the mother belonged to at the time of giving birth. This is illustrated in the figure below, supposing one is computing fertility rates using data from a survey conducted in the year 2010. The figure also illustrates the point of difference between the ASMFR and CEB.

Figure 1 shows six births delivered from 2004 to 2010 by three women (W1 – W3). For the calculation of ASMFRs following the standard procedure recommended for DHS data analysis, only three of these births which are highlighted in red would be considered. The numerator for the ASMFR for the age group 15 – 19 will comprise one birth by woman number two (W2) and four person-years of exposure distributed as two for W2 and two for W3. For the 20 – 24 age group, the numerator will be two births by W1 and W2 who contribute three and one person-years of exposure to the denominator, respectively. Using the birth history data transformed into person-periods, the ASMFRs are computed as:

$$\lambda_i = \exp \left[\alpha + \sum_{k=20-24}^{45-49} b_k A_{ki} \right] \quad (2)$$

Where α is a constant term, b is the intercept, A_{ki} is dummy variables for 5-year age groups from 20 – 24 to 45 – 49 years with the 15 – 19-year age group being used as the reference category (Schoumaker, 2013). Using the same Poisson model, the TMFR is computed by multiplying the exponentiated sum of the constant term and the regression coefficients for the respective age groups by five as follows:

$$TMFR = 5 * \left(\exp[\alpha] + \sum_{k=20-24}^{45-49} \exp[\alpha + b_k] \right) \quad (3)$$

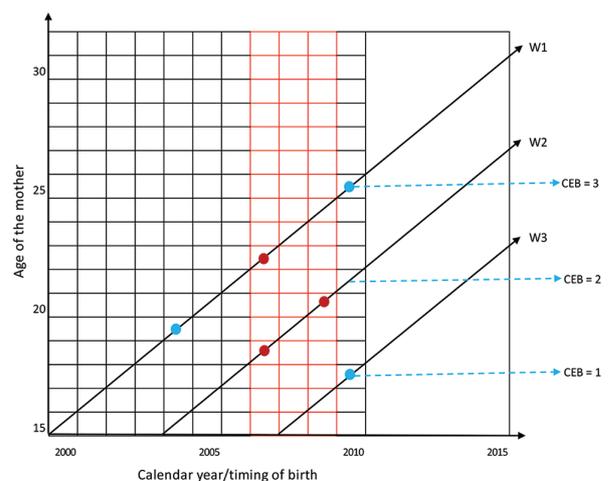


Figure 1. Lexis diagram illustrating birth history data for individual women for a DHS survey conducted in 2010
Note: Adapted from Schoumaker (2013).

The equation [3] was used to compute the point estimates of TMFRs which were used in the comparative assessment with the average CEB₄₅₋₄₉ to show trends in fertility levels.

2.5. Multivariable analysis of fertility

We demonstrated the effect of a fertility measure on the results of multivariable regression analysis by exploring a two-fold Oaxaca-Blinder (OB) decomposition method on both CEB and ASMFRs. The OB decomposition technique partitions a change in the mean estimate of an outcome measure into a part explained by changes in compositional characteristics of the sample and a part that is attributed to the behavioral changes of the sample. This regression-based decomposition method was used to comparatively examine how the choice of a fertility measure can affect the findings from the analysis of drivers of marital fertility change in situations, where the CEB and ASMFRs have followed different trends. The OB technique is a counterfactual decomposition which estimates conditional contributions of characteristics and coefficients associated with the independent variables in relation to the dependent variable. Applied to this study, it, therefore, means that it estimates the expected magnitude of change in the mean of CEB and ASMFRs based on the observed change in the distribution of the sample by age and education status, and differences in reproductive behaviors associated with identified age groups and education status.

When the change in the dependent variable is not consistent with the change in the independent variables, the OB decomposition produces illogical results. Furthermore, when the difference in the mean outcome is underestimated, the OB decomposition tends to overestimate the role of the independent variables. The overestimation of the effect of independent variables can potentially lead to erroneous determination of the depth and focus of investment in fertility management programs. The two features of the OB decomposition relating to illogical results and overestimation of factors' impact can, thus, be used to determine the comparative suitability of CEB and ASMFRs in the multivariable analysis of drivers of marital fertility trends.

3. Results

3.1. Data quality and sample distribution

The quality of data was generally good for Kenya, Rwanda, and Zimbabwe, where the proportions of women whose ages were potentially misreported were mostly below 10%. It was only Ghana which had higher indices of digit preference with the GDHS1988 showing the highest score. However, the differences in the Myer's Indices between

the successive GDHS surveys were very small. When successive surveys have comparable levels of data quality, the impact on fertility measures is minimal. Therefore, the potentially spurious trends in demographic indicators due to improvements in data quality could not have occurred in Ghana. These spurious demographic trends due to improvements in data quality occur when there is sudden positive change in the quality of the data.

The sample distribution shows that for all the countries, the age distribution of the married women has been shifting toward predominance of older age groups (Figure 2). The proportions of women in unions aged 15 – 24 progressively decreased in the four countries. The pattern of education status was markedly different among the countries. In Ghana and Zimbabwe, an overwhelming majority of the women have secondary education while, in Kenya and Rwanda, they have primary education only.

3.2. Trends in fertility levels

The results from the comparative analysis of TMFRs and average CEB₄₅₋₄₉ are presented in Figure 3 below. The trends of marital fertility levels obtained from TMFRs were notably different from those constructed from average CEB₄₅₋₄₉. A notable observation is the inability of CEB to capture stalls in the marital fertility transitions in all the four countries. The marital fertility transition of Ghana has stalled post 1998 with inter-survey increases in TMFRs 1998 – 2003 and 2008 – 2014 periods. In these periods, the average number of CEB to women in the 45 – 49 age group decreased, suggesting a continuous decline in marital fertility. We find the same contradictions between CEB and TMFRs in Kenya between the KDHS1998 and KDHS2003. This 1998 – 2003 period is shown by CEB to have been marked by decreasing marital fertility in Kenya. The trends of CEB₄₅₋₄₉ and TMFRs for Rwanda also followed different trajectories reflecting differences in their ability to capture short- and medium-term changes in birth rates. The pre-2005 era in Rwanda, which was characterized by sociopolitical instabilities and the 1990s genocide, saw the disruption of family planning and health infrastructures which resulted in crisis fertility-driven upsurge in birth rates. The CEB₄₅₋₄₉ is unable to capture this increase in fertility as effectively as TMFR. If one argues that the rise in crisis fertility in Rwanda was potentially concentrated among young women, this increase would be reflected when considering the mean CEB for all women 15 – 49 years. However, this too is unable to effectively capture the increases in fertility in Rwanda pre-2005. The trends of CEB₄₅₋₄₉ and TMFRs for Zimbabwe were more different compared to the other countries. The rapid marital fertility transition from 1988 to 1999 reflected by TMFRs is shown to be mild by CEB. The difference between the CEB₄₅₋₄₉

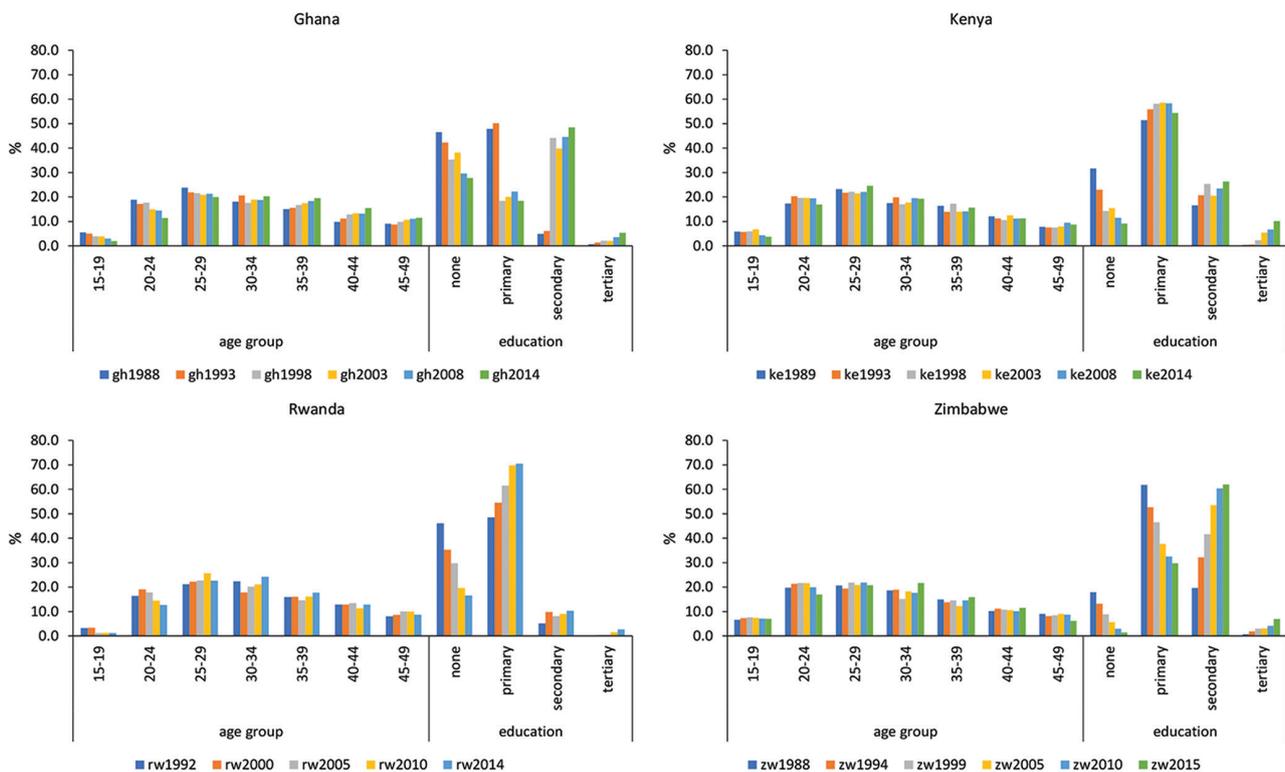


Figure 2. Sample distribution by age group and education status in Ghana, Kenya, Rwanda, and Zimbabwe

and TMRs trends continued post-1999 with the former indicating a continuous decline in marital fertility, while the latter revealed a stalled transition. From 2005 to 2014, Zimbabwe experienced rebounds in marital fertility rates, a stark contrast with the accelerated decline depicted by CEB. The mean CEB₁₅₋₄₉ starts to capture the stall in marital fertility transition of Zimbabwe about 10 years after the TMR did so. Just like the case in Rwanda, the CEB₄₅₋₄₉ and CEB₁₅₋₄₉ measures were not sensitive to the occurrence of stalls and rapid decreases of marital fertility in Zimbabwe.

3.3. Age patterns of fertility

The trends presented in the preceding section can be further unpacked by analyzing the underlying age patterns of fertility. This was accomplished by comparatively analyzing the differences in the age patterns of fertility between successive DHS surveys. We draw particular attention to the inter-survey periods characterized by notable differences between CEB and TMRs. These were 2008 – 2014 in Ghana, 1998 – 2003 in Kenya, 2000 – 2005 in Rwanda, and the three inter-survey periods after 1999 in Zimbabwe [Figure 4]. During all the periods, there were stalls in marital fertility transition as shown by TMRs, while CEB₄₅₋₄₉ indicated decreases in marital fertility.

Ghana’s 2008 ASMRs for especially for age groups 25 – 29 and 30 – 34 were notably lower than those in 2014. This is arguably the source of the higher the TMR in 2014 than in 2008 in Ghana. Meanwhile, there were no differences in the average number of CEB for all age groups between the GDHS2008 and GDHS2014 except the 45 – 49-year age group. The CEB₄₅₋₄₉ estimate for GDHS2014 was lower than that for GDHS2008, thus giving the impression that completed fertility continued to decrease in Ghana which was contrary to the stall indicated by TMRs.

The fertility stall which occurred in Kenya in the early 2000s is a widely reported phenomenon in demographic literature. As also shown in this study, this stall was well defined among married women as reflected by the increase in TMRs between the KDHS1998 and KDHS2003. The stall in the marital fertility transition of Kenya was likely because the ASMRs for the 25 – 29, 30 – 34, 35 – 39, and 45 – 49-year age groups were lower in KDHS1998 compared to the KDHS2003. On the contrary, the age patterns of average CEB were the same between the KDHS1998 and the KDHS2003 from age group 15 – 19 to 35 – 39, and slightly lower in the KDHS2003 for the 40 – 44 and 45 – 49 age groups.

The notable increase in TMR of Rwanda from the RDHS2000 to the RDHS2005 is well reflected in the

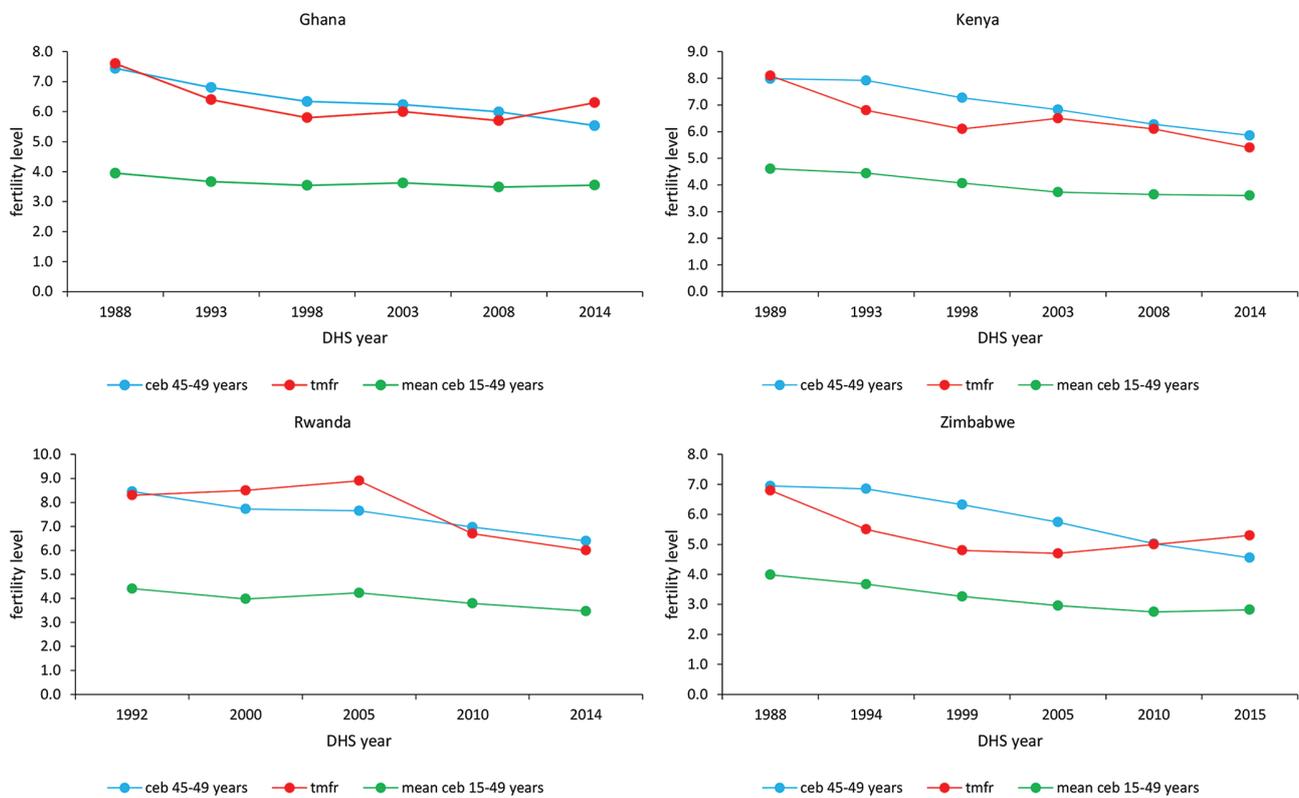


Figure 3. Trends in children even born (CEB) versus total marital fertility rate (TMER)

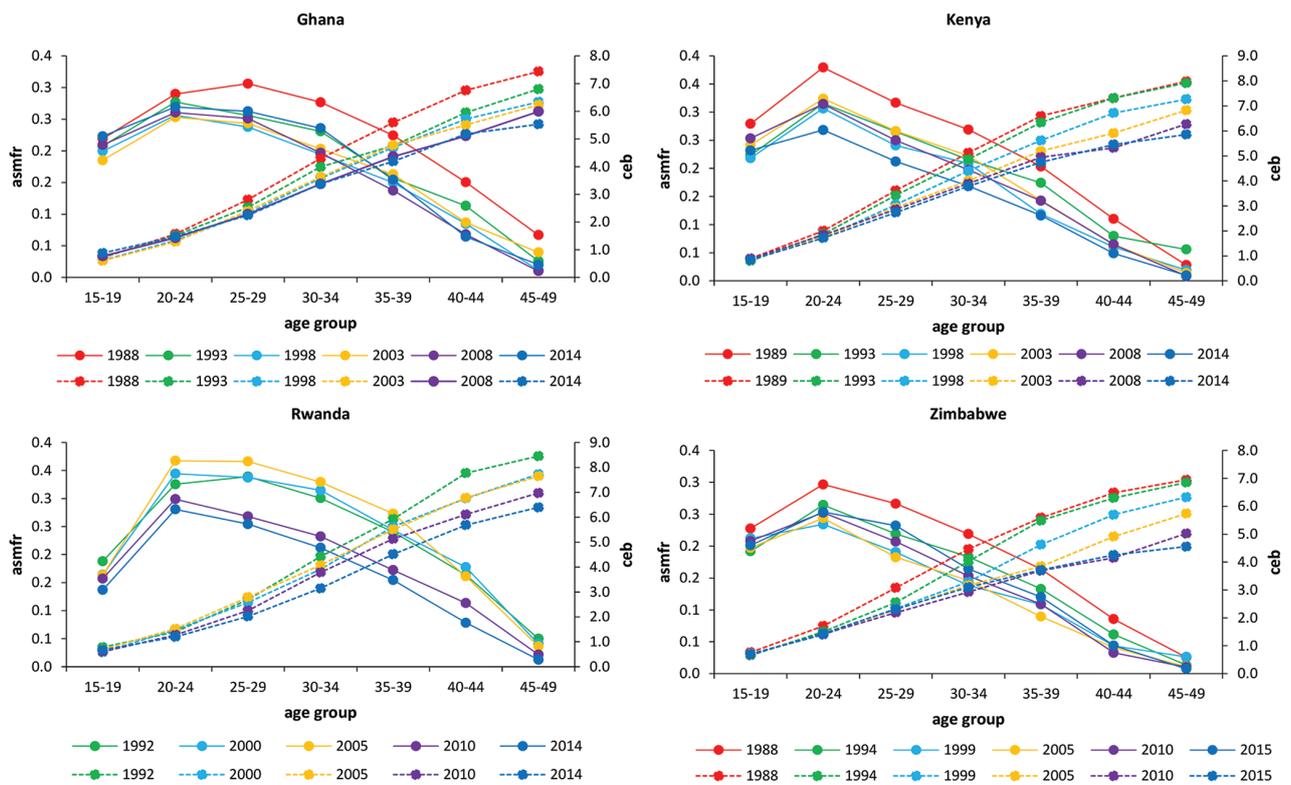


Figure 4. Age patterns of fertility according to average children even born (CEB) and age-specific marital fertility rates (ASMFRs)

schedules of the ASMFRs from the two surveys. The RDHS2005 clearly had higher ASMFRs for the peak childbearing age groups of 20 – 24, 25 – 29, as well as the 30 – 34 and 35 – 39 compared to the RDHS2000. These clear differences were absent when comparing the two surveys' age patterns of average CEB. There were no differences between RDHS2000 and RDHS2005 in terms of CEB across all the age groups, which, further, strengthens the argument that the CEB measure is not robust to capture changes in fertility rates.

Zimbabwe displayed the most defined contradictions between ASMFRs and average CEB. The ASMFRs of the first three ZDHS surveys were consistent with the rapid decrease in TMRs from 1988 to 1999, something which CEB also suggested especially for the age groups 30 – 34, 35 – 39, and 40 – 44. However, after 1999, TMRs for Zimbabwe stalled and started to increase. These increases were more defined during the 2005 – 2010 and 2010 – 2015 inter-survey periods, where TMRs notably increased. The ASMFRs reflect these stalls as shown by the schedules of the ZDHS2020 and ZDHS2015 which had higher rates than the preceding the ZDHS2005 and ZDHS2010, respectively. While the ASMFRs proved effective at capturing marital fertility stalls in Zimbabwe, the cumulative CEB measure was unable to do so. For all the surveys post 1988, the CEB₄₅₋₄₉ was higher than that of the preceding survey. This was also the case for most of the age groups from 25 – 29 to 40 – 44. The results for Zimbabwe thus further confirm that CEB is not an effective measure for capturing trends in fertility rates, especially where these trends are characterized by episodes of stalls and rebounds.

3.4. Differences between CEB and ASMFR in multivariable analysis

We executed the OB decomposition using education and age group as the independent variables to explain the change in the marital fertility levels as measured by CEB and ASMFR. This analysis determined how the difference between CEB and ASMFR affects the nature of the conditional contributions from a decomposition analysis of change in the level of fertility. The analysis focused on two inter-survey periods from Zimbabwe, the 1988 – 1994 which was a period of rapid marital fertility transition and the 2010 – 2015 which was characterized by stalled marital fertility transition. We used Zimbabwe as a case in this study because it had the most defined differences in the trends of its unadjusted and adjusted measures of fertility. The aggregate results from decomposition analysis were that in the 1988 – 1994 period, the mean ASMFR decreased by 16%-points, while the mean CEB declined by 8% points, showing an underestimation of the decline by the latter (Figure 5). In the 2010 – 2015 period, ASMFR showed a rebound of marital fertility rates equivalent to 6% points, while the mean CEB was found to increase by 3% points. As was the case in the 1988 – 1994 period, the CEB underestimated the rebound of marital fertility by 50% compared to the mean ASMFR.

In interpreting the results of the decomposition, where the difference in the mean estimate of CEB/ASMFR between the ZDHS1988 and ZDHS1994 is negative and the changes in characteristics and coefficients supported the decrease (denoted by negative sign), the percentage

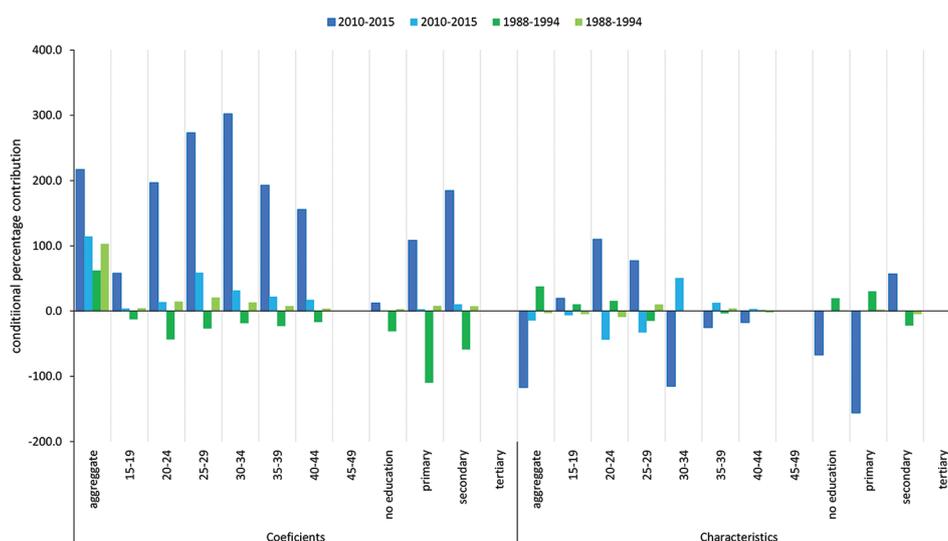


Figure 5. Differences in fertility change determinants based on type of fertility measure

*Constants for CEB are -1.413 and -0.698 for 1988-1994 and 2010-2015 respectively. For ASMFR, the constants are -0.006 and -0.005 for 1988-1994 and 2010-2015 respectively.

conditional contribution is positive. This means that the characteristics and the coefficients were positively associated with the decrease in marital fertility. The results reported in Figure 5 that highlights how the use of CEB and ASMFR as dependent variables affects the results. In the period 1988 – 1994, the results based on ASMFR suggest that the changes in characteristics of the sample by age group and education did not positively support the rapid decrease in marital fertility rates of Zimbabwe. This was in complete contrast with the results based on the analysis of CEB which suggested that compositional characteristics had a notable positive impact on the decrease of marital fertility. Because characteristics measure the distribution of the sample, a look at the changes in the sample distribution reveal that the results based on ASMFR are more realistic compared to those from CEB.

4. Discussion

This study found that the CEB and ASMFRs (TMFRs) have fundamental implications on the nature of findings from the investigation of drivers of marital fertility transition. The main finding of this study was that, compared to the cumulative CEB, ASMFRs represent an arguably more effective outcome measure in the multivariable analysis of the determinants of marital fertility transition. Compared to the ASMFR, the CEB tended to underestimate the magnitude of marital fertility decline and stall and this impacts on the relative importance of the determinants of fertility change. The superior effectiveness of ASMFRs emanates from the reference time period it is derived from, which is considered current. Consequently, the ASMFRs capture the period changes in the age patterns of fertility. The period changes are also associated with the changing socioeconomic characteristics of the women and their wider communities of residence. For instance, in communities lacking education and health infrastructure, many women may have more unwanted births thus inflating the average number of CEB as well as period fertility rates. If over a 15-year period, there is high investment in social infrastructure and many women start having access to schooling, adult education, and family planning programs and health services, the impact will be a reduction of unwanted births which reduce the levels of period fertility. When analyzing the fertility change using CEB, births which occurred before education, health infrastructure, and family planning services were introduced are also counted in the outcome measure such that unwanted births from 15 years ago will continue to influence the estimate of the level of fertility in the current period. This nature of CEB is the underlying reason why the CEB was found to underestimate the change in marital fertility levels between successive DHS surveys. The ASMFRs, contrary to CEB

in the abovementioned example, will treat births from 15 years ago to produce a distinct measure of fertility rate separate from the measure based on a time period after the introduction education, health, and family planning infrastructures. This is the reason why ASMFRs were more effective at reflecting the marital fertility transition and stalls presented in the results section.

The results from the illustrative multivariable decomposition analysis showed that the conditional percentage contributions based on the analysis of ASMFRs were intuitive, while those from the analysis of CEB were sometimes counterintuitive. The reason for this is linked to an extent with the 15-year illustration in the preceding paragraph. In this study, we used education as one of the predictor variables. Suppose a cohort of women with only primary schooling completed had an average CEB of three births before their 20th birthday during a period when there was no access to education and health services. This cohort then goes on to have access to secondary education and health services from their 20th birthday such that by age 25 their average CEB remains at three, but they have completed secondary schooling. In this case, there is no change in the outcome variable, but the independent variable education status has changed significantly. Analyzing this relationship between CEB and education using the OB decomposition will produce large and counter intuitive conditional percentage contributions of education status. This is because the predictor variable, has improved but the dependent variable remains unchanged, giving the impression that education did not have any effect on fertility. Substituting CEB with ASMFRs in this case, the latter will be able to decrease in the births due to the increase in education status and the change in the reproductive behavior associated with the shift from primary to secondary education. Consequently, the OB decomposition will produce percentage contributions which are not counterintuitive. This is because the changes in the education status and ASMFRs will have commensurate period references unlike the case with CEB, where both primary and secondary education attainment will be associated with three births.

The importance of using age-adjusted measures is apparent when critically reflecting on the findings of the present study in relation to those from existing literature. In this study, the coefficients which measure behavior change effects on fertility were shown to be more closely associated with the trends in marital fertility rates. This contrasts somewhat with the studies by Ariho, *et al.* (2018) and Ariho & Nzabona (2019) which reported that changes in characteristics drove the decline in the mean number of CEB in Uganda between 2006 and 2011, thus concluding

that the composition of the female population of the country underlay the decrease in TFRs. It therefore can be argued that had the study by Ariho, *et al.* (2018) analyzed ASFRs as the dependent variable instead of CEB, the findings of the study would have observed a more pronounced effect of behavioral changes than compositional characteristics. This is because it has already been shown in different studies that the trends in fertility decline in African populations have been parallel across the age-groups and socioeconomic classes (Garenne & Zwang, 2006; Udjo, 1996). The study by Liu & Raftery (2020) which used TFR as a dependent variable employing Granger causality found moderate effects of modern contraceptives on fertility transition and we found similar results elsewhere by analyzing ASMFRs, finding that changes in reproductive behaviors have been more influential than compositional characteristics (Ndagurwa & Odimegwu, 2019).

5. Conclusions

This study sought to investigate the relative benefits of analyzing cumulative and age-adjusted measures of fertility in multivariable analysis of drivers of fertility trends. The CEB and ASMFRs were used to represent the cumulative and age-adjusted measures of fertility respectively. Data were obtained from all the DHS surveys from Ghana, Kenya, Rwanda, and Zimbabwe collected between 1988 and 2015 were analyzed. The results of the study suggest that ASMFRs are more effective at identifying short term changes in marital fertility rates and associated factors compared to the average CEB. In conclusion, the study recommends that the multivariable analysis of drivers of marital fertility transition, as also for fertility transition in general, should look to use age adjusted fertility measures as dependent variables instead of the cumulative CEB measure.

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Conflict of interest

The authors certify that they have no conflicts of interest to declare.

Author contributions

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Ethics approval and consent to participate

Not applicable. The study analysed publicly available secondary data.

Consent for publication

Not applicable.

Availability of data

Data analyzed in this study are publicly available on the Measure DHS website <https://dhsprogram.com/data/available-datasets.cfm>. To access the data, researchers should register as a DHS data user. The access to the datasets is granted for legitimate research purposes.

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