

## Recent Fertility Declines in Sub-Saharan Africa: Analysis of country trends of fertility decline

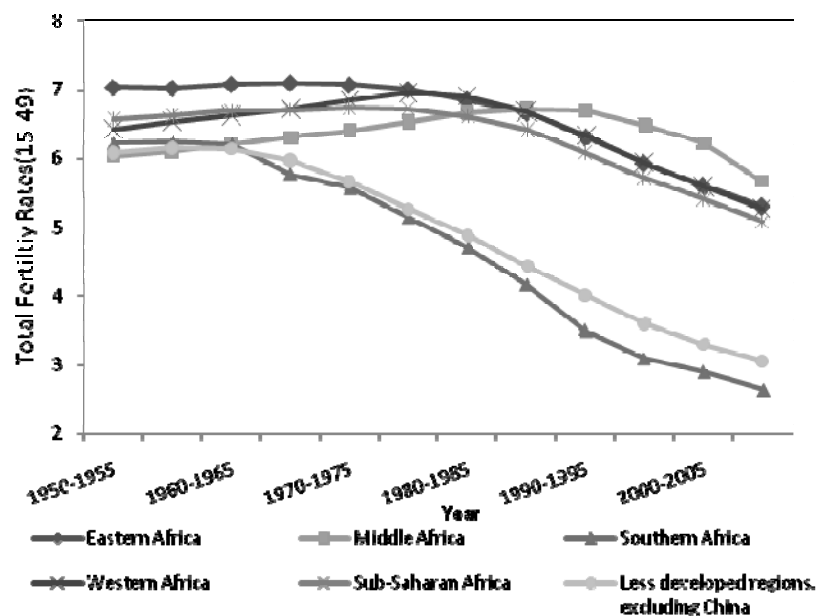
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### Introduction

Fertility transitions began in many sub-Saharan African countries in the 1980s. Kenya, Zimbabwe, Namibia, and South Africa were the early-transition countries and fertility declined by more than one child per woman in the 1980s (Cohen 1993). In the 1990s fertility declines started in most other countries at different paces. Fertility in the countries of Southern Africa declined at almost the same pace as the average rate in less developed countries in other regions, whereas the transitions in Eastern, Western and Middle Africa have been much slower (see Figure 1). The average total fertility rate (TFR) for the whole of sub-Saharan Africa is 5.08 in 2005-2010 (United Nations 2009).



**Figure 1:** Total fertility rates, Africa and global less developed regions, 1950-2010

Source: United Nations. 2009. *World Population Prospects: The 2008 Revision*. New York: United Nations.

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It is often assumed that fertility decline, once initiated, would steadily continue until reaching the replacement level, i.e. TFR of 2.1 children per woman. Therefore, the pace of fertility decline in the later stages of transition had not been much explored until recently (Aminzade 1992; Bongaarts 2002; Casterline 2001). Recent studies, however, challenged this widespread assumption. Bongaarts reported that the pace of decline has decelerated in the early 2000s in sub-Saharan Africa (Bongaarts 2006, 2008). Moreover, he concluded that 12 sub-Saharan African countries have ‘stalled’ fertility decline in the midst of transitions (Bongaarts 2008). Bongaarts defines a stall as no statistically significant decline in the TFR between two successive surveys, using the TFR from data obtained over three years prior to each of the two most recent surveys (Bongaarts 2008). In spite of using the same data, i.e. Demographic and Health Surveys (DHS), other studies have arrived at inconsistent conclusions about the extent of the apparent fertility stalls. Garenne found that fertility declines have stalled in six countries while Schoumaker identified fertility stalls only in Kenya and possibly in Rwanda (Garenne 2008; Schoumaker 2009). Westoff and Cross also provided evidence of stalling fertility decline in Kenya (Westoff and Cross 2006). Sneeringer assessed cohort fertility trends and reported that only in Congo (Brazzaville) and Madagascar fertility transitions have slowed (Sneeringer 2009).

One reason for these contradictory results is failure of the analyses to take fully into account the quality of DHS data. While DHS is acknowledged to exercise high standards in data collection, no survey is immune to errors, and there is abundant evidence that such errors tend to be more pervasive in sub-Saharan Africa than elsewhere (Arnold 1990; Johnson et al. 2009; Pullum 2006; Rutstein and Bicego. 1990). The most serious and measurable problem in using this type of cross-sectional household survey data to examine demographic trends is age displacement of children. In the DHS Women’s Questionnaire, women with children born during a predetermined number of years prior to the survey (generally between January of the fifth full calendar year and the month of interview) are asked a range of questions on maternal and child health related to the children. The questions are not asked for children born before the predetermined boundary year. As a result, interviewers could be motivated to transfer dates of childbirths backward and avoid asking the additional questions to reduce their workloads. In fact, births occurring 0-5 years preceding a survey tend to be pushed backwards, leading to underestimation of births during the period and to overestimation of births six and more years prior to the survey. This pattern of age transfer can overstate the speed of recent fertility decline

(Goldman, Rutstein and Singh 1985; Potter 1977). This was also pointed out in studies of child mortality (Murray et al 2007, Sullivan 2008).

The fertility stalls reported in earlier studies often relied on unadjusted average TFR estimates for three or five years preceding each survey on approach which is vulnerable to age transfer of children, particularly when such transfers are more pronounced in some surveys than others (Askew et al. 2009; Bongaarts 2006, 2008; Ezeh, Mberu and Emina 2009; Shapiro and Gebreselassie 2008; Westoff and Cross 2006). A few studies developed a method to adjust for the data errors and produced more reasonable trends, but the results appear rather sensitive to recent data and the procedure may contain subjectivity (Machiyama 2010; Schoumaker 2009). More robust methods are needed.

While few studies have assessed fertility changes at sub-national level (Garenne 2008), residence and education are two of the most important intermediate factors associated with fertility decline. Women living in urban areas and educated women are generally more likely to postpone marriage, and have access to education, health services and formal jobs as well as to adopt new behaviours such as use of modern contraception. Urbanisation has accelerated in sub-Saharan Africa. The population in urban areas has increased from only 26 per cent in 1975 to 40 per cent (UN-HABITAT 2008). Also, women's educational attainment has dramatically improved in the last decades. While these social changes are part of the engine of fertility decline there are also considerations as to whether successive surveys have sampled different proportions of women in these sub-groups. However, there seem little differences in proportion of educational attainment by cohort (Machiyama, 2010). It is important to understand to what extent change in educational and residential composition of women's population have contributed to national fertility changes.

This paper re-assesses fertility decline in 17 sub-Saharan African countries. It incorporates five important developments since the previous study (Machiyama 2010). First, we increased the number of countries studied to 17. Second, this study applied a smoothing method developed by Murray et al for child mortality estimation (Murray et al. 2007). The use of a range of weights made the estimates more robust for short- and long-term estimation. Third, reasonable uncertainty intervals were obtained to provide the levels of precision of the estimates. Fourth, we present an approach to assess clustering by multilevel analysis as the TFR (15-39) estimates derived from the same survey are highly correlated with each other within each

country. Finally, we examined the extent to which the national fertility changes are attributable to compositional changes.

## **Methods**

### *Data*

Our study used individual, birth and household member datasets from 63 DHS surveys in 17 sub-Saharan African countries which have conducted three or more DHS surveys, namely: Benin (1996, 2001, 2006), Burkina Faso (1993, 1998/9, 2003), Cameroon (1991, 1998, 2004), Ghana (1988, 1993, 1998, 2003, 2008), Kenya (1989, 1993, 1998, 2003, 2008/9), Madagascar (1992, 1997, 2003/4, 2008/9), Malawi (1992, 2000, 2004), Mali (1987, 1995/6, 2001, 2006), Namibia (1992, 2000, 2006/7), Niger (1992, 1998, 2006), Nigeria (1990, 1990, 2003, 2008), Rwanda (1992, 2000, 2005, 2007/8), Senegal (1986, 1992/3, 1997, 2005), Tanzania (1991/2, 1996, 1999, 2004/5), Uganda (1995, 2000/1. 2006), Zambia (1992, 1996, 2001/2, 2007) and Zimbabwe (1988, 1994, 1999, 2005/6). Selection of countries with three and more surveys enabled us to assess fertility trends for about three decades as well as to mitigate the vulnerability to errors which would occur more often when using only two surveys.

### *Methods*

#### *Adjusted Total Fertility Rates (15-39) by Single Calendar Year*

Partial TFR estimates among women age 15-39 were generated for every calendar year for 10 years prior to the year each survey was conducted. Partial TFRs were computed by cumulating age-specific fertility rates among women age 15-39, because women age 40-49 at 10 years prior to the time of a survey (i.e. women age 50-59 at the time of the survey) were truncated from the individual dataset. Age-specific rates of women 40-49 usually contribute to 10 per cent of a TFR (15-49) (Garenne 2008). If we push the analysis beyond this 10-year period it would bring increasing problems of truncation and data quality.

It is worth noting that the data in the year that data collection ended contains a smaller fraction of births and exposure than would have occurred in the whole year. As a result, the estimated rate would not represent the fertility rate in the calendar year and the reference period

is likely to be distorted (Becker and Pullum 2007). Therefore, the data in the year of each survey were excluded when the data collection was conducted between January and June, because they might heavily affect directions of the loess smoothing line.

Second, the TFR (15-39) estimates were adjusted for downward age displacement of women and age displacement of children using Pullum's method (Machiyama 2010; Pullum 2006). The estimated proportions of women age 15-19 misreported as the age 10-14 were transferred back to 15-19 age group. Age displacement of children was corrected by adjusting births in a year preceding a predetermined boundary year for the additional maternal and child questions and in the boundary year itself using the proportions of children transferred between these two years. Subsequently, partial TFRs were re-estimated using the above adjusted number of births and women-years. This made assumptions that no births had occurred among the women transferred back to the 15-19 age group, a reasonable assumption given their younger age, and that age transfer was restricted to the two years across the boundary year (Pullum 2006).

#### *Loess Approach*

We applied the method developed by Murray et al for child mortality estimation to fit loess (locally weighted scatterplot smoothing) regression curves to partial TFR (15-39) data points (Murray et al. 2007). Loess is a widely used smoothing method, which produces a new smoothed value for each required time point by running a linear regression with the highest weight on data points close to the time point of interest and less weight on other data points according to their distance from the time point of interest. This procedure was repeated to obtain smoothed values for every year. The basic loess function we used is:

$$\log(\hat{y}) = \beta_0 + \beta_1x + \varepsilon$$

where  $\hat{y}$  is partial TFR (15-39),  $x$  is calendar year and  $\varepsilon$  is an error term.

This function was fitted using weighted least squares regression. The weights for each data point were tuned by a parameter  $\alpha$ . For each country we used a range of  $\alpha$  values between 0.1 and 2.0, starting with the lowest value of  $\alpha$  that can be used given the number of observed data points, increasing the value of  $\alpha$  by 0.05 until 1.0 and then increasing it by 0.1 between 1.0 and 2.0. The detailed definition of  $\alpha$  is given in Murray et al 2007 (Murray et al. 2007). For each value of  $\alpha$  the loess function was fitted using weighted least squares. 1000 random draws were simulated from the multivariate normal distribution defined by the estimated regression coefficients and their variance covariance matrix, and the fitted TFR for the required time point calculated for each set of random draws. The 1000 fitted TFRs per  $\alpha$  value were then pooled across the set of alpha values, with the median value providing the final fitted TFR and the 2.5th and 97.5th centiles giving the uncertainty interval.

The previous study used a built-in loess command in STATA (Machiyama 2010). Only a single  $\alpha$  was rather arbitrarily selected, and the value was small (approximately 40 per cent), meaning the results were perhaps overly sensitive to recent (potentially spurious) estimates which deviated from the overall trend. In contrast, the current method uses a range of  $\alpha$  values, so that both short- and long-term trends are incorporated (Silverwood and Cousens 2008).

### *Multilevel Analysis*

Within each country estimates of TFR (15-39) derived from the same DHS survey are likely to be more correlated with each other than estimates from different surveys. The current loess approach, however, assumes that the estimates are independent. In order to assess how this dependency may have affected the overall loess trends, we incorporated a simple random slope and intercept multilevel model into the loess approach in place of the linear model given above. The basic model is:

$$\log(\gamma_{ijt}) = \mathbb{I}(\beta_0 + u_{0i}) + (\beta_1 + u_{1i})x_{ij} + \varepsilon_{ij}$$

where

$$\begin{pmatrix} u_{0i} \\ u_{1i} \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_{u0}^2 & \sigma_{u01} \\ \sigma_{u01} & \sigma_{u1}^2 \end{pmatrix}\right)$$

and  $\varepsilon_{ij} \sim N(0, \sigma_\varepsilon)$ , with  $y_{ij}$  and  $x_{ij}$  now the  $j$ th values within the  $i$ th survey.  $u_{0i}$  is the random intercept and  $u_{1i}$  the random slope for survey  $i$ . The multilevel model was fitted using the same

weight function as for the standard loess approach and the fitted TFR values were calculated as before.

When deciding on the set of  $\alpha$  values to use we introduced two additional criteria: 1) data from at least 3 surveys are used at all required time points; 2) at least 2 surveys contribute at least 2 data points at all required time points.

#### *Standardisation of education and urbanisation*

We estimated loess TFR (15-39) for 6 population strata defined by type of residence (urban / rural) and 3 levels of highest educational attainment (no education, primary education, secondary or higher education) for each country. The estimates were then standardised by educational and residential composition of women in the first survey for each country. The difference between the observed loess partial TFR (15-39) and the standardised loess TFR (15-39) in the latest year divided by the observed change in partial TFR in 1980 or 1985, provides the percentage of change attributable to compositional changes on national fertility decline during the period.

STATA SE/11 and R version 2.11.1 were used for the entire analysis.

## **Results**

Figure 2 show trends of partial TFR (15-39) in the past 15-20 years in the 17 countries. Table 1 shows average annual per cent decline by decade. When the pace is less than 1 per cent in the 3 decades, the country is considered to be in early-transition. If annual per cent decline is similar across decades we consider the trend as steady decline. Deceleration is regarded when the pace has substantially reduced from the 1980s.

Overall, all the countries show at least some fertility decline, despite various patterns, pace and levels of fertility. Among the countries studied, five (Benin, Kenya, Malawi, Zambia and Zimbabwe) have clearly experienced a reduction in the pace of fertility decline since the 1980s. In Kenya and Zimbabwe, the annual declines was over 2.0 per cent in the 1980s and mid-1990s, though the pace decelerated to 1.3 per cent or lower in the 2000s.

In Ghana and Rwanda the pace was rapid in the 1980s, slowed down in the 1990s, and then was similar or slightly further reduced during the 2000s. Nigeria appears to have recently

experienced deceleration, but due to the very poor quality of data we need be careful when interpreting this result (National Population Commission [Nigeria] 2000).



Figure 2: Partial TFR (15-39) by single calendar year and loess trends

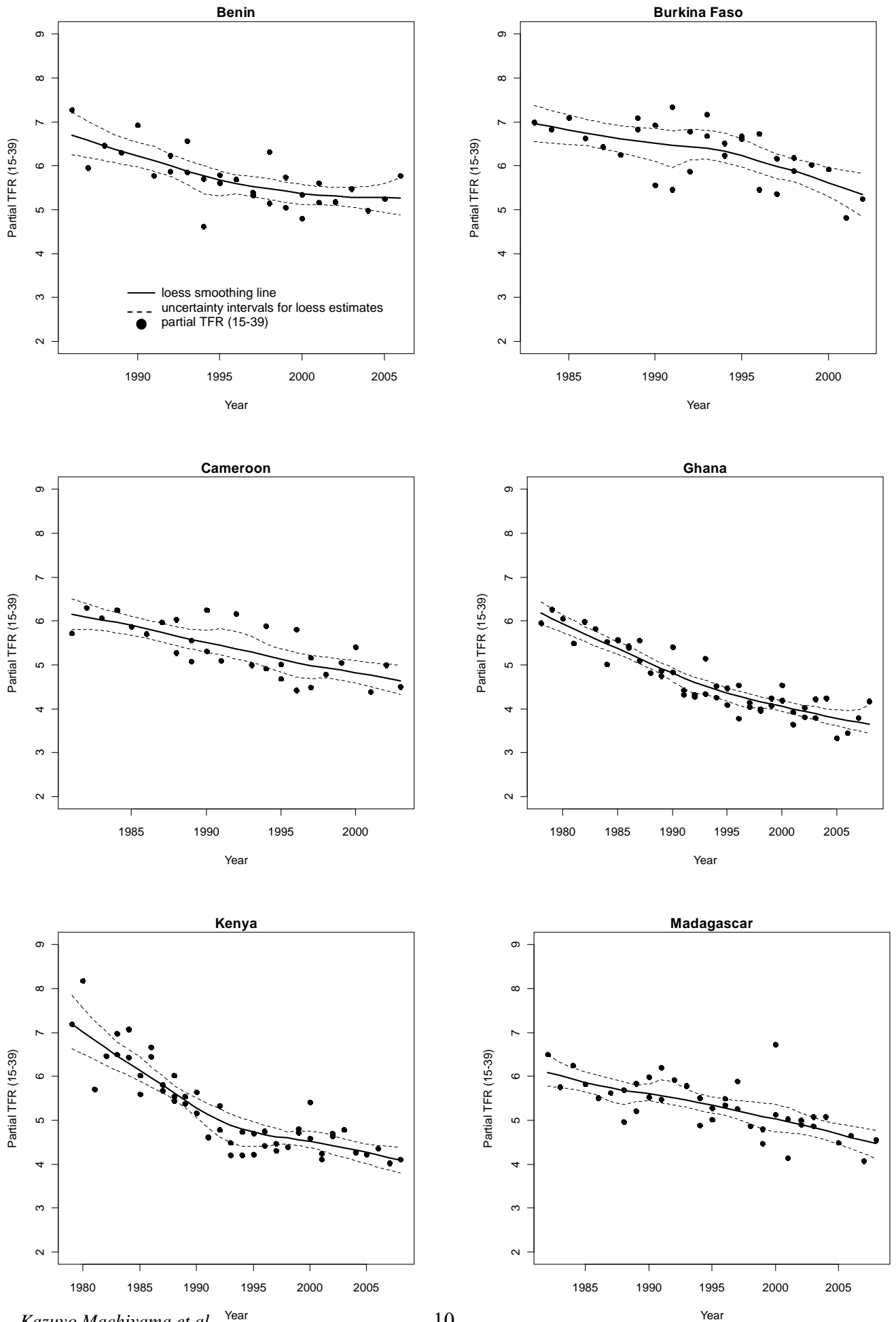


Figure 2: Partial TFR (15-39) by single calendar year and loess trends

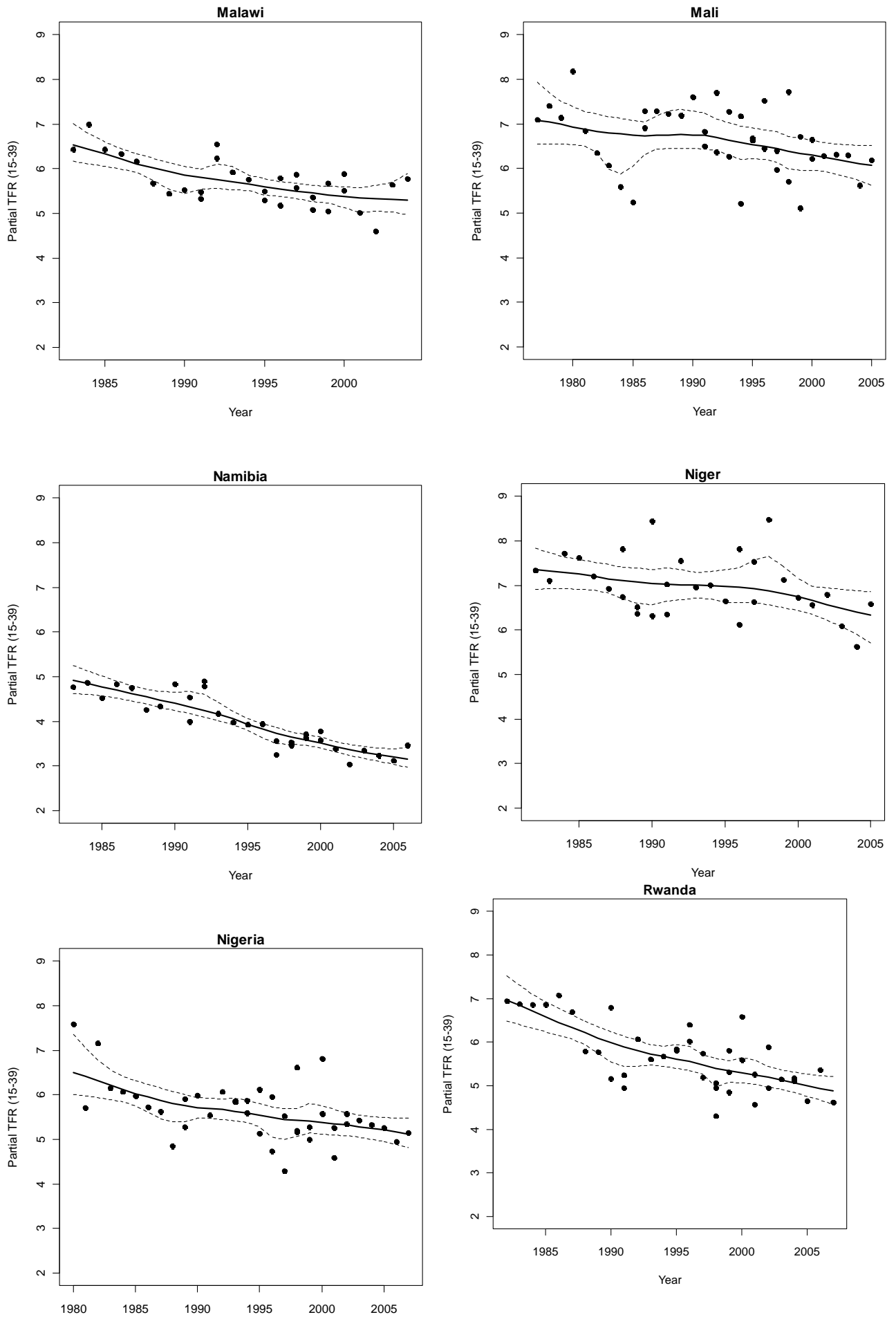
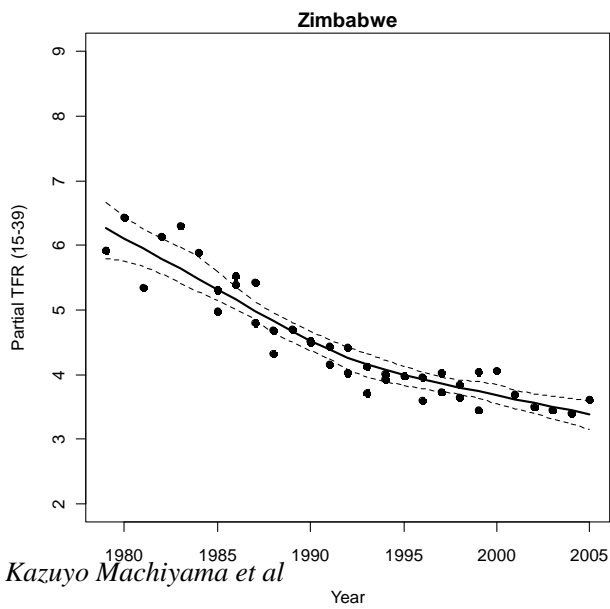
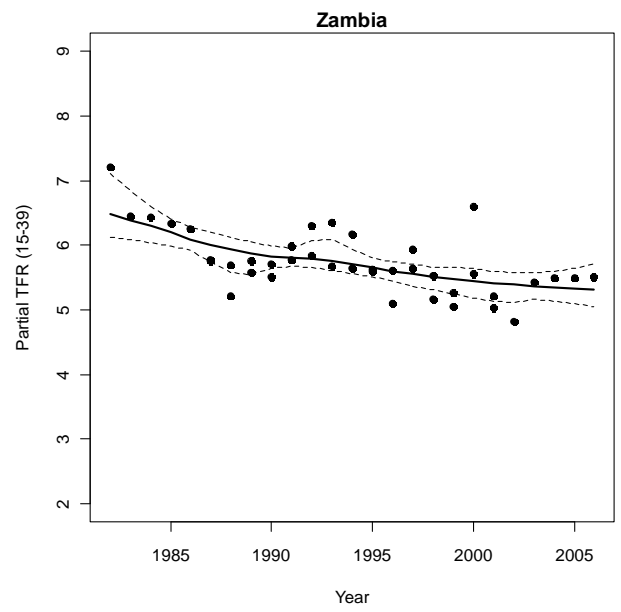
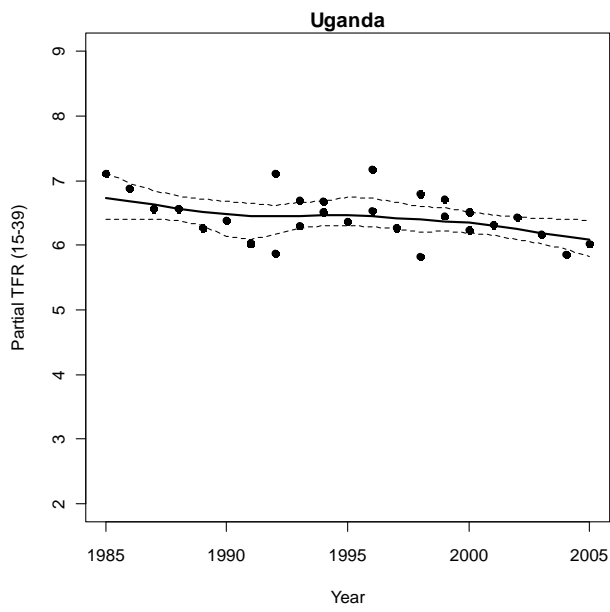
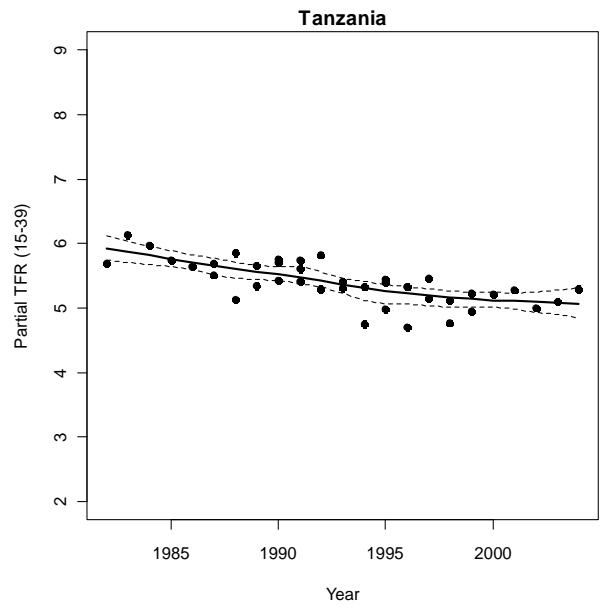
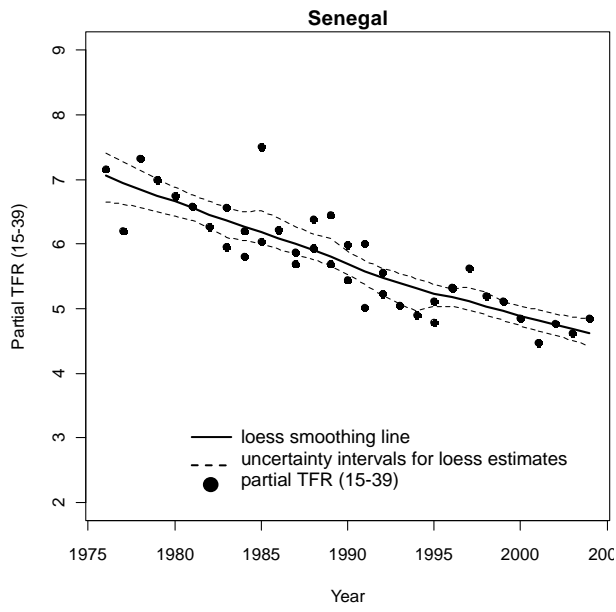


Figure 2: Partial TFR (15-39) by single calendar year and loess trends



**Table 1: Pace of fertility decline in 17 sub-Saharan African countries**

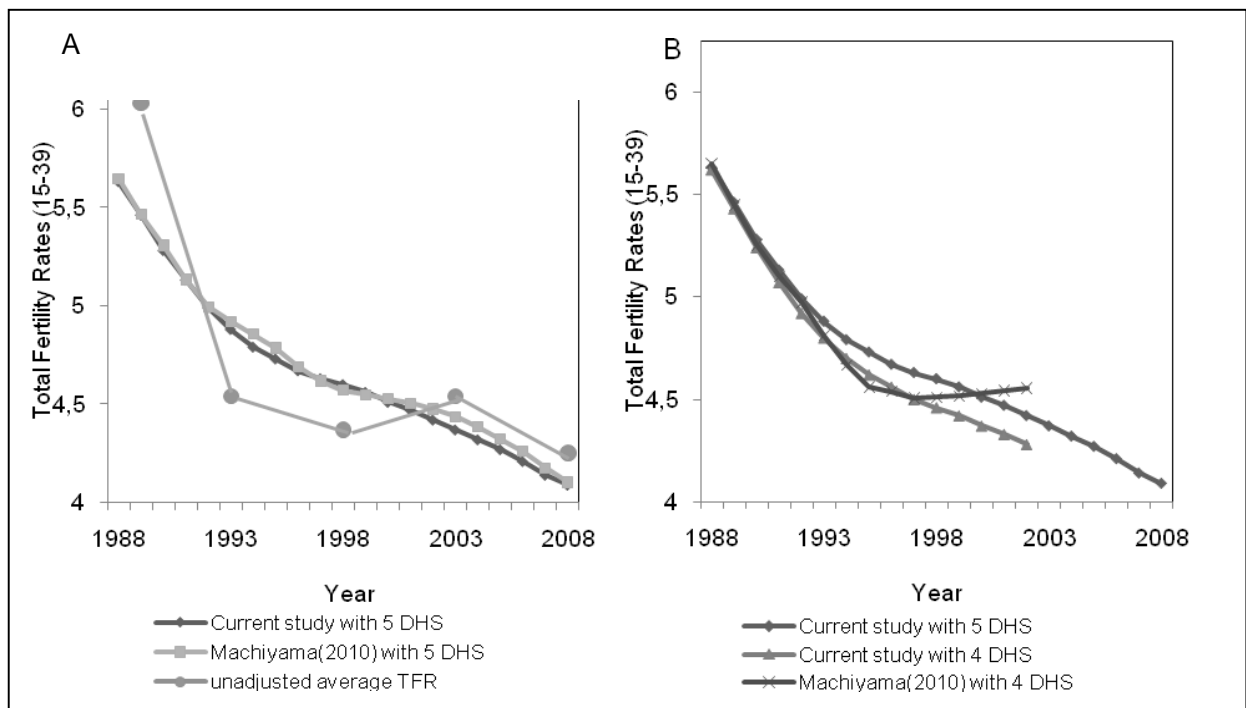
Country	Annual % change			Description of trends
	1980s	1990s	2000s	
Benin	-1.72	-1.38	-0.37	Deceleration
Burkina Faso	-0.94	-1.38	-2.32	Acceleration*
Cameroon	-1.16	-1.25	-1.24	Steady decline
Ghana	-1.90	-1.58	-1.41	Steady decline
Kenya	-2.46	-1.46	-1.16	Deceleration
Madagascar	-1.01	-1.04	-1.37	Acceleration
Malawi	-1.47	-0.84	-0.37	Deceleration
Mali	-0.27	-0.67	-0.76	Early-transition
Namibia	-1.32	-2.02	-1.71	Steady decline
Niger	-0.54	-0.41	-1.24	Early-transition/ recent decline
Nigeria	-1.22	-0.58	-0.69	Deceleration
Rwanda	-1.74	-1.15	-1.13	Steady decline
Senegal	-1.46	-1.41	-1.38	Steady decline
Tanzania	-0.84	-0.72	-0.29	Early-transition
Uganda	-0.77	-0.22	-0.79	Early-transition
Zambia	-1.27	-0.64	-0.43	Deceleration
Zimbabwe	-2.78	-1.80	-1.30	Deceleration

\* only two annual estimates were included to estimate annual % change for 2000s

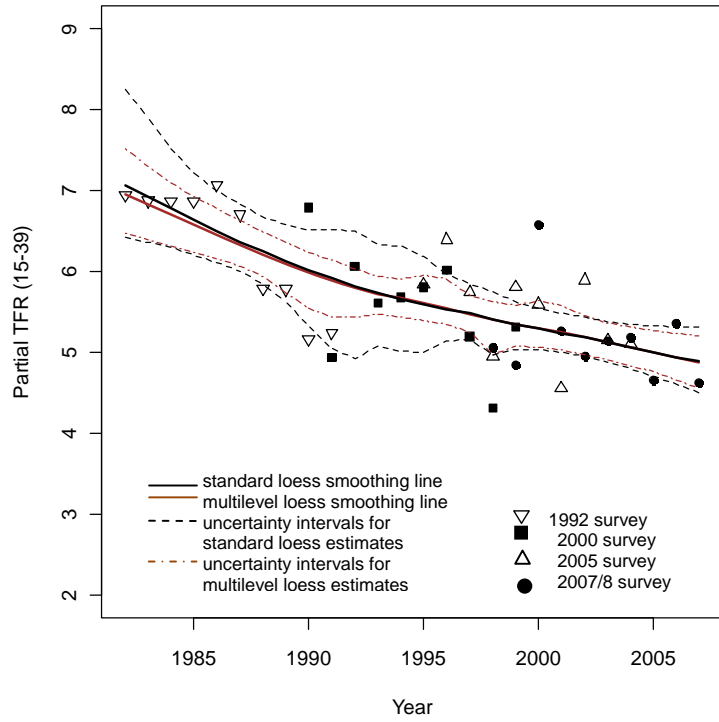
In contrast, in Cameroon and Senegal fertility continued to drop at almost the same pace over the past 20 years. The slopes of the trends were steadily linear downward throughout the period. In Mali, Tanzania, and Uganda, annual declines have been consistently below one per cent. In Niger, the evidence suggests an onset of decline in the 2000s.

Figure 3 shows trends of TFR (15-39) between 1998 and 2008 in Kenya using 5 different approaches: Figure 3.A presents trends from 3 approaches using the data derived from 5 surveys: (a) current approach using 5 DHS surveys; (b) previous approach with the 5 DHS surveys; (c) approach using unadjusted average TFR (15-39) for 3 years prior to each survey. The trend derived from unadjusted TFRs which has often been used in previous studies depicts a reversal of fertility decline between 1998 and 2003, followed by a small decline between 2003 and 2008. On the other hand, the current study and previous studies display similar deceleration of the pace

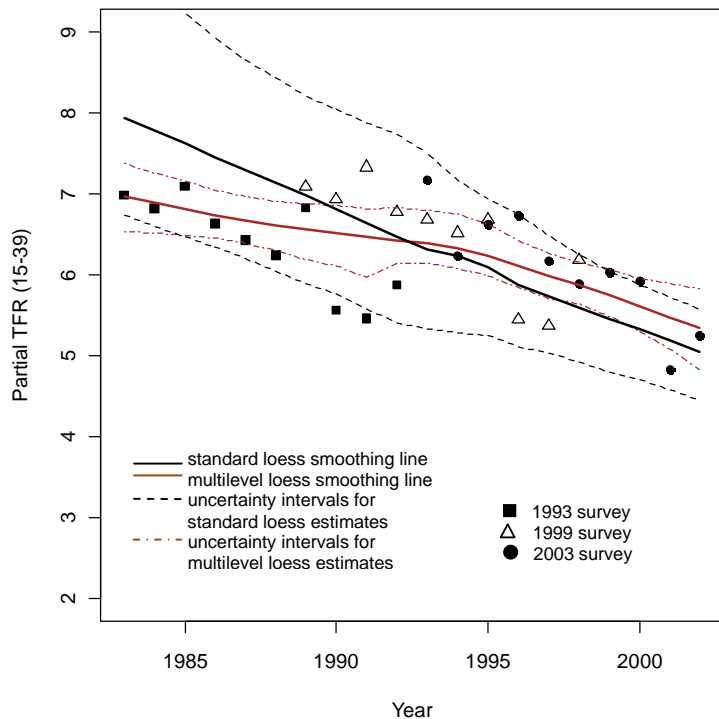
since around 1995, though the fertility decline did not level off. Figure 3.B. shows trends from (d) current approach using the data from the first 4 DHS surveys (1989, 1993, 1998 and 2003); (e) previous approach with the 4 DHS surveys, and the current approach with 5 DHS surveys. The previous approach with 4 surveys (e) shows a complete plateau of fertility decline around 2000. This is probably because the trend lines were pulled down by the deviated estimates around 1995. This underestimation might be attributable to omission, age shifting of children, or combination of both in the period possibly due to the fact that the 1998 Kenya DHS survey had two boundary years: 1993 for anthropometry and 1995 for child health questions. In contrast, the current approach both show moderate deceleration with similar slope, though the trends estimates from the approach with 4 surveys declined more quickly. Again these findings suggest the current approach is more robust for estimating short- and long-term trends than previous methods which give a different trajectory when adding a new data.



**Figure 3:** Partial total fertility rates (15-39), 1988-2008, Kenya



**Figure 4:** Comparison of standard loess and multilevel loess approaches for estimating TFR (15-39) trends, Rwanda



**Figure 5:** Comparison of standard loess and multilevel loess approaches for estimating TFR (15-39) trends, Burkina Faso

The multilevel analysis was performed to assess how clustering of partial TFR (15-39) estimates derived from the same survey affects the overall loess trend. Figure 4 displays the trends from the standard and the multilevel analysis in Rwanda. The point estimates were almost identical. The uncertainty intervals were much wider in the loess multilevel analysis through the 1980s and most of the 1990s, but since around 1998 the differences have been smaller, indicating that the data from the 2005 and 2007/8 surveys were more consistent. Given that there are only four independent sources of data, rather than the 40 incorrectly assumed in the standard approach, these wider uncertainty areas might actually be more appropriate.

Figure 5 shows the fitted standard and multilevel loess trends for Burkina Faso. There are discrepancies in point estimates, particularly during the earlier period, due to clear differences between the within- and between-survey trends. All three surveys have similar within-survey slopes which are reflected in the multilevel trend, but there are between-survey differences in level. As the second and third surveys are more similar, with the first survey being somewhat anomalous, the multilevel trend is fitted closer to the level of estimates from these surveys. The differences between the fitted trends under two approaches highlight issues with the data which should be considered.

Table 2 presents observed loess partial TFRs in either 1980 or 1985, and observed and standardised loess partial TFRs in the latest year. The results show that a considerable proportion of fertility decline in the last 15-30 years was attributable to compositional changes. In Cameroon, Malawi, Nigeria and Tanzania, over 30 percent of decline was due to compositional changes whereas Burkina Faso has the lowest. In fact there are very limited changes in the composition of women in the country. The proportion of women living in rural areas remains at 80 per cent, and 80 per cent of women has never been to school. This is an interesting case, because fertility changes seem to have been occurring with limited social changes.

**Table 2: Partial TFR trends between 1980s and 2000s: Observed and standardised by educational/residential composition of women**

Country	1980/1985		2000s			
	Year	Observed loess partial TFR	Year	Observed loess partial TFR	Standardised loess partial TFR	% decline attributable to composition
Benin	1990	6.23	2006	5.27	5.47	20.8%
Burkina Faso	1985	6.81	2002	5.35	5.35	0.0%
Cameroon	1985	5.90	2003	4.64	5.05	32.5%
Ghana	1980	5.94	2007	3.65	4.09	19.2%
Kenya	1980	7.00	2008	4.09	4.7	21.0%
Madagascar	1985	5.86	2008	4.47	4.49	1.4%
Malawi	1980	6.33	2005	5.29	5.83	51.9%
Namibia	1985	4.92	2006	3.15	3.51	20.3%
Nigeria	1980	6.50	2007	5.12	5.88	55.1%
Rwanda	1985	6.58	2008	4.88	5.07	11.2%
Senegal	1980	6.66	2004	4.62	5.21	28.9%
Tanzania	1985	5.76	2004	5.06	5.37	44.3%
Zambia	1985	6.20	2006	5.31	5.32	1.1%
Zimbabwe	1980	6.23	2005	3.45	3.71	9.4%

## Discussion

Our analysis confirms that fertility declines have slowed down in recent years in some parts of sub-Saharan Africa. However, the extent of deceleration was relatively limited compared to those suggested by the findings from previous studies. There was compelling evidence that Benin, Kenya, Malawi, Zambia and Zimbabwe have clearly decelerated the pace of fertility decline in the past two decades, but we did not find any plateau of decline in the countries studied. This different finding is likely to be attributable to use of the new methods, consideration of the data quality and some new datasets being added. Contrary to the deceleration, constant declines were observed in Cameroon and Senegal, and acceleration was found in Burkina Faso and Madagascar since the 1980s.

Another key finding is that compositional changes have substantially contributed to recent fertility changes. Over 30 per cent of fertility changes in Cameroon, Malawi, Nigeria and Tanzania since 1980 or 1985 were attributable to the educational and residential compositional changes. This sheds light on structural changes at the country level.

There are several limitations in this study. First, we solely relied on the data from DHS surveys. We adjusted major non-sampling errors, age displacement of children, but the adjustment was limited as discussed earlier. For instance, substantial omissions of births in the 1990 Nigeria DHS survey and digit preference in the 2006 Benin DHS survey were not able to be fully adjusted. With regard to loess smoothing, selection of the minimum and maximum values of  $\alpha$  could be somewhat arbitrary, as is the density of  $\alpha$  values between these limits (Silverwood and Cousens 2008). While it will not seriously affect the point estimates, the uncertainty areas could be affected. But we made a distinct improvement on relying entirely upon a single, arbitrarily chosen, value of alpha from the previous study, and the results we obtained appear to provide reasonable uncertainty intervals.

It is theoretically important to take into account the clustering of TFR (15-39) estimates within surveys as the assumption of independence is clearly invalid. Currently the number of surveys available within each country is at the very lower limit of what is feasible for multilevel modelling. However, as the number of surveys increases the reliability of the multilevel approach will improve. Presently it is perhaps best to consider the multilevel approach more as a useful diagnostic tool to identify countries in which the within- and between-survey trends differ substantially, such as in Burkina Faso, indicating that closer scrutiny of the results may be required.

We significantly improved the method of estimating fertility decline by use of a new method which is more robust, not easily affected by anomalous estimates, and incorporated both short- and long-term trends. Secondly, the uncertainty areas help significantly in the interpretation of the estimates. Furthermore, the multilevel analysis helps to assess how trends from each survey affect the overall loess trends.

The UN medium variant assumes that TFR in Africa would reach 2.5 by 2050 (United Nations, 2009). But our findings suggest that the region may find other equilibrium. The countries with partial TFR (15-39) of above 5, such as Benin, Malawi, Mali, Niger, Nigeria, Rwanda, Tanzania, Uganda, and Zambia, are projected to double or triple their populations by

2050 even based on the medium variant. If TFR does reach 3.0 by 2050 as projected in the high variant, sub-Saharan Africa would have 260 million more people. The implication of the enormous population growth is immense on social and economic development as well as vulnerability to climate changes. Therefore, close and robust assessment of fertility trends is crucial.

The United Nations and the international community pledged to increase efforts to address population and reproductive health in less developed countries in the annual meeting of the United Nations Commission on Population and Development held in early April 2009 (Guttmacher Institute 2009). This methodological improvement makes a pivotal contribution to population projection and to a close assessment of family planning programmes.

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