Trends and Socioeconomic Gradients in Adult Mortality around the Developing World

Damien de Walque
Deon Filmer

Premature mortality in developed countries is negatively associated with income and education. The same gradient is expected in developing countries, although, given the lack of vital registration systems, its existence has been more difficult to demonstrate. What has generally been shown is that the poor are more likely to experience poor health and less likely to have access to health services (Filmer 2005; Gwatkin, Wagstaff, and Yazbeck 2005). Additional information is available over a wide range of socioeconomic differences in health, nutrition, and population including indicators on child mortality, malnutrition, fertility, immunization coverage, treatment of diarrhea and acute respiratory infections, antenatal care visits and delivery attendance, use of modern contraception, and knowledge of HIV/AIDS prevention (Gwatkin et al. 2007). However, adult mortality is not included among the indicators reported. Since adult mortality is the most objective measure of adult health (as opposed to self-reported health status or diseases), analyzing the socioeconomic gradient in premature adult mortality adds to our knowledge about the disparities in health in developing countries.

Bicego (1997), Timæus and Jasseh (2004), Gakidou and King (2006), Obermeyer et al. (2010), and Reniers, Masquelier, and Gerland (2011) have analyzed adult mortality using various data sources (including the Demographic and Health Surveys that we use in this study) and have gradually improved the methods for doing so, but they have limited their analysis to overall trends and to differences by sex and age.

Part of our analysis looks at the extent of adult mortality in countries affected by conflicts and as such generalizes earlier analyses of the distribution and consequences of excess adult mortality in Cambodia (de Walque 2005 and 2006) and Rwanda (de Walque and Verwimp 2010). The HIV/AIDS epidemic is another important contributor to adult mortality, especially in sub-Saharan Africa. In contrast to conflicts and famines, its impact is spread over a long period. Bicego (1997) and Timæus and Jasseh (2004) have attempted to determine whether, by looking at mortality by age and time period, the effects of the HIV/AIDS epidemic could be detected in mortality trends. Using more recent data sets, we document large increases in adult mortality in countries heavily affected by HIV/AIDS, especially in southern Africa.

We extend this literature in several ways. First, we assess the correlation of mortality to national income and how it has changed over time. Second, we update the analysis of mortality changes in the era of HIV/AIDS. Third, we go beyond "extreme mortality" events and assess how adult mortality changes as a result of conflicts more generally. And last, by using the socioeconomic characteristics of the female respondent as a proxy for the socioeconomic background of her siblings, we analyze how these trends and variations in adult mortality differ with socioeconomic status, including an analysis of the variation in the gradient over time.

Data

We derive estimates of adult mortality from an analysis of Demographic and Health Survey (DHS) data from 46 countries, 33 of which are in sub-Saharan Africa and 13 of which are in other regions (see Appendix Table 1). Several of the countries have been surveyed more than once, and we base our estimates on the total of 84 surveys that have been carried out (59 in sub-Saharan Africa, 25 elsewhere). The countries covered by DHS in sub-Saharan Africa represent almost 90 percent of the region's population. Outside of sub-Saharan Africa the DHS surveys we use cover a far smaller share of the population, even if this is restricted to countries whose GDP per capita never exceeds US$10,000: overall about 14 percent of the population is covered by these countries, although this increases to 29 percent if China and India are excluded (countries for which we cannot calculate adult mortality using the DHS). It is therefore important to keep in mind that our sample of non-African countries cannot be thought of as "representative" of the rest of the world, or even the rest of the developing world.

DHS data are useful for two main reasons. First, these surveys have been carried out systematically using similar protocols and questionnaires.[1] No other collection of large, nationally representative datasets has such a high degree of cross-country comparability. Second, the surveys include a "sibling mortality" module from which we can derive mortality estimates.[2] Originally intended to be used to estimate maternal mortality, these modules record the survival status of all main female respondents' siblings. Subject to various assumptions and adjustments (described below), the responses can be extrapolated to form an estimate of national-level mortality.

Estimating mortality based on sibling reports

At one level, using sibling reports to estimate adult mortality is straightforward. The nationally representative DHS identifies all women aged 15–49 as respondents.[3] These women list all of their siblings born to the same biological mother and the birth dates of those siblings, and they report on the survival status of those siblings, and on the age and date at death if relevant. For any timeframe, therefore, we can establish which siblings were alive at the beginning of the timeframe and whether they died during that timeframe. The number of deaths during the timeframe, divided by the population at risk at the beginning of the timeframe, determines the timeframe-specific mortality rate. As an example, consider the timeframe 1995–99. We establish the population at risk at the beginning of 1995 (P_{1995}), calculate the number of deaths between 1995 and 1999 ($D_{1995,1999}$), and estimate the mortality rate ($M_{1995,1999}$) as the ratio between the two. The generic form of this relationship is given in equation (1)

$$M_{t,t+4} = \frac{D_{t,t+4}}{P_t} \tag{1}$$

where t is the beginning year of the timeframe of interest. Using these data, we are able to cover the periods 1975–79, 1980–84, 1985–89, 1990–94, 1995–99, and 2000–04. Not all surveys provide information on all the periods, as we require that the full period be captured by the survey for it to be included (that is, a survey conducted in 1997 will not contribute to the estimate of mortality in the periods 1995–99 or 2000–04).

The population at risk needs to be more specifically defined, and we do this by specifying the age range of interest:

$$M_{t,t+4}^{a,a+n} = \frac{D_{t,t+4}^{a,a+n}}{P_t^{a,a+n}} \tag{2}$$

where a is the beginning age of the age group of interest, and $a+n$ is the ending age. For much of the analysis, we consider the population at risk to be aged 15–54 (which we refer to, for expository purposes, as "adult mortality"). When disaggregating the data, we use ten-year age ranges so, concretely, we consider siblings aged 15–24 at risk at the beginning of time t, and then siblings aged 25–34, 35–44, and 45–54 in turn.

Estimates based on equation (2) are subject to a number of problems, such as double-counting, selection bias, and recall errors. These are discussed in the Appendix.

The mortality estimates we generate based on this approach are derived from the sibling history reports of 850,000 female respondents aged 15–49 (473,000 of which are from sub-Saharan Africa). These respondents generate almost 5 million adult mortality reports, that is, reports of sibling survival status for siblings who survived until age 15 (2.8 million are for sub-Saharan

Africa). Of these, 2.9 million are reports on women (including respondents) and 2.1 are reports on men (corresponding figures for sub-Saharan Africa are 1.6 million and 1.2 million).[4]

Determining socioeconomic characteristics

The DHS include a large number of variables that could be used to characterize respondents' socioeconomic status. For the task at hand, we face two challenges. First, the data describe the socioeconomic characteristics of the respondents, and not necessarily those of their siblings whose mortality we are analyzing. Second, the data pertain to the time of the survey, and not necessarily to the timeframe for which we are estimating mortality.

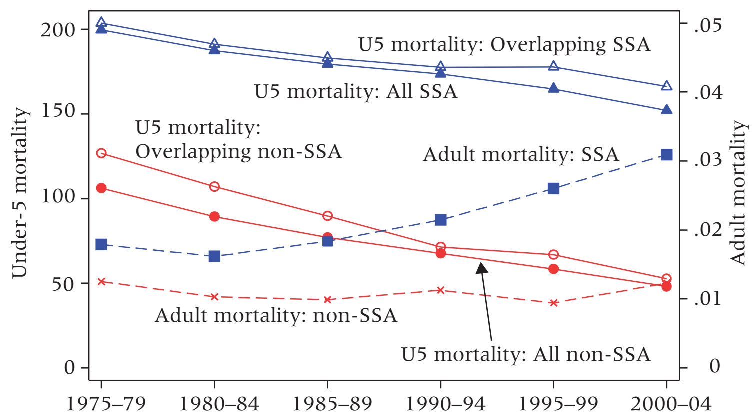
We address the first of these potential problems by using information about the respondents as a proxy for the socioeconomic status of their siblings. We address the second by focusing on relatively stable indicators of socioeconomic status. We limit our analysis to two variables: urban/rural residence and educational attainment. It is impossible using the DHS to determine the extent to which these variables are correlated across siblings. Two facts give us confidence that the approach is legitimate. First, some DHS datasets include a variable that indicates whether a respondent lived in a rural or urban area as a child. It is very likely that siblings would share the same residential location in childhood. Our results are very similar using either current residence or childhood residence. Second, Conley and Glauber (2005) indicate that in the United States the correlation in the educational outcomes of siblings is 0.576. Dahan and Gaviria (2001) report that this correlation is substantially higher in a sample of 16 countries in Latin America, suggesting that using the educational status of a sibling as a proxy might be even more appropriate for developing countries. We also investigated the extent to which variation in educational attainment occurs primarily within or between households. Among 15–19-year-olds, the intra-household correlation of the years of schooling attained ranges from 0.70 to 0.95 across these surveys, with a mean of 0.86. This suggests a very high degree of correlation among siblings in school attainment.

Aggregate trends in adult mortality

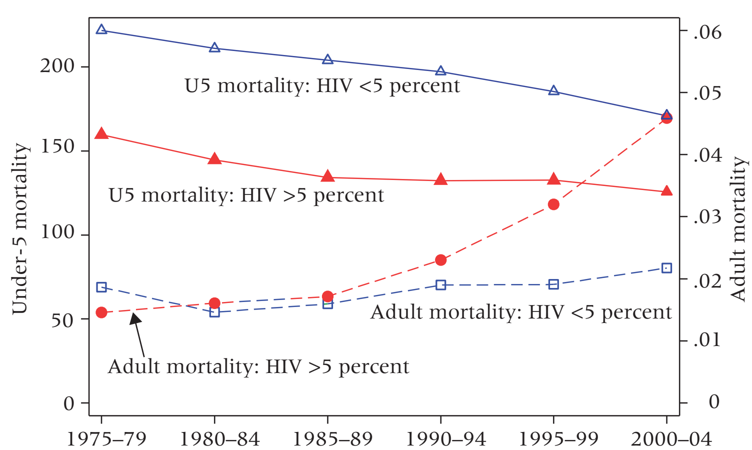
Figure 1 summarizes the aggregate trends in under-5 mortality (solid lines) and adult mortality (dashed lines) for countries in sub-Saharan Africa and countries from other regions.[5] Under-5 mortality (obtained from the World Bank's World Development Indicators database) is shown for two sets of countries.[6] First, we show the full sample of countries for which under-5 mortality data are available and for which GDP per capita never exceeds $10,000 (in real 2000 dollars) during the periods under consideration; and second, we restrict the set of countries to those for which we also have adult mortality data (referred to as "overlapping" countries). Comparing under-5 mortality

FIGURE 1 Trends in under-5 and adult mortality (both sexes), selected DHS countries, by region and HIV prevalence, 1975–79 to 2000–04

(A) All regions



(B) Sub-Saharan African countries



NOTE: "All" refers to full sample; "overlapping" refers to countries/years that are also in the adult mortality database. Under-5 (U5) mortality is the probability of dying under age 5 per 1,000 births. Adult mortality is the probability of dying during the five-year period for adults aged 15–54. SSA = sub-Saharan Africa.
SOURCE: HIV prevalence for adults of both sexes in 2001, from UNAIDS (2010).

between the full and overlapping samples suggests that our DHS sample is fairly representative of the regions as a whole: indeed, the levels and trends in these mortality estimates are very similar. This is consistent with the fact that the countries surveyed in sub-Saharan Africa cover a high share of the population in that region. It also suggests that while our group of countries outside of sub-Saharan Africa are not representative of developing countries as a whole, they do have similar levels and trends of under-5 mortality.

Figure 1 confirms that under-5 mortality rates have been steadily declining in the developing world, both within and outside of sub-Saharan Africa. In the former, the overall rate declined from about 200 deaths per thousand births in 1975–79 to 152 deaths per thousand births in 2000–04 (from 203 to 165 focusing on only the overlapping countries). In the non-African countries, the rate fell from 106 deaths per thousand births in 1975–79 to 48 in 2000–04 (in overlapping countries the decline was from 127 to 53).

Part of the decline can be attributed to increases in national incomes. Table 1 reports results of a regression of the log of under-5 mortality in each country and for each period on the log of GDP per capita for that country in that period, and dummy variables for period. The estimated association is log-log so the interpretation of the coefficient in this case is that of elasticity. The coefficients on GDP per capita suggest a statistically significant and large effect: a 10 percent increase in GDP per capita is associated with a 3 to 5 percent decrease in under-5 mortality (for example, the coefficient of –0.395 for the full sample of sub-Saharan African countries in the first column of Table 1 indicates that a 10 percent increase in GDP per capita is associated with a –3.95 percent decrease in under-5 mortality).

Income alone, however, does not explain the decline in under-5 mortality. Figures 2A and 2B illustrate the change over time in the relationship

TABLE 1 Child and adult mortality (ln) as a function of per capita income (ln) and period: regression coefficients and standard errors

	Sub–Saharan African countries			Countries in other regions		
	Child mortality			Child mortality		
	Full sample	Overlapping sample	Adult mortality	Full sample	Overlapping sample	Adult mortality
GDP per capita	–0.395	–0.288	–0.053	–0.449	–0.317	–0.263
	(0.021)**	(0.021)**	(0.036)	(0.022)**	(0.049)**	(0.065)**
1980–84	–0.192	–0.087	–0.067	–0.410	–0.114	0.027
	(0.068)**	(0.063)	(0.108)	(0.076)**	(0.128)	(0.170)
1985–89	–0.289	–0.189	0.051	–0.627	–0.319	–0.047
	(0.064)**	(0.062)**	(0.107)	(0.071)**	(0.127)*	(0.170)
1990–94	–0.334	–0.237	0.251	–0.800	–0.512	0.006
	(0.064)**	(0.062)**	(0.107)*	(0.066)**	(0.125)**	(0.166)
1995–99	–0.407	–0.278	0.502	–1.014	–0.614	–0.099
	(0.063)**	(0.063)**	(0.109)**	(0.064)**	(0.135)**	(0.180)
2000–04	–0.448	–0.325	0.742	–1.162	–0.778	0.058
	(0.063)**	(0.070)**	(0.120)**	(0.064)**	(0.146)**	(0.194)
Observations	329	166	166	589	61	61
R-squared	0.58	0.56	0.34	0.63	0.58	0.25

NOTE: Standard errors in parentheses. * significant at 5%; ** significant at 1%. For distinction between full sample and overlapping sample, see text.

between national income and mortality. Panel (A) of Figure 2A shows, for sub-Saharan African countries, (log) mortality on the vertical axis plotted against (log) GDP per capita on the horizontal axis. Round dots show the points for 1975–79 while the points for 2000–04 are indicated by an x. The solid line shows the fitted line for the early period and the dashed line shows the fitted line for the late period. The lines are sloped downward, indicating that mortality declines with income. From the early to the late period, the whole line has shifted down: at any given level of income, mortality has fallen. Panel (B) shows the fitted lines for all periods, starting with 1975–79 and ending with 2000–04. Clearly the shift has been incremental and progressive. Panels (C) and (D) show the same relationships for countries in other regions, which display greater mortality declines from each period to the next when compared to sub-Saharan Africa.

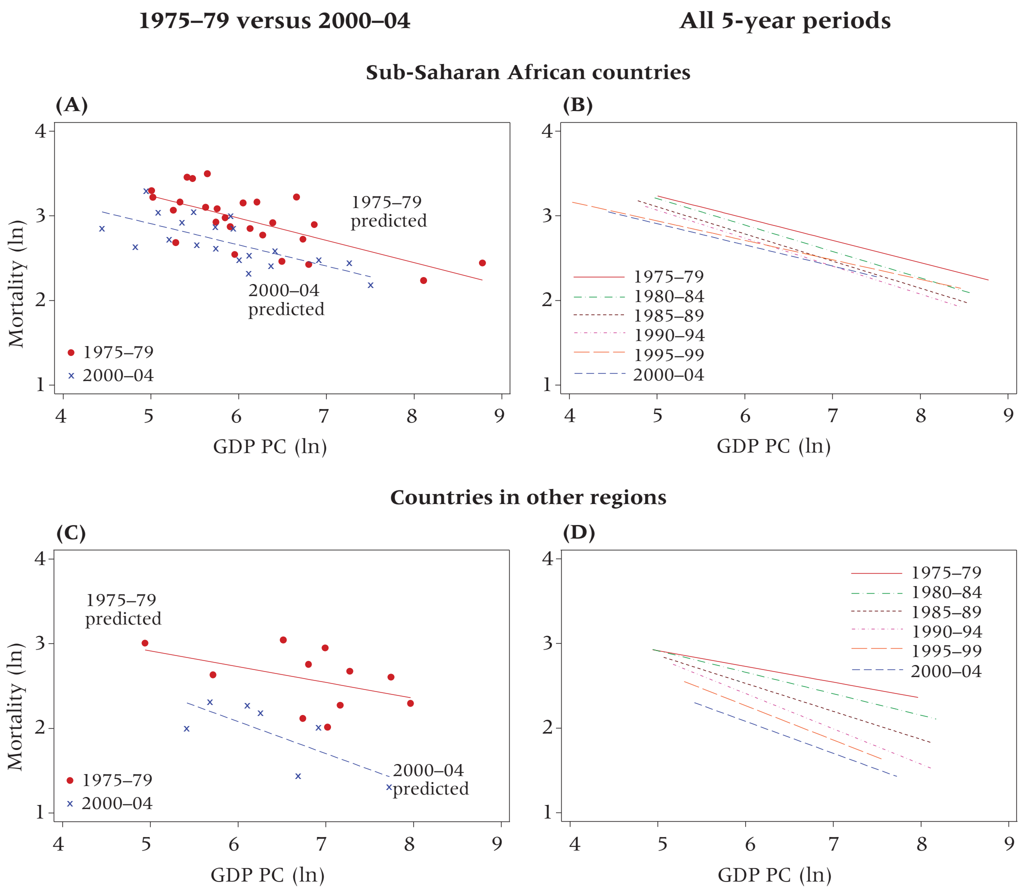
Table 1 indicates these changes statistically by showing significant and steadily increasing (in absolute value) coefficients on the dummy variables for period. The model specification here is semi-log: the dependent variable is in log form and the coefficient of interest is a dummy variable. The coefficients can be simply transformed so that they can be interpreted as the percentage change in the dependent variable of interest (mortality) associated with the dummy variable changing from 0 to 1. If the coefficient on the dummy variable is α, then the implied percentage change in adult mortality is $\exp(\alpha) - 1$ (Halvorsen and Palmquist 1980). When α is small, the two values are very close and α is itself an approximation of $\exp(\alpha) - 1$.

In sub-Saharan African countries the coefficient reaches –0.448 in the full sample and –0.325 in the overlapping sample for the period 2000–04 (the reference period is 1975–79). These correspond to declines of 36 and 28 percent respectively ($\exp(-0.448) - 1 = -0.36$). For the non-African countries, the coefficients reach –1.162 and –0.778, which correspond to declines of 69 and 54 percent. These results are another way of restating the finding by Preston (1975, 1980) that, conditional on incomes, under-5 mortality rates have declined over time as a consequence of improvements in public health and health technologies.

Adult mortality (defined here as mortality among persons aged 15–54) does not follow the same pattern. As shown in Figure 1, adult mortality outside of sub-Saharan Africa has remained fairly constant over the entire period from 1975 to 2004, with a slight increase in the most recent period. The regression results reported in Table 1 suggest that for each person "at risk" (that is, a 15–54-year-old who is alive at the beginning of each of the five-year periods) the probability of death is between 1 and 1.6 percent. In stark contrast, while adult mortality remained steady at around 2 percent prior to the mid-1980s in the sub-Saharan countries, it has increased steadily ever since: to 3 percent in 1990–94 and to over 4 percent by 2000–04.

Outside of sub-Saharan Africa, adult mortality is responsive to national income. Indeed the coefficient on GDP per capita in the results reported in Table

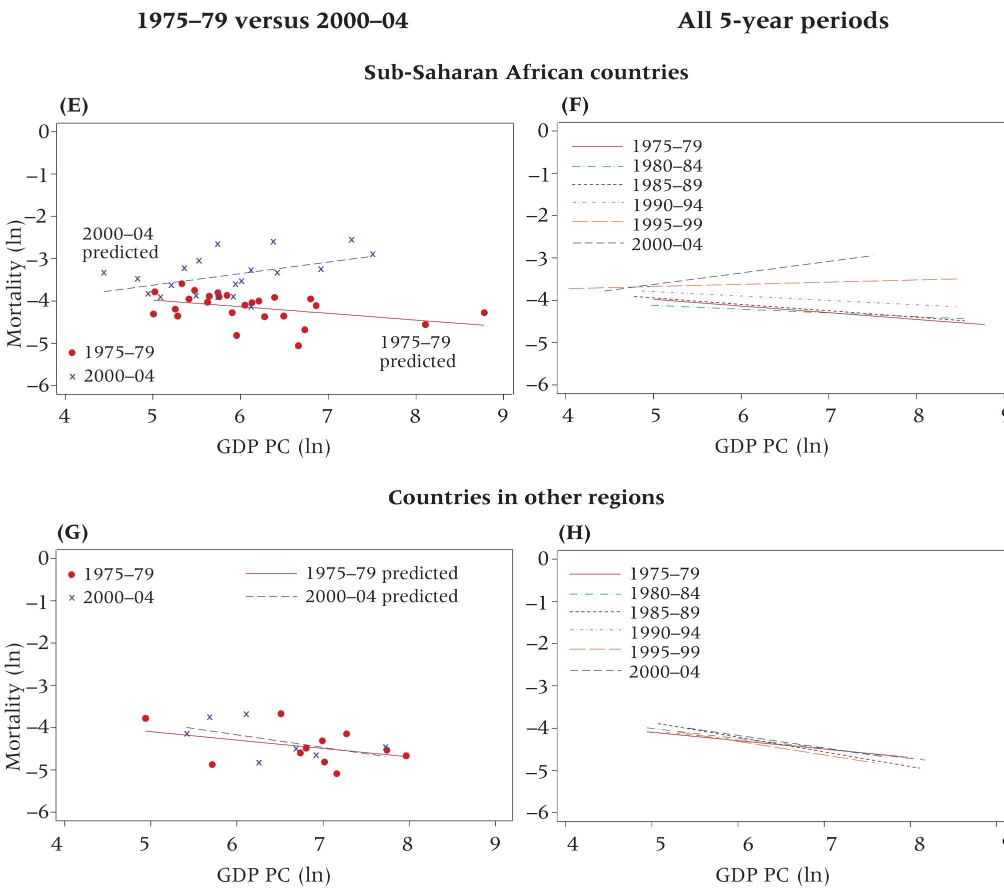
FIGURE 2A Relationship between child mortality (both sexes) and GDP per capita over time, sub-Saharan African countries and countries in other regions



1, while smaller than that for under-5 mortality, is statistically significant in the adult mortality models. The models suggest that a 10 percent increase in GDP per capita is associated with a 2.6 percent decline in adult mortality outside of sub-Saharan Africa. In sub-Saharan Africa the association between GDP per capita and adult mortality is not statistically significantly different from zero.

Figure 2B clearly illustrates how the trends differ. In countries outside of sub-Saharan Africa, adult mortality and national income are related, and the relationship has barely shifted between 1975–79 and 2000–04. By contrast, adult mortality has shifted upward in sub-Saharan Africa. The coefficients on period reported in Table 1 for sub-Saharan Africa become progressively larger. By 1990–94 adult mortality (conditional on GDP per capita) is statistically significantly higher than in 1975–79, with a coefficient of 0.251 (a 28 percent increase). After steady increases, the coefficient reaches 0.742 in 2000–04 (a

FIGURE 2B Relationship between adult mortality (both sexes) and GDP per capita over time, sub-Saharan African countries and countries in other regions



110 percent increase). Figure 2B reveals a more startling trend: the relationship between national income and adult mortality has become upward sloping: that is, adult mortality tends to be highest in the higher-income countries of sub-Saharan Africa. The shift coincides with the start and spread of the HIV epidemic. This reversal of the gradient might be driven by the fact that the countries in southern Africa with the highest HIV prevalence are also among the richest in sub-Saharan Africa.

The HIV/AIDS pandemic is certainly a major factor explaining these changes. The bottom panel of Figure 1 separates the sub-Saharan African countries into those in which the prevalence of HIV among adults of both sexes was above 5 percent in 2001 and those where it was below 5 percent (according to UNAIDS 2010). The effects of high levels of HIV on adult mortality are readily apparent, with the average adult mortality rate almost tripling

FIGURE 3 Trends in adult mortality (both sexes), selected countries, 1975–79 to 2000–04

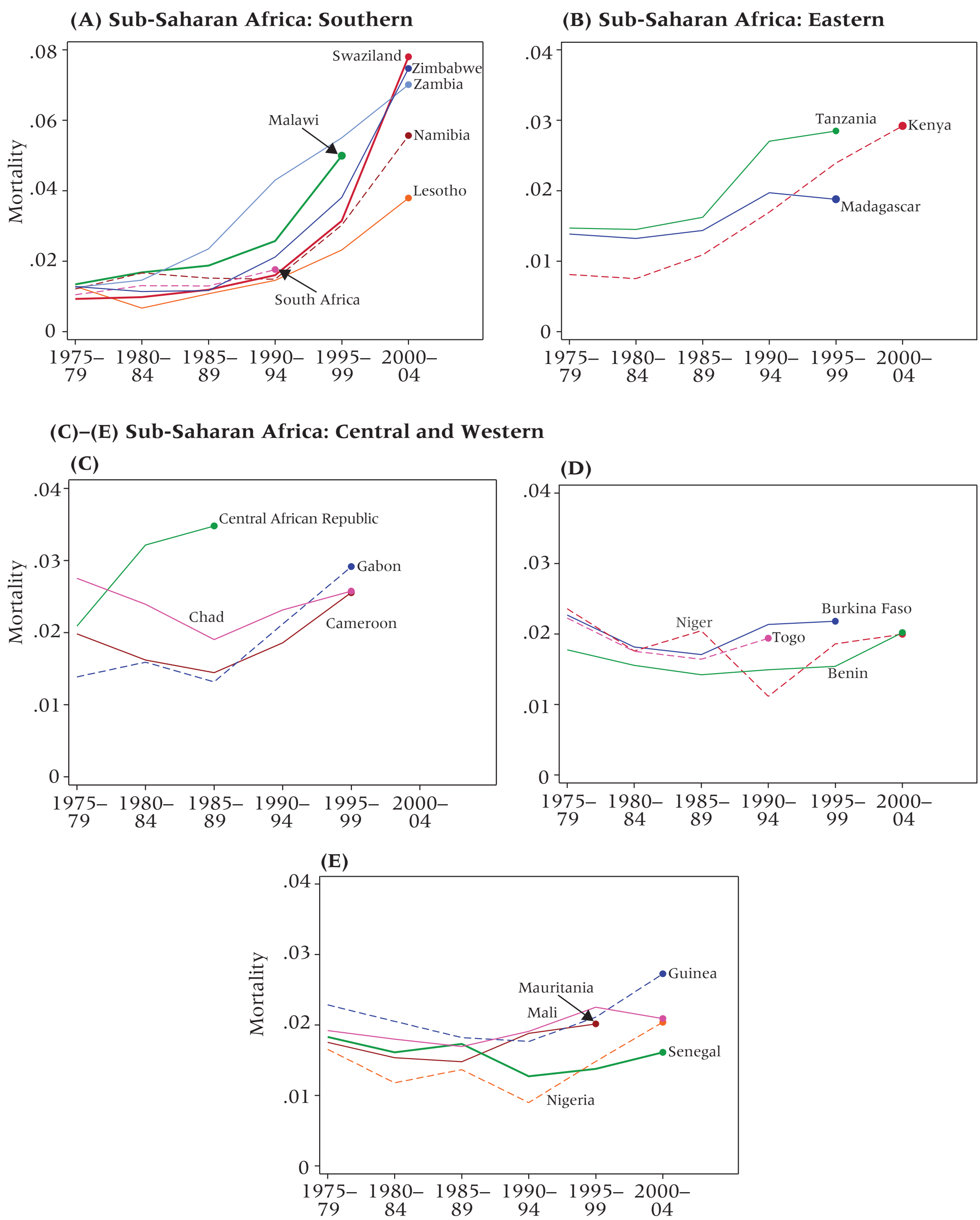
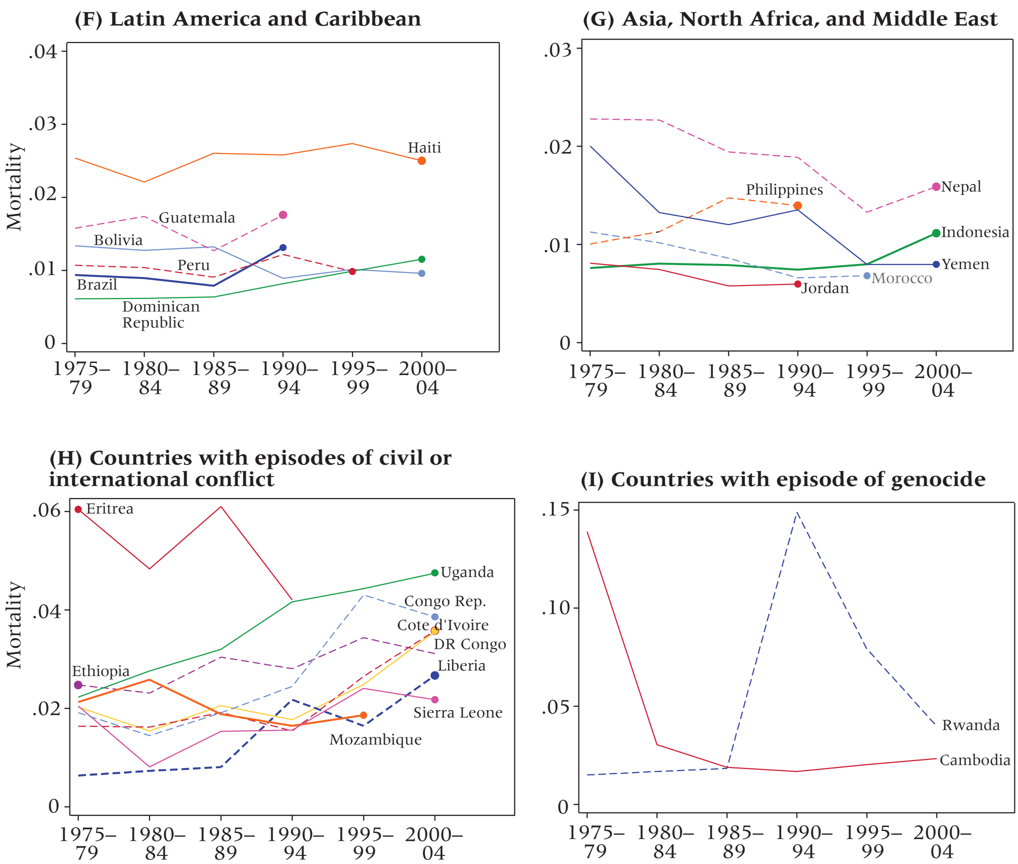


FIGURE 3 (continued)



NOTE: Adult mortality is the probability of dying during the five-year period for adults aged 15–54.

between 1985–89 and 2000–04 (from a probability of around 1.7 percent to almost 5 percent) in the high-prevalence sub-Saharan countries. Importantly, however, mortality also increased in the low-prevalence sub-Saharan countries, from around 1.6 percent in 1985–89 to over 2 percent in 2000–04 (a point we return to below).

Country-specific trends in adult mortality

The aggregated results presented so far mask substantial heterogeneity across countries and may be driven by a few large countries (note that while the figures presented here aggregate using population weights, the regression analyses are not weighted). Figure 3 shows the trends in adult mortality for each country in our study.[7] Countries are grouped by region, although we highlight two groups of countries (regardless of region): those in which there has been an episode of civil or international conflict, and those in which that episode resulted in a period of genocide. (Note that the vertical scales in Figure 3 differ from graph to graph: while this downplays differences across groups of countries—for example, the countries where mortality is rising versus those where it has remained relatively stable—it allows the maximum amount of information to be shown in each graph.)

Panel (A) of Figure 3 shows countries in southern sub-Saharan Africa. The increases in adult mortality are very steep. In 1980–84, the five-year probability of death was less than 2 percent in all of these countries. By 1995–99, for the six countries with data, the probabilities range from 2.3 percent (Lesotho) to 5.5 percent (Zambia). For the five countries with data for 2000–04, the five-year probability of death ranges from 3.8 (Lesotho) to 7.8 percent (Swaziland). These increases, unparalleled in other countries in our sample, are consistent with the high HIV prevalence in these sub-Saharan countries.[8]

Panels (B) through (E) show the trends for other sub-Saharan African countries. All indicate an increase in mortality that starts in the late 1980s or early 1990s. While the increase is not surprising in those countries with high HIV prevalence (e.g., Kenya and Tanzania, where HIV prevalence in 2001 was 8.4 and 7.1 percent respectively), it is more puzzling for countries with low prevalence. In 2001 HIV prevalence was less than 2 percent in Benin, Guinea, Mali, Mauritania, and Niger while adult mortality rates increased in all of these countries after 1985–89. For example the probability of death in Benin increased from 1.4 percent to 2.0 percent between 1985–89 and 2000–04. Over the same timeframe, mortality increased from 1.8 to 2.7 percent in Guinea and from 1.7 to 2.1 percent in Mali. In none of these countries, however, does the five-year probability of death exceed 3 percent.

Consistent with the aggregate results, mortality rates outside of sub-Saharan Africa have remained relatively low and constant over the study period (panels F and G), and in several cases they have fallen (Bolivia, Jordan, Morocco, Nepal, Yemen). Haiti stands out as an exception with high mortality among these countries—although the rate remains consistently high from 1975–79 to 2000–04 at just under 3 percent probability of death. In the other sample countries, mortality never exceeds 2 percent (except for Nepal prior to 1985–89).

We distinguish two groups of countries. Panel (H) shows trends for countries in sub-Saharan Africa that have experienced civil or international conflict.[9] Panel (I) shows the trends for two countries in which there was an episode of genocide. In the latter, the mortality effects of genocide are readily apparent. In Cambodia the five-year probability of death was 14 percent in 1975–79, and in Rwanda it reached 15 percent in 1990–94 (and was estimated at 8 percent in 1995–99).[10] The effects of conflict are apparent in the other countries—mortality rates are noticeably higher than in the non-southern countries in sub-Saharan Africa—but spikes in mortality are harder to discern than in the countries that experienced genocide. Uganda illustrates the point, with mortality continuing to increase after the end of the conflict in 1986—a result likely related to the increase in HIV prevalence (which was 7 percent in 2001). In general, whereas the five-year probability of death is typically less than 3 percent in other sub-Saharan African countries (outside of the southern region), it reaches around 4 percent in several of the conflict-affected countries.

One startling comparison revealed by these estimates is that in the countries in which HIV infection is widespread, namely in the southern African countries in our sample (Panel A), mortality rates are higher than those in countries that experienced conflict (Panel H). The exceptions are countries where conflict escalated into genocide, although these appear as sharp peaks in mortality that subsequently return to non-conflict levels (Panel I). By contrast, elevated levels of mortality in countries with high HIV prevalence are sustained and, to date, increasing.

Demographic and socioeconomic gaps in adult mortality

Age

We begin disaggregating the association between GDP per capita, period, and adult mortality by the age of adults at risk. These results by ten-year age group, reported in Table 2, are generally consistent with those for the entire group of 15–54-year-olds in Table 1. In countries outside of sub-Saharan Africa, the association between mortality and GDP per capita is statistically significantly negative for all age groups, with the estimate of the elasticity ranging from –.214 to –.274. In these countries, moreover, there are no systematic shifts in mortality for any of the age groups: coefficients on the period dummy variables in the regressions are typically negative (meaning mortality is lower in the later periods than the earlier ones), although these associations are virtually never significantly different from zero.

In sub-Saharan Africa, by contrast, the negative association between GDP per capita and mortality is not statistically significantly different from zero at ages 25–34 (although the point estimate remains negative). At ages above 35, when HIV/AIDS mortality tends to be highest, the negative association disappears (that is, it is close to zero and statistically insignificant).

The patterns in the coefficients on the period dummy variables show that the largest jumps in mortality occurred among persons aged 25–34 and 35–44 starting in the period 1990–94. The magnitude of the jumps resulted in mortality being 23 and 56 percent higher, respectively, in 1990–94 than corresponding mortality rates in 1975–79 (the reference category). In the

TABLE 2 Mortality as a function of per capita income (ln) and period, by age group: regression coefficients and standard errors

	Sub–Saharan African countries				Countries in other regions			
	15–24	**25–34**	**35–44**	**45–54**	**15–24**	**25–34**	**35–44**	**45–54**
GDP per capita	–0.132	–0.045	0.054	0.026	–0.258	–0.274	–0.243	–0.214
	(0.037)**	(0.042)	(0.051)	(0.064)	(0.081)**	(0.083)**	(0.073)**	(0.106)*
1980–84	–0.100	–0.000	0.120	0.130	–0.180	–0.135	–0.194	0.639
	(0.102)	(0.117)	(0.146)	(0.232)	(0.195)	(0.199)	(0.175)	(0.252)*
1985–89	–0.014	0.048	0.173	0.112	–0.335	–0.335	–0.270	0.179
	(0.103)	(0.118)	(0.146)	(0.230)	(0.195)	(0.199)	(0.175)	(0.252)
1990–94	0.107	0.207	0.444	0.266	–0.335	–0.330	–0.171	0.282
	(0.104)	(0.120)	(0.148)**	(0.231)	(0.195)	(0.199)	(0.176)	(0.254)
1995–99	0.221	0.507	0.628	0.651	–0.463	–0.399	–0.255	0.345
	(0.108)*	(0.124)**	(0.153)**	(0.235)**	(0.219)*	(0.223)	(0.197)	(0.285)
2000–04	0.360	0.725	0.852	0.849	–0.479	–0.234	–0.119	0.604
	(0.120)**	(0.137)**	(0.169)**	(0.249)**	(0.237)*	(0.242)	(0.213)	(0.308)
Observations	180	179	175	147	68	68	68	66
R-squared	0.23	0.25	0.19	0.18	0.35	0.34	0.37	0.38

NOTE: Standard errors in parentheses. * significant at 5%; ** significant at 1%.

subsequent period, 1995–99, the younger age group (15–24) also experienced a sharp increase in mortality (leaving it 25 percent higher than in 1975–79). Nevertheless, mortality increases over the entire period through 2000–04 remain highest for the older (25–34, 35–44, and 45–54) age groups, closely corresponding to the HIV/AIDS mortality profile given the median of nine years between HIV infection and death in the absence of treatment.[11]

Sex, residence, and education

We next turn to differences disaggregated by the three socio-demographic dimensions that we extracted from the data: sex, urban or rural residence, and education. We further disaggregate the cells for which we calculate the mortality estimates given by equation (2), but now specified by sex. The age intervals are the ten-year age groups 15–24, 25–34,..., 45–54; and the time periods, as before, are 1975–79, 1980–84,...2000–04. We then estimate the regression model that relates these mortality values to a dummy variable for sex, as well as a full set of dummy variables for age group and for time period. We also include a variable for GDP per capita in the country and time period. In some specifications, we also include a set of country fixed-effects. The number of observations in each regression equation is therefore the number of cells for which we can calculate mortality values. We carry out a similar disaggregation for the other socioeconomic subgroups.

Ideally one would like to analyze the three dimensions simultaneously, but our experience suggested that interacting residence and education led to very small cell sizes, which resulted in unstable estimates. This is perhaps unsurprising since urban residence is correlated with more education. We therefore proceed in two steps, first examining sex and residence and subsequently focusing on sex and education. When analyzing sex and residence simultaneously, for example, we calculate country-, age-group-, and time-period-specific mortality rates for each of the four cells—urban male, urban female, rural male, and rural female—and then regress these mortality rates on dummy variables capturing these groups as well as the age group, time period, and variable for GDP per capita. The full results of this analysis are presented in de Walque and Filmer (2011) and are available on request. Here we briefly summarize them. We should note that residential status and education potentially capture a range of other attributes (including each other), and the results should be interpreted as descriptive and not causal.[12]

Sex and residence. In sub-Saharan Africa, being male is associated with almost 20 percent higher adult mortality, while urban residence is negatively associated with mortality. When we use current residence, the association is statistically significant; when we use residence as a child, the association is not. In both cases the magnitude of the coefficient is small (implying between about 3 and 7 percent lower mortality in urban areas). Outside of sub-Saharan Africa the coefficients have the same signs—and in the case of sex a similar magnitude. However, urban residence in these countries is associated with substantially lower mortality (on the order of 17 percent lower).

Both within and outside of sub-Saharan Africa, urban and rural women have substantially and statistically significantly lower mortality than men, with urban women having the lowest mortality rate. The gap is especially large for urban women outside of sub-Saharan Africa. For example, in sub-Saharan Africa rural and urban women have mortality rates that are 13 and 21 percent lower than those of rural males; in countries outside of sub-Saharan Africa they are 11 and 32 percent lower than those for rural males. When we use residence as a child to identify location, the differential between rural and urban women is reduced in sub-Saharan Africa. The general pattern of results, however, is not affected. Because residence as a child is available only for a subset of countries, we restrict the remainder of the discussion to current residence.[13]

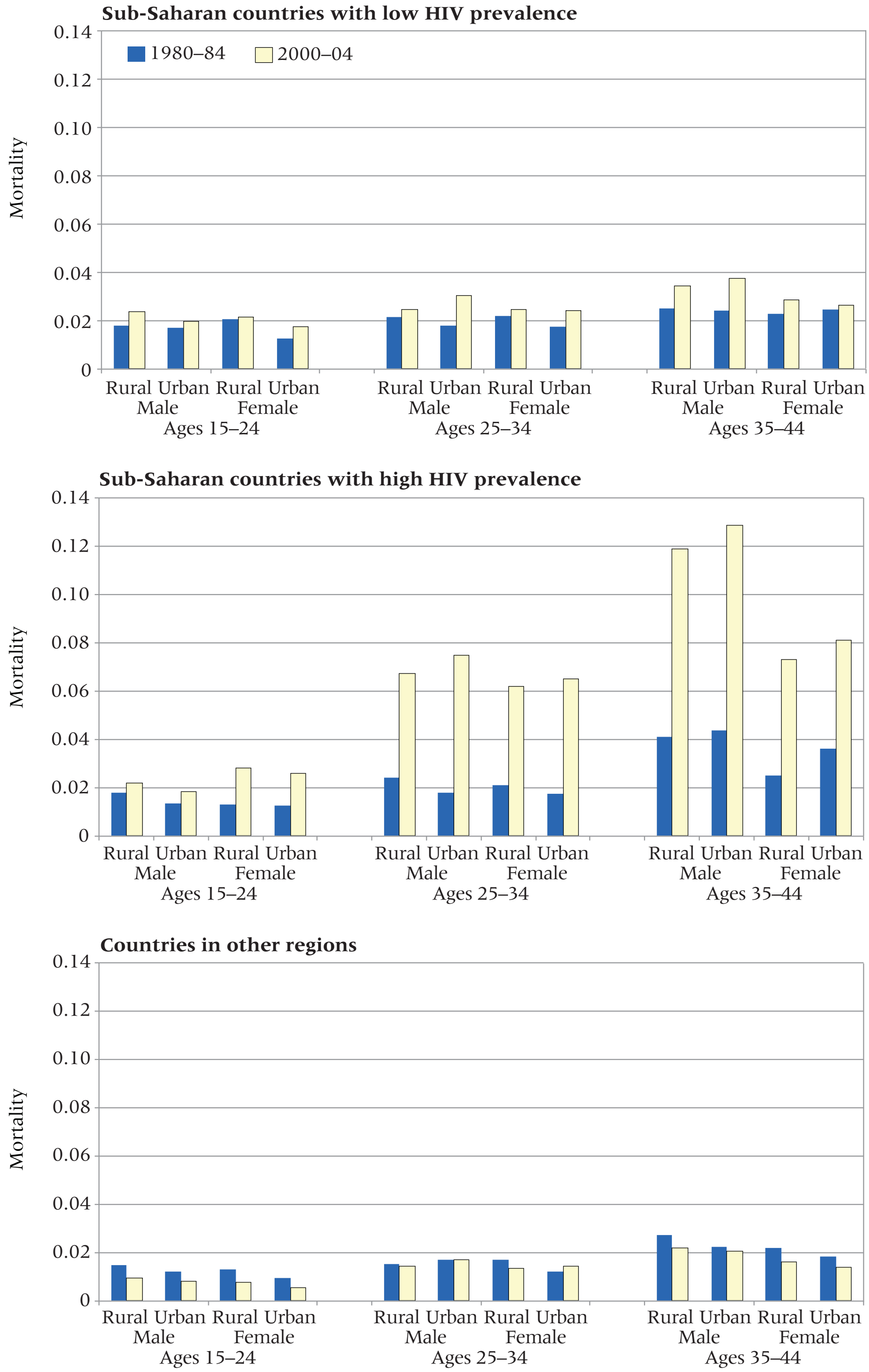
The relationship between mortality, sex, and location is not substantially affected by the inclusion of country fixed-effects. This suggests, in particular, that the results are not being driven by systematic differences across countries in the rate of urbanization.

But even this disaggregation masks significant trends over time. In countries outside of sub-Saharan Africa, mortality levels for men diminished slightly over time. Among women reductions were largest among rural women, although the fact that urban women had lower mortality to begin with results in their having the lowest mortality rate in the latest period we observe (2000–04). In this period, urban women outside of sub-Saharan Africa have a mortality rate 34 percent lower than that for rural men.

Within sub-Saharan Africa mortality rates have increased in most countries, dramatically so in countries with high HIV prevalence. This is clearly the main result to emerge from these calculations. But the trend in differences by sex is interesting as well. In the high-prevalence countries, mortality increased among both men and women and in rural and urban areas. The increase was largest for men: while mortality rates were roughly equal by sex in the earlier periods, women's mortality was around 20 percent lower than men's by the later periods. While the patterns are similar in the low-prevalence countries, the magnitudes are substantially smaller. The gap by sex is similar in percentage terms, although only urban women have a statistically significant lower mortality rate in the most recent period.

Figure 4 further refines the analysis by reporting predicted mortality rates in three age groups, namely 15–24, 25–34, and 35–44.[14] In countries outside of sub-Saharan Africa, declines in mortality are largest in the youngest and oldest of these three groups, with especially large proportionate reductions among the youngest group. In the sub-Saharan countries, the increases in mortality are evident across all three age groups.

FIGURE 4 Predicted adult mortality by year, sex, and location according to age group

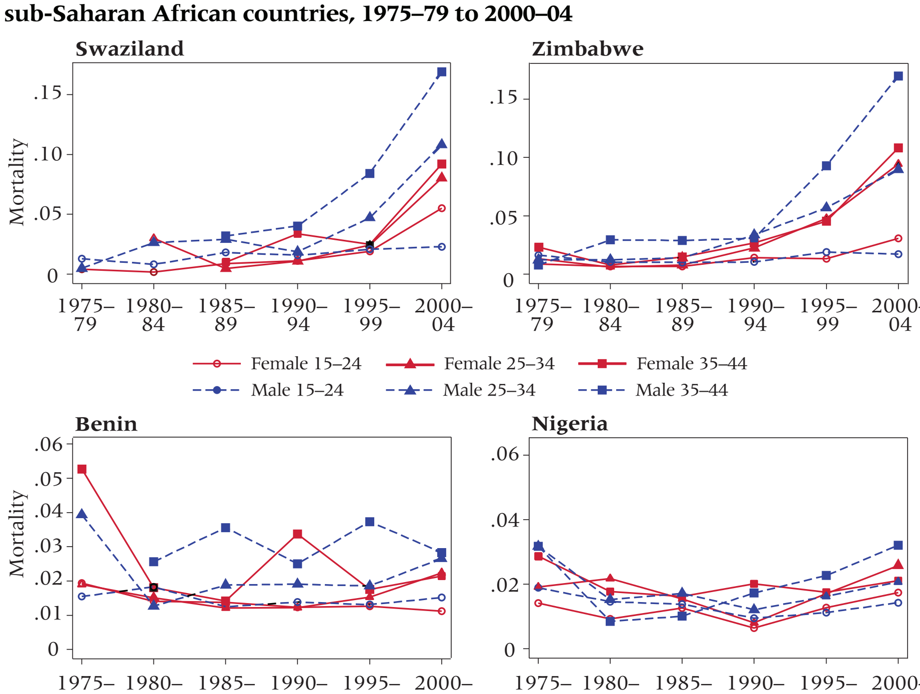


In the high-HIV-prevalence countries, mortality increases are especially large in the oldest age group (35–44), particularly for men. Mortality rates among both rural and urban men aged 35–44 in 2000–04 are 60 to 70 percent higher than those of women of the same age. But Figure 4 also points to a disturbing emerging phenomenon, namely excess mortality among women in the youngest group. In 1980–85 mortality rates were lower for women than for men among 15–24-year-olds; in 2000–04 they were substantially higher. For example, the adult mortality rate among rural women aged 15–24 was 30 percent higher than that among rural men of the same age. This finding is consistent with the sex/age profile of the HIV/AIDS epidemic in sub-Saharan Africa in which HIV prevalence is increasing more rapidly at younger ages among women than among men.

In the low-prevalence countries the patterns for the two older groups are similar, but the magnitudes are substantially smaller. Mortality increased over time, with male mortality outpacing female mortality. There is no evidence among the youngest group that mortality is increasing faster for women than for men.

Figure 5 illustrates these overall patterns with age-specific mortality trends for rural areas in four countries: Swaziland and Zimbabwe with high

FIGURE 5 Trends in age- and sex-specific mortality rates in rural areas of four sub-Saharan African countries, 1975–79 to 2000–04



HIV prevalence (2001 prevalence estimated at 23.6 and 23.7 percent) and Benin and Nigeria with low HIV prevalence (2001 prevalence estimated at 1.4 and 3.8 percent). The graphs illustrate the rise in mortality in the high-prevalence countries. Mortality increases among males in the oldest group are remarkably large in Swaziland and Zimbabwe, from less than 5 percent in 1980–84 to over 15 percent in 2000–04. Mortality rates among the other groups increased substantially starting around 1990–94, with the increase accelerating after 1995–99. Mortality among women aged 15–24 begins to exceed that of men of the same age only in the most recent period—and by a large margin in Swaziland.

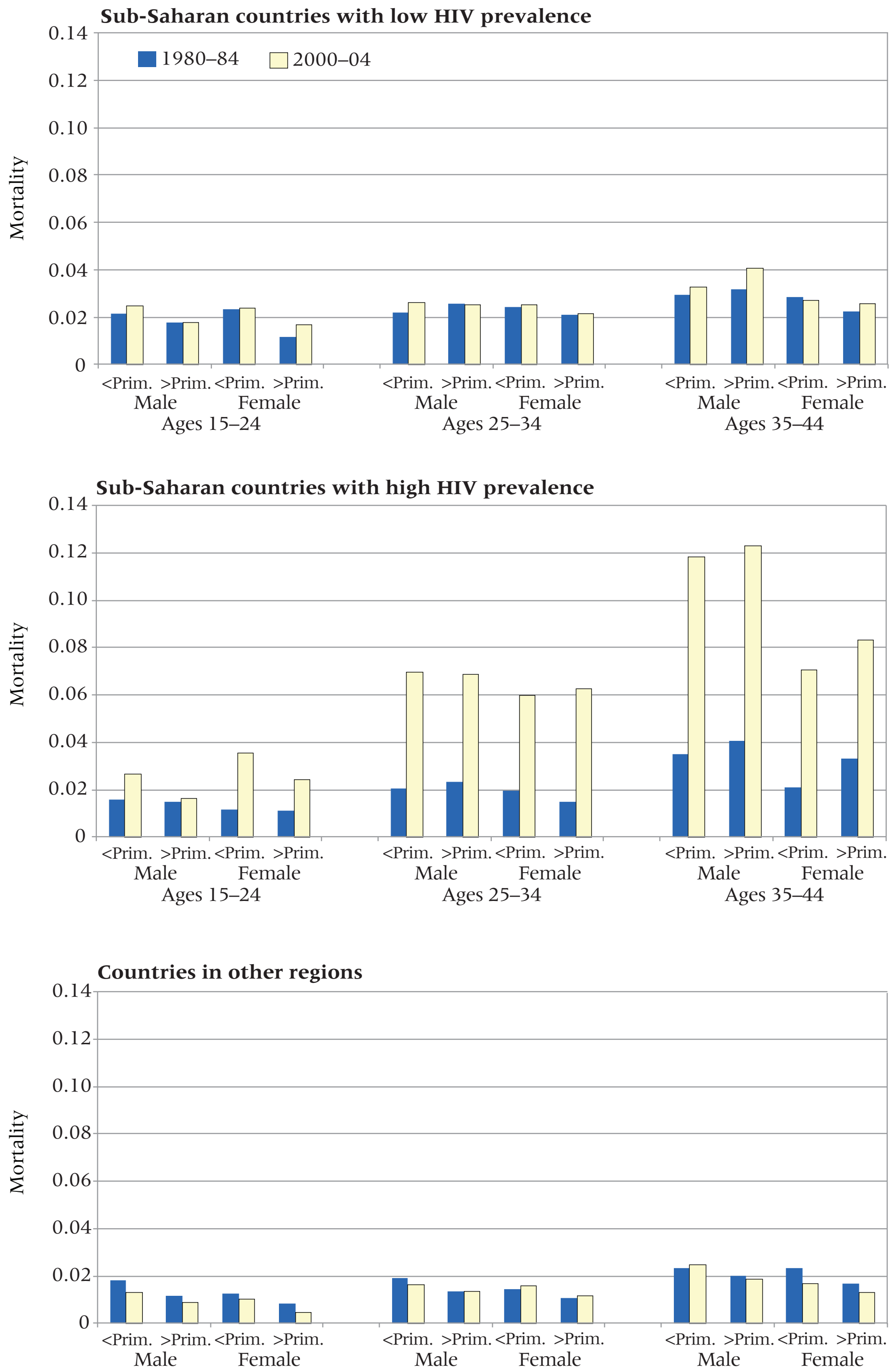
Overall mortality levels are substantially lower in Benin and Nigeria (note the different scales on the vertical axes). Mortality fell in both countries in the earliest periods (from 1975–79 to 1980–84) and stagnated thereafter. In Nigeria mortality appears to be slowly increasing after 1990, especially for men 35–44 and women 25–34. As in the high-prevalence countries, mortality among the youngest women appears to exceed that of the youngest men in 2000–04. It is unclear whether this observation is related to HIV/AIDS or to other factors.

Sex and education. We use dichotomous categories to distinguish the level of education attained: completed primary school or more versus less than completed primary school. (We also used three education categories: no education, at least some primary education, and at least some secondary education. The qualitative findings were unaffected.[15]) Recall that the level of education considered is that of the respondent's sister, which serves as proxy for the educational background of her siblings.

In sub-Saharan Africa, women have lower mortality than men, and this is especially true for better-educated women. Women with less than primary schooling have a mortality rate 13 percent lower than that of men, while women with primary schooling or more have a mortality rate 26 percent lower than that of men. Outside of Africa better-educated individuals are substantially less likely to die. Men with primary schooling or more have mortality that is about 13 percent lower than that of men without primary schooling. As in the earlier models, women have lower mortality overall, and mortality for women with primary schooling or more is 30 percent lower than among women with less than primary schooling.

In sub-Saharan Africa the education gradient in mortality has sharpened over time in countries with high HIV prevalence, particularly for men. In the earlier periods male mortality was similar across education groups, but in the latest period (2000–04) the gradient had become statistically significant and sizable. In the high-prevalence countries adult male mortality was 17 percent lower among those with primary schooling than among those without. In these countries the education gradient among women is small and

FIGURE 6 Predicted adult mortality by year, sex, and education according to age group



not statistically significant. In the low-prevalence countries, only women with more education have statistically significantly lower mortality rates—a finding that is consistent in both the earlier and the later periods. Outside of sub-Saharan Africa, adult mortality rates have fallen, especially among those with more schooling. By 2000–04, mortality was 23 percent lower among men with at least primary schooling than among men without, and 36 percent lower among women with at least primary schooling than among women without.

Figure 6 further disaggregates the results by showing predicted mortality rates for separate age groups (ages 15–24, 25–34, and 35–44). In countries outside of sub-Saharan Africa, reductions in mortality rates were sharpest for better-educated men and women in the youngest group, and among better-educated women aged 35–44. In high-prevalence countries in sub-Saharan Africa the negative association between higher education and lower mortality in the later period is evident only within the youngest cohort of 15–24-year-olds. In the earlier period (1980–84) there was no education gradient in mortality for this group. This is consistent with the discussion in Case and Paxson (2010), who argued that younger, better-educated women are beginning to change behaviors in such a way as to protect themselves against HIV (e.g., by delaying initial sexual activity and by marrying earlier). It is also consistent with de Walque (2007), who showed that in 1999–2000 there was a negative gradient between education and HIV prevalence among young women in rural Uganda. The cohort aged 25–34 showed no perceptible education gradient in mortality for either men or women. In the oldest age group (ages 35–44) the results are somewhat different. In the later period there is a positive association between education and mortality, especially among women. This is consistent with findings on the positive association between HIV infection and education among women and the absence of an association among men (Fortson 2008). However, it is puzzling why this gradient in mortality is found in the 1980–84 period as well, before the takeoff of the epidemic.

Conclusions

We combined data from DHS datasets from 46 countries (33 of which are in sub-Saharan Africa) to analyze trends and socioeconomic differences in adult mortality. We calculated mortality on the basis of sibling mortality reports collected from some 850,000 female respondents aged 15–49. In total, the estimates are based on mortality histories of almost 5 million individuals.

The analysis yields four main findings. First, trends in adult mortality over time differ from those in child mortality.This bears stating since under-5 mortality is often used—perhaps implicitly—as a measure of "population health." Several key features of the data suggest that this is not a legitimate assumption. A first feature is that while under-5 mortality shows a definite improving trend over time, adult mortality does not. Second, the cross-sectional association between under-5 mortality and national income is far stronger than that for adult mortality. Third, while under-5 mortality has fallen over time conditional on national income, this is not the case for adult mortality. Indeed, in sub-Saharan Africa the trend is the opposite, with adult mortality rising at any given level of income. In countries outside of sub-Saharan Africa, the relationship between adult mortality and national income has remained the same.

The second main finding is the magnitude of this increase in mortality in sub-Saharan Africa. The increase is pronounced in countries most affected by the HIV/AIDS pandemic. Mortality rates in the high-prevalence countries of southern Africa (e.g., Swaziland, Zimbabwe, Zambia, Namibia) exceed those in countries that experienced episodes of armed conflict. Excess mortality during episodes of genocide is readily apparent in these data, with aggregate adult mortality rates approaching 15 percent (i.e., a 15 percent probability of dying in the 5-year period encompassing the genocide). But mortality rates decline at the end of these extreme mortality events, whereas adult mortality in the high-prevalence countries shows little sign of declining through the period 2000–04.

Third, even in sub-Saharan countries where HIV prevalence is low, mortality rates at best appear to be stagnating, and are even increasing in several cases. It is unlikely that this finding is driven by the data or methods we use—in many countries outside of sub-Saharan Africa, adult mortality rates have fallen, in some cases sharply. It is unclear whether this stagnation or increase is occurring simply because even low HIV rates are resulting in higher mortality in these countries, or because of some other underlying cause.

Finally, the primary dimension along which mortality appears to differ in the aggregate is sex. Adult mortality rates in sub-Saharan Africa have risen substantially higher for men than for women, especially in the high-HIV-prevalence countries. On the whole, the data do not show large gaps by urban/rural residence or by educational attainment.

Young women (ages 15–24), especially those with less education, are an exception to the general finding that mortality is higher among men. For this group, mortality rates are higher than for all other groups of the same age. This is consistent with the age profile of HIV/AIDS, but it is also consistent with findings by others that younger, better-educated women appear to be engaging in more “protective” behaviors as knowledge about HIV and AIDS is disseminated.

Appendix

APPENDIX TABLE 1 DHS surveys in sub-Saharan Africa and other regions used to derive estimates of adult mortality, with HIV prevalence rates in 2001 for countries in Africa

	Sub-Saharan African countries		Countries in other regions	
Country	Survey years	HIV prevalence in 2001 (percent)	Country	Survey years
Benin	1996; 2006	1.4	Bolivia	1993; 2003; 2008
Burkina Faso	1999; 2003	2.1	Brazil	1996
Central African Republic	1994	8.9	Cambodia	2000; 2005
Cameroon	1998; 2004	5.5	Dominican Republic	2000; 2007
Chad	1998; 2004	3.2	Guatemala	1995
Congo Rep.	2005	3.8	Haiti	2001; 2005
Côte d'Ivoire	1994; 2005	6.5	Indonesia	1994; 1997; 2002; 2007
DR Congo	2007	—		
Eritrea	1995	1.2	Jordan	1997
Ethiopia	2000; 2005	—	Morocco	1992; 2003
Gabon	2000	5.3	Nepal	1996; 2006
Guinea	1999; 2005	1.7	Peru	1996; 2000
Kenya	1998; 2003; 2008	8.4	Philippines	1993; 1998
Lesotho	2004; 2009	24.5	Yemen	1991
Liberia	2007	3.1		
Madagascar	1997; 2003	0.2		
Malawi	1992; 2000; 2004	13.8		
Mali	1995; 2001; 2006	1.6		
Mauritania	2000	0.6		
Mozambique	2003	9.4		
Namibia	1992; 2000; 2006	16.1		
Niger	1992; 2006	1.0		
Nigeria	2008	3.8		
Rwanda	2000; 2005	3.7		
Senegal	1992; 2005	0.6		
Sierra Leone	2008	1.1		
South Africa	1998	17.1		
Swaziland	2006	23.6		
Tanzania	1996; 2004	7.1		
Togo	1998	3.6		
Uganda	1995; 2000; 2006	7.0		
Zambia	1996; 2001; 2006	14.3		
Zimbabwe	1994; 1999; 2005	23.7		

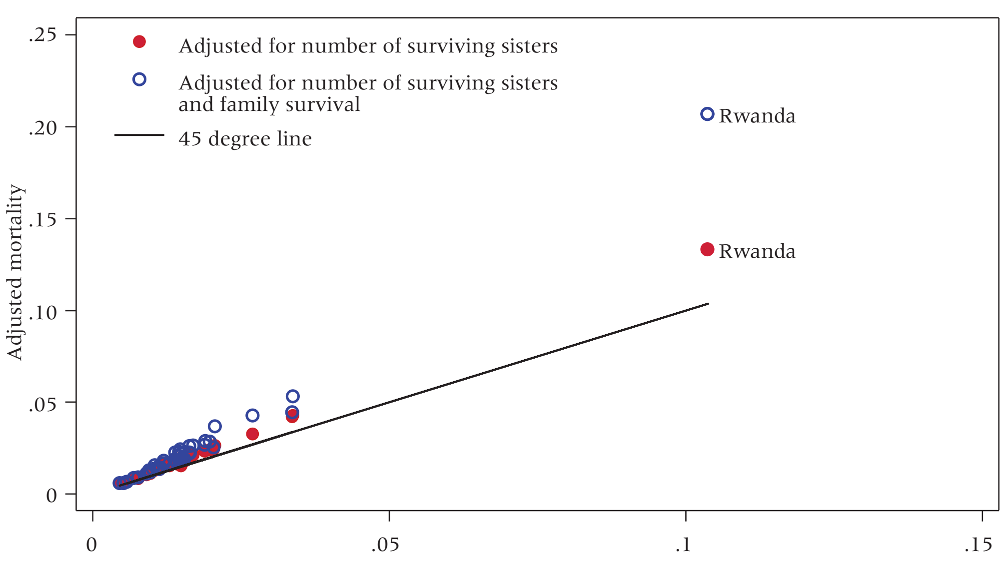
Potential biases in sibling-based adult mortality estimates

Four potential sources of bias can be identified.

First, there is a possibility of double-counting if a sibling is reported twice in the survey, which would decrease the efficiency of the estimates. This could occur if the households of two siblings were randomly selected to be in the study sample (and each reports about the same set of siblings), or if two siblings live in the same household (and, again, each reports about the same set of siblings). We cannot investigate the first situation as the data are anonymous and it would be difficult to establish sibling status across households. Nevertheless, we believe the chances that siblings would be found in randomly selected households are quite small. For the second situation, we identify households in which more than one sister responded to the questionnaire and eliminate all but one randomly selected sister from the analysis.[16]

Second, a potential bias could emerge since sets of sisters with lower mortality are more likely to appear in the sample, which would lead us to underestimate mortality. The bias could be exacerbated (or somewhat offset) if mortality were correlated with the number of sisters. If the correlation were positive, then respondents with a large number of siblings would be more likely to have had siblings who died, and bias in the mortality estimates would be reduced; if the correlation were negative, then mortality estimates would be biased even further downward. We account for this potential correlation by following the methodology proposed by Gakidou and King (2006), weighting each sibling observation by the inverse of the number of surviving female siblings aged 15–49 (including the respondent) at the time of the survey.[17] Specifically, each observation contributes $1/s_i$ in the calculation of D and P in equation (2), where s_i is the number of surviving female siblings aged 15–49 in a family. As illustrated with the solid points in Appendix Figure 1 for the period 1990–94 and the population aged 15–59, the general effect of this adjustment, for all countries with a DHS survey permitting calculation of mortality for that period, is to increase the estimate of adult mortality.[18]

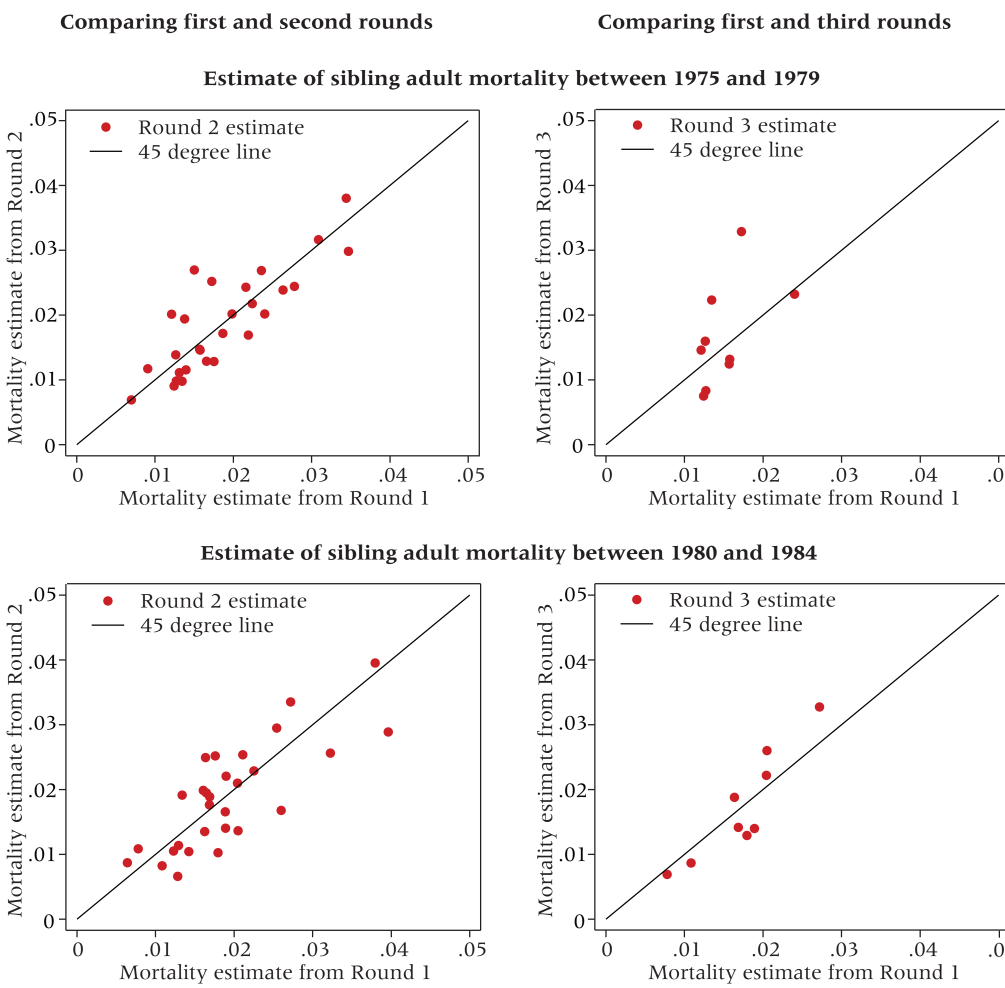
APPENDIX FIGURE 1 Alternative approaches to estimating the adult mortality rate 1990–94, both sexes



Another potential bias could emerge if all of the sisters aged 15–49 in a family die and none appears in the survey. Excluding such families would tend to bias mortality estimates downward since high-mortality sets of siblings would be excluded from the estimation sample. We again followed the approach suggested by Gakidou and King (2006) by estimating the number of "missing" siblings who have died. The approach consists of estimating the relationship between the number of siblings who have died and the total number of surviving children in each family, and then projecting out of sample to a case where there are zero surviving children. This approach is data-intensive in that it requires a substantial number of observations to reliably estimate a relationship between the number of survivors and the number of children who have died. Moreover, it requires imposing strong assumptions about the functional form of the relationship between those two quantities. We found, as illustrated with the open circles in Appendix Figure 1 for 1990–94 for the population aged 15–54, that the effect is quite small at most (relatively low) mortality levels and only meaningful in the case of very large mortality events. Indeed, the circles on the right side of the graph are data from Rwanda—in the midst of genocide at that point. While it is feasible to implement this approach for the adult population as a whole, this adjustment became very unstable when considering more narrow age ranges, especially when disaggregating the data further by sex, education, or residence.[19] We chose therefore not to implement this adjustment in the analysis for this article. We acknowledge, however, that not adjusting for the potential "zero-surviving-respondent" bias is a limitation of our study, with the consequence that our estimates for very-high-mortality events are likely to be biased downward.

A last potential source of bias concerns the recall nature of the data. Respondents are asked to remember the date at which one (or more) of their siblings died and to specify the siblings' age at death. Both of those pieces of information are subject to recall error (as discussed in Obermeyer et al. 2010). To assess whether there is any systematic recall bias, we rely on the fact that many countries have several rounds of data and, therefore, some of the sibling mortality rates from earlier periods can be derived from more than one round of the survey.[20] If the estimated sibling mortality rates were systematically lower or higher in the more recent the survey, then this would suggest a problem. Appendix Figure 2 illustrates the mortality rates among siblings for 1975–79 (top panel) and 1980–84 (lower panel). The left column compares the sibling mortality estimate based on the first DHS survey conducted after the relevant period (where recall bias should be smallest) with the estimate from the subsequent DHS survey. The right column compares the first survey to the third survey (where it exists). While in most cases the mortality estimates are not identical, it is hard to discern any systematic pattern.[21] Multivariate analysis confirms this result: a regression of the adult mortality rate on dummy variables for survey round, controlling for country fixed-effects and period dummies, yields coefficients that are small and not close to statistically significant at conventional levels for second- and third-round estimates of mortality rates.

APPENDIX FIGURE 2 Repeated estimation of sibling mortality (both sexes) comparing consecutive rounds of the DHS



NOTE: 1975–79 graphs exclude Cambodia where the mortality estimate using the first round of DHS is 0.165 and the second round of DHS is 0.166.

Notes

We thank Jishnu Das and Adam Wagstaff for helpful discussions and comments on an earlier draft. We thank Shannon Wilson for research assistance. This work benefited from funding from the World Bank's Research Support Budget (P104962). In the course of this study, we created two databases of adult mortality estimates based on the original DHS datasets, both of which are publicly available at «http://go.worldbank.org/RIIWM53VS0». For other results indicated in endnotes as available on request, contact authors at ddewalque@worldbank.org and dfilmer@worldbank.org. The findings, interpretations, and conclusions expressed in this article are those of the authors and do not necessarily represent the views of the World Bank, its Executive Directors, or the governments they represent.

1 DHS data collection and cleaning are typically conducted in a partnership between MeasureDHS and a local implementing partner with funding from USAID. By monitoring quality at all stages, MeasureDHS ensures that the protocols meet quality standards, resulting in extremely reliable data. More information on the DHS is available at «http://www.measuredhs.com».

2 Not all DHS surveys include the sibling mortality module. We restrict ourselves here to those that do.

3 In some countries this is all ever-married women aged 15–49.

4 An appendix available on request describes two datasets of adult mortality estimates we created for this project. These datasets are publicly available at «http://go.worldbank.org/RIIWM53VS0». The first dataset includes mortality estimates for all subgroups at the level of each DHS survey (that is, for each country and each survey). The second dataset includes mortality estimates for all subgroups at the level of each country (that is, after we averaged multiple country- and period-specific mortality rates).

In our analysis, we run cell-level regressions where one cell is defined for each country, age group, and time period, and then further disaggregated by sex, education category, and rural/urban status. The categories in each cell are further defined in the aforementioned appendix.

5 When there are multiple estimates of adult mortality for the same country and same period (based on different rounds of the DHS), the estimates are averaged, weighting each estimate by the inverse of the variance of the estimate so that more precise estimates are given greater weight. Regional averages are population weighted, where the weights are the total population at the beginning of the period in question.

6 Under-5 mortality for each period is the average of the rate reported for the beginning and end of the period. For example, under-5 mortality for 2000–04 is estimated as the average of the WDI-reported mortality rates for 2000 and 2005.

7 These country-specific estimates and trends are generally consistent with estimates previously published, for example in Timæus and Jasseh (2004), Obermeyer et al. (2010), and Reniers, Masquelier, and Gerland (2011), even though a few differences are observed. It is difficult to ascertain whether those differences are statistically significant.

8 All of these countries had an HIV prevalence rate greatly exceeding 5 percent in 2001.

9 In de Walque and Filmer (2011), we further analyze the socioeconomic distribution of adult mortality in a group of African countries affected by conflict.

10 Recall that these probabilities are likely to be underestimated, since these figures do not adjust for households in which all siblings have died.

11 The pattern of coefficients on period dummies emerges clearly in models restricted to sub-Saharan African countries with high HIV prevalence in 2001. On the other hand, the coefficients are all statistically insignificant when the sample is restricted to countries with low HIV prevalence. (These results are available from the authors.)

12 In our datasets the correlation between ever attending school and urban residence among adults aged 15–49 ranges from 0.04 to 0.52, with a mean of 0.22.

13 The results are consistent with mortality being most closely associated with current residential status, and childhood residence being a noisy measure of current residence. In such a situation, the lower coefficient on childhood residence than on current residence is consistent with attenuation bias imparted by measurement error.

14 These predicted values are based on age-specific regressions with the same structure as those in Table 4 in de Walque and Filmer (2011). The regression results are available from the authors.

15 These results using three education categories are available from the authors.

16 Since the DHS specifies only household members' relationship to household head, we implement a series of steps to characterize two members as sisters. Sisters are defined as: (a) two women who are both daughters of the household head, or both sisters of the household head; (b) women in the same household who report the identical structure of siblings (sex, years since birth, years since death of sibling); (c) women in the same household who report a structure of siblings that is "fuzzily" the same (the sex, years since birth, and years since death of sibling are very similar). We implement (c) to allow for some misreporting.

17 We also weight each sibling observation by the survey weight associated with the responding sibling assigned on the basis of the original sampling strategy. Therefore, each sibling observation is weighted by the survey weight divided by the number of surviving female siblings.

18 An appendix available on request provides a simulation of how various approaches to weighting affect the results and reduce the biases, particularly when mortality and the number of siblings are correlated. In addition, it shows how including the respondent herself in the mortality calculations is an important part of removing bias in the estimation of mortality.

19 Indeed, in these smaller sample cells, the size of the adjustment depended almost exclusively on the functional form specified for the estimation of the relationship between the number of surviving and dead siblings.

20 For this discussion, we focus on the mortality of siblings only, and exclude respondents on the grounds that the reporting on their status is correct (that is, they are alive).

21 This is consistent with Obermeyer et al. (2010), who find only small and inconsistent recall effects.

References

Bicego, George. 1997. "Estimating adult mortality rates in the context of the AIDS epidemic in sub-Saharan Africa: Analysis of DHS sibling histories," *Health Transition Review* 7(Suppl 2): 7–22.

Case, Anne and Christina Paxson. 2010. "The changing role of education in the AIDS crisis," Center for Health and Wellbeing, Princeton University. Mimeo, August. «http://econ.tulane.edu/seminars/Paxson_AIDS.pdf».

Conley, Dalton, and Rebecca Glauber. 2005. "Sibling similarity and differences in socioeconomic status: life course and family resource effects," NBER Working Paper 11320.

Dahan, Momi and Alejandro Gaviria. 2001. "Sibling correlation and intergenerational mobility in Latin America," *Economic Development and Cultural Change* 49(3): 537–554.

Deaton, Angus, and Christina Paxson. 2003. "Mortality, income, and income inequality over time in Britain and the United States," in David A. Wise (ed.), *Perspectives on the Economics of Aging*, vol. 8. University of Chicago Press for NBER.

de Walque, Damien. 2005. "Selective mortality during the Khmer Rouge period in Cambodia," *Population and Development Review* 31(2): 351–368.

———. 2006. "The socio-demographic legacy of the Khmer Rouge period in Cambodia," *Population Studies* 32(2): 223–231.

———. 2007. "How does the impact of an HIV/AIDS information campaign vary with educational attainment? Evidence from rural Uganda," *Journal of Development Economics* 84(2): 686–714.

de Walque, Damien, and Deon Filmer. 2011. "Trends and socioeconomic gradients in adult mortality around the developing world," World Bank Policy Research Working Paper 5716, Washington, DC.

de Walque, Damien, and Philip Verwimp. 2010. "The demographic and socioeconomic distribution of excess mortality during the 1994 genocide in Rwanda," *Journal of African Economies* 19: 141–162.

Filmer, Deon. 2005. "Fever and its treatment among the more and less poor in sub-Saharan Africa," *Health Policy and Planning* 20(6): 337–346.

Fortson, Jane. G. 2008. "The gradient in sub-Saharan Africa: Socioeconomic status and HIV/AIDS," *Demography* 45(2): 303–322.

Gakidou, Emmanuela and Gary King. 2006. "Death by survey: Estimating adult mortality without selection bias from sibling survival data," *Demography* 43: 569–585.

Gwatkin, Davidson et al. 2007. "Socioeconomic differences in health, nutrition, and population within developing countries: An overview," Country Reports on HNP and Poverty. Health Nutrition and Population, The World Bank, Washington, DC.

Gwatkin, Davidson R., Adam Wagstaff, and Abdo S. Yazbeck. 2005. *Reaching the Poor with Health, Nutrition and Population Services*. Washington, DC: The World Bank.

Halvorsen, Robert and Raymond Palmquist. 1980. "The interpretation of dummy variables in semilogarithmic equations," *The American Economic Review* 70(3): 474–475.

Obermeyer, Ziad, Julie Knoll Rajaratnam, Chang H. Park, Emmanuela Gakidou, Margaret C. Hogan, Alan D. Lopez, and Christopher J.L. Murray. 2010. "Measuring adult mortality using sibling survival: A new analytical method and new results for 44 countries, 1974–2006," *PLoS Medicine* 7(4): e1000260.

Preston, Samuel H. 1975. "The changing relation between mortality and level of economic development," *Population Studies* 29(2): 231–248.

———. 1980. "Causes and consequences of mortality declines in less developed countries during the 20th century," in R.A. Easterlin (ed.), *Population and Economic Change in Developing Countries*. Chicago: University of Chicago Press.

Reniers Georges, Bruno Masquelier, and Patrick Gerland. 2011. "Adult mortality in Africa," in R. Rogers and E. Crimmins (eds.), *International Handbook of Adult Mortality*. Springer, pp.151–170.

Timæus, Ian and Momodou Jasseh. 2004. "Adult mortality in sub-Saharan Africa: Evidence from Demographic and Health Surveys," *Demography* 41(4): 757–772.

UNAIDS. 2010. "Global report: UNAIDS report on the global AIDS epidemic 2010," UNAIDS «http://www.unaids.org/globalreport/Global_report.htm».