Life Expectancy and Economic Development: Evidence from Micro Data

Belgi Turan*
University of Houston

November 2009

Abstract

Using birth and sibling histories from Demographic Health Surveys conducted in sub-Saharan Africa I construct age-specific birth rates and age-specific mortality rates at the country-region level. I use this data to test the implications of a general equilibrium model linking life expectancy to fertility, education, and labor supply. I find that increased life expectancy lowers fertility, but the size of the effect is small. I find no difference between high HIV countries (those with greater than 5 percent prevalence) and low HIV countries, ruling out the possibility that fear of infection dramatically lowers fertility. I find a positive relationship between life expectancy and education when I pool all countries. Within high HIV countries, however, the relationship between life expectancy and education is less robust. Finally, I find a weak positive relationship between life expectancy and labor force participation for females, but no relationship among males. Overall the new data suggests that in sub-Saharan Africa, increases in life expectancy will have a positive impact on growth through fertility and education but the effect will be small.

JEL Codes: O12, J13, J22, I21
Keywords: Economic Development, Life Expectancy

---

*I thank my co-advisors Chinhui Juhn and Sebnem Kalemli-Ozcan, my committee members Bent Sorensen and Aimee Chin, and graduate workshop participants at University of Houston for valuable suggestions and comments. Contact Information: E-mail: bkturan@mail.uh.edu, Address: Department of Economics, 242 McElhinney Hall, University of Houston, Houston, TX, 77004.

1 Introduction

A large literature studies the effect of improving health and life expectancy on economic development and growth. However, as of yet, there is little consensus either on the theoretical or the empirical front. On the theory side, the standard neoclassical model highlights the limits of improvement in health and life expectancy. Increased life expectancy increases population which reduces capital-labor ratios and depresses per capita income. On the other hand, endogenous growth models in the tradition of Becker and Barro (1988) suggest that human capital investment and fertility responses may offset the grim predictions of the neoclassical model. In particular, increased life expectancy could lead to a quantity-quality trade-off where parents have fewer children but invest more in the education of their children and their own education (see Kalemli-Ozcan (2003), Soares (2005), Cervellati and Sunde (2007), Tamura (2006) among others). This suggests that behavioral responses in fertility and human capital investment can offset the decline in capital-labor ratios and productivity.

There is likewise little agreement on the empirical front. While Bloom and Sachs (1998), Gallup, Sachs and Mellinger (1999), Bloom, Canning and Sevilla (2002), Lorentzen, McMillan and Wacziarg (2008) find large effects of increasing life expectancy on growth, a recent paper by Acemoglu and Johnson (2007) find little effect. They instrument changes in life expectancy with dates of global health interventions to combat 15 major diseases. While health interventions increase life expectancy, they find little impact on per capita GDP.[1]

[1]Several papers have challenged their results. Cervellati and Sunde (2009) argue that the causal effect of life expectancy on income per capita differs during different phases of development. Increases in life expectancy reduce income per capita in countries that did not go through the demographic transition, whereas in post-transitional countries gains in life expectancy increase per capita income. This nonlinear dynamic cannot be captured in AJ since they pool the countries in their sample. Additionally, Bloom, Canning and Fink (2009) argue that AJ's results are based on the assumption that initial health and income do not affect subsequent economic growth. The healthiest nations in 1940 are those that benefitted least from the health interventions and also the ones that grew the most, giving a negative relationship between health interventions and growth. While identifying the causal impact of health and longevity on growth is the desired goal, the literature demonstrates the difficulty of finding such instruments. Shastry and Weil (2003), Weil (2007), Ashraf et al. (2008) take a different approach and present models and calibrations and

In this paper I write down a general equilibrium model linking life expectancy to important behavioral variables such as fertility, human capital investment, and labor supply. I extend the models introduced by Zhang and Zhang (2005), who model education and fertility but not labor supply, and Boucekkine et. al (2009), who model fertility and labor supply but not education. My model incorporates all three taking into account both the partial and general equilibrium effects. There are two offsetting effects in the model. On the one hand, an increase in life expectancy leads to a quantity-quality trade-off where parents have fewer children but invest more in their own education as well as the education of the children.[2] Individuals also work and save more since they have a higher probability of surviving to old age. This is called the horizon effect. On the other hand, there is a countervailing effect in which increased life expectancy expands the size of the adult population and lowers wages. Under certain parameter configurations, this general equilibrium effect, which works through lower wages, can increase fertility (since the opportunity cost of bearing and rearing children is lower) and reduce education and labor supply, leading to overall ambiguous effects.

The ambiguous theoretical predictions suggest that the proper understanding of the link between life expectancy and fertility, education, and labor supply, rests on empirical work. The empirical work to this point, however, has been limited by the lack of data. Researchers in this area have largely relied on country-level data (Shastry and Weil (2003), Acemoglu and Johnson (2007), Lorentzen, McMillan and Wacziarg (2008)).[3] The empirical work has also largely focused on per capita GDP as the outcome variable.[4]

conclude that while positive, the effect of improved health on growth is likely to be small.

[2]Alternatively, parents may have precautionary demand for children and respond by giving fewer births when child mortality falls (Kalemli-Ozcan, 2003). Cervellati and Sunde (2007) identify yet another possible channel where increases in life expectancy raise the returns to human capital for the parents and the opportunity cost of raising children thereby leading to a negative relationship between longevity and fertility.

[3]See Bloom, Canning, Sevilla (2004) for review of such studies.

[4]There are notable exceptions. There are two studies which have used micro-level data. Jayachandran and Lleras-Muney (2009) show that exogenous declines in maternal mortality increased female literacy and years of schooling in Sri Lanka. Soares (2006) uses the 1996 Demographic Health Survey from Brazil to construct family specific adult longevity from sibling histories. He finds that longevity is positively related to schooling and negatively related to fertility. While the use of sibling histories to construct

In this paper, I fill this gap by constructing a new panel data set from Demographic Health Surveys and testing the implications of endogenous growth models that relate life expectancy to fertility, human capital, and labor supply. More specifically, I use 67 Demographic Health Surveys of 28 countries from sub-Saharan Africa taken between the years 1987 and 2007. I calculate fertility rates and child mortality rates from birth histories and adult mortality rates and life expectancy from sibling histories. Based on this information I construct birth and death rates by region, year and age of the mother.[5]

There are several advantages to this data. First, by building mortality rates from sibling histories, I obtain more accurate measures of mortality for some countries. Country level life expectancy measures for developing countries, especially for sub-Saharan Africa, are often not accurate since reliable vital registration data are not available. Estimated infant mortality and under-five mortality rates and an assumed age pattern of mortality are used to calculate life expectancy. My mortality data set is based on actual reported deaths. Secondly, since my data are at the individual level, I can construct age-specific birth and mortality rates by region and exploit variations in the data beyond the usual cross-country variation. Finally, the data set I have constructed is unique in terms of the number of countries covered (28) and the period covered (1975 to 2007).[6] Most of the related studies do not cover sub-Saharan Africa due to lack of reliable data. However my approach enables me to extend my analysis to sub-Saharan Africa. Africa is also an interesting testing ground for these models since adult mortality suffered a large negative shock with the introduction of HIV/AIDS in the mid 1980s. How fertility, education, and labor supply have responded in this environment has been the topic of

mortality rates is similar to my approach, he uses a single survey from a single country and does not utilize the panel aspects of the birth and mortality histories. In addition to mortality, morbidity is also shown to be an important determinant for educational outcomes. Miguel and Kremer (2004) and Bleakley (2007) show that deworming interventions improved educational outcomes in Kenya and American South, respectively.

[5] Countries and the years included are explained in the Appendix II.

[6] Oster (2009) covers 12 countries and years between 1981 and 2005. Soares (2006) covers Brazil since mid-60s but aggregates the information up to 1996. While they do not examine mortality, Juhn et al. (2009), Fortson (2009) and Fink and Linnemayer (2009) use fertility histories. Coverage is much smaller however.

special interest in a recent set of papers. Young (2005) suggests that similar to the "Black Death" plague in Europe, HIV/AIDS will reduce fertility and population and eventually enhance growth among the affected African nations. Recent papers by Juhn et. al (2009), Fortson (2009) and Fink and Linnemayer (2009) find little impact on fertility and negative impact on education.

To preview my empirical results, I find that adult life expectancy is negatively related to fertility suggesting that the horizon effect dominates the general equilibrium effect and behavioral changes in fertility counter-act the rise in population. While the relationship is negative the size of the effect is small. I find no systematic difference between high HIV countries, which I define as those with greater than 5 percent prevalence rate, and low HIV countries. I find little evidence that fertility declines rapidly through fear of infection as suggested by Young (2005). I also find that life expectancy is positively related to education which again suggests that the horizon effect dominates. In the case of education, however, I find that the results are driven by low HIV countries. Among high HIV countries, I find no systematic relationship between life expectancy and education. Finally, I find a weak positive relationship between life expectancy and labor force participation for females, but no relationship among males. Overall, results using this newly constructed data suggests that in the context of sub-Saharan Africa, increases in life expectancy will have a positive impact on growth through fertility and education, but the size of effect will be small.

The rest of the paper is organized as follows. Section 2 lays out the conceptual framework. Section 3 describes the data. Section 4 presents the empirical results. Section 5 concludes.

2 The Model

Assume a 3 period over-lapping generations (OLG) model. In period t, individual invests in education, e_t. Human capital h_{t+1} accumulation is given by:

$$h_{t+1} = e_t h_p \tag{1}$$

where h_p denotes parental human capital.

In period $t+1$, 1 unit time endowment is allocated among raising children, working and leisure. Individual gives birth to n_{t+1} children, consumes c_{t+1}, saves s_{t+1}, works l_{t+1} and earns w_{t+1} per unit time based on his human capital. Income is given by:

$$y_{t+1} = h_{t+1} l_{l+1} w_{t+1} \tag{2}$$

The time cost of child bearing is v, where $v > 0$.[7] Young adults have p_{t+1} probability of survival to period $t+2$, where $p \ \epsilon \ (0,1)$. In period $t+2$, survivors do not work but only consume c_{t+2} out of their savings s_{t+1}.

The maximization of the utility function subject to the intertemporal budget constraint can be written as follows:

$$max \ U(e_t, c_{t+1}, n_{t+1}, l_{t+1}, c_{t+2}) = \frac{(1-e_t)^{1-\sigma}}{1-\sigma} + \frac{c_{t+1}^{1-\sigma}}{1-\sigma} + \frac{(n_{t+1})^{1-\sigma}}{1-\sigma} + \frac{(1 - v n_{t+1} - l_{t+1})^{1-\sigma}}{1-\sigma} \tag{3}$$

$$+ p_{t+1} \frac{c_{t+2}^{1-\sigma}}{1-\sigma}$$

$$\tag{4}$$

$$s.t. \ \ c_{t+1} + p_{t+1} c_{t+2} = h_{t+1} l_{t+1} w_{t+1}$$

where σ governs risk aversion and intertemporal elasticity of substitution. The first order conditions with respect to e_t, n_{t+1}, l_{t+1}, and will yield the following equations:

[7] There is no uncertainty about child survival since my focus is on adult longevity.

$$1-(1-n_{t+1}v-n_{t+1}v^{\frac{1}{\sigma}})[1+[w_{t+1}^{\frac{\sigma-1}{\sigma}}\frac{1}{1+p_{t+1}}(1+w_{t+1}^{\frac{\sigma-1}{\sigma}}(1-n_{t+1}v-n_{t+1}v^{\frac{1}{\sigma}})^{\frac{\sigma-1}{\sigma}}\frac{1}{1+p_{t+1}})^{\frac{1-\sigma}{\sigma}}$$

$$(1+v^{\frac{\sigma-1}{\sigma}})]]=0 \tag{5}$$

$$1-[\frac{(1-e_t)(1+p_{t+1})}{e_t w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}}}]^{\frac{\sigma}{\sigma-1}}[1+[(1+v^{\frac{\sigma-1}{\sigma}})(w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}}\frac{1}{1+p_{t+1}}e_t^{\frac{\sigma-1}{\sigma}})]]=0 \tag{6}$$

$$1-l_{t+1}-l_{t+1}[(1+v^{\frac{\sigma-1}{\sigma}})(1+w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}} l_{t+1}^{\frac{\sigma-1}{\sigma}}\frac{1}{1+p_{t+1}})^{\frac{1-\sigma}{\sigma}} w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}}\frac{1}{1+p_{t+1}}]=0 \tag{7}$$

Proposition 1: An exogenous increase in adult survival probability p_{t+1} lowers fertility n_{t+1} and increases education e_t and labor supply l_{t+1}, for any $\sigma > 0.5$, as shown in Figures 1, 2 and 3.[8] The intuition is as follows. In a low mortality environment, parents have more incentive to invest in themselves and their children, since the horizon over which human capital investments can be realized by them and by their children is longer. This is called the "horizon effect." Labor supply is also increasing due to this horizon effect, since with a longer life span there are more years to save and consume for retirement, leading to an increase in the labor supply.[9]

Proposition 2: The effect of an increase in wages on fertility, education and labor supply decision is ambiguous. Fertility increases with wages only if $\sigma > 1$. Education decreases with wages when $\sigma > 1$, and labor supply also decreases with wages when $\sigma > 1$. Figures 4, 5, and 6 summarizes the different effects of wages on fertility, education and labor supply given the σ parameter.

The intuition for this ambiguity is straightforward. In order for higher wages to decrease fertility, the substitution effect, which lowers fertility through increasing the op-

[8]See Appendix I for derivations.

[9]There also can be an indirect effect of mortality on labor force participation stemming from an increase in human capital investment as in Soares, 2008.

portunity cost of rearing children, needs to dominate the income effect which increases fertility through a higher amount of resources available to bring up more children. And this is the case only if $\sigma < 1$. As returns to education increases due to higher wages individuals have more incentive to invest in themselves. Likewise, with higher wages opportunity cost of leisure is higher, therefore more people would prefer to work. But again for these effects to be prevalent, the substitution effect needs to be dominating. If $\sigma < 1$, elasticity of intertemporal substitution is high enough that substitution effect dominates income effect and labor supply increases.

In general, the empirical estimates suggest that σ is around 3.[10]

2.1 General Equilibrium Implications:

As outlined above, exogenous shocks to mortality and wages may induce opposing effects on fertility, education and labor supply. To show the general equilibrium effect, I assume a Cobb-Douglas production function:

$$Y_t = K_t^{\alpha}(l_t L_t h_p)^{1-\alpha} \tag{8}$$

where K_t is the capital stock, L_t is the active population, l_t is the labor supply, and α is the capital share. Here, I assume no technological progress and full capital depreciation in one period. The factors get paid their marginal products and population growth is given by n_t. The capital accumulation and wages are given by:

$$K_{t+1} = L_t s_t \tag{9}$$

[10]Hansen and Singleton (1983) reports relative risk aversion estimates between 0.68 and 0.97, Szpiro (1986) shows that it is between 1.2 and 1.8, Mankiw (1985) shows even larger estimates in the range of 2.44 to 5.26, Halek and Eisnehauer (2001) finds 3.75. On the theoretical front, assumptions both below or above 1 are common. While Becker, Philipson and Soares (2005), Doepke (2005), Boucekkine et al. (2009), Chakraborty and Das (2009) among many others, assume that $\sigma < 1$, Cordoba and Ripoll (2009), Benito et al. (2009), to name a few, assume that $\sigma > 1$.

$$w_{t+1} = (1-\alpha)(\frac{s_t}{n_t l_{t+1}})^\alpha \quad (10)$$

In Proposition 1, I showed that an increase in adult survival probability reduces fertility and increases labor supply and education. However, from the above equation, one can see that an increase in labor supply leads to a decrease in wages. So, in general equilibrium a reduction in adult mortality can lead to labor surplus and lower wages.[11] If $\sigma > 1$, lower wages induced by higher labor supply due to reduced mortality will also reduce fertility. Combined with the direct positive effect of reduced mortality on fertility the net effect of mortality and wage changes on fertility will be a reduction of fertility. However, if $0.5 < \sigma < 1$, horizon effect and wage effect work in the opposite directions giving an ambiguous effect on fertility. While longer time horizon shifts quantity-quality trade-off towards less children, lower wages increase fertility due to lower opportunity cost. Similarly, while longer time horizon increases incentive to get more schooling and work more, lower wages reduce incentive to do so. On the other hand, if $\sigma > 1$, both lower wages and higher survival probability reduce fertility and increase education and labor supply.

Following table summarizes the theoretical predictions of the model:

[11] A well-researched example in the history is the Black Death in the late fourteenth century. Black Death is estimated to have reduced Britain's population to about half of its pre-plague level in three decades. With a declining labor force, real wages rose rapidly during the plague years, and then remained high throughout the fifteenth century (Herlihy (1997), Young (2005)).

	Panel A: $0.5 < \sigma < 1$		
	Fertility	Education	Labor Supply
Longer Horizon	$-$	$+$	$+$
Lower Wages	$+$	$-$	$-$
Net Effect	$+/-/0$	$+/-/0$	$+/-/0$
	Panel B: $\sigma > 1$		
	Fertility	Education	Labor Supply
Longer Horizon	$-$	$+$	$+$
Lower Wages	$-$	$+$	$+$
Net Effect	$-$	$+$	$+$

3 Data

I use 67 Demographic Health Surveys (DHS) from 28 countries in sub-Saharan Africa with survey years spanning between 1987 and 2007.[12] The DHS surveys are nationally representative samples designed to gather detailed demographic and fertility information of women. Similar to Young (2005), I use birth histories to construct a time-series of birth rates by region and age of the mother. In the survey, adult women (aged 15 to 49) answer retrospective questions about each birth, including year of birth, gender, and year of death, in case the child died. I divide the number of births in the region and year and age of mother by the total number of women in the region and year and age category. Infant and child mortality rates are also constructed using birth histories. Using birth and death years, I calculate the fraction of children who were alive at the beginning of each year and died during that year. By this method, I obtain a time-series of regional child mortality rates between 1975 and 2007.

[12]Details about the surveys used are in Appendix II.

In order to accurately estimate adult mortality rates, complete vital registration system through which all deaths are reported to a government agency is crucial. However, vital registration systems in developing countries, particularly in sub-Saharan Africa, are underdeveloped. Therefore, reliable mortality data for these countries are not available. For this reason, I use sibling history modules of the DHS to construct time-series of adult mortality rates. In most of the DHS surveys, adult women are asked about their siblings. Respondents give information on sibling's gender, date of birth and death. Using this information, I construct age-specific mortality rates that vary by year, region, and gender. Again, I divide the number of siblings who died at each age in each region in each year by the number siblings alive at each age at the beginning of the year in each region.[13] The constructed average age-specific death rates are shown in Tables 1 and 2. Numbers accord with the usual age profile with high infant mortality rates followed by U-shaped death rates. Furthermore, as established in the literature, female mortality rates are lower than male mortality rates for all age groups in my sample.

Although Bicego (1997), Timaeus and Jasseh (2004) show that sibling histories usually estimate mortality rates fairly accurately, there might still be concerns about potential biases. Estimations can be downward biased since families in which all adult members died are not represented. Dead people with no siblings are also not included since there is no one to report on them. Additionally, families with favorable mortality rates are misrepresented in the sample since experience of sisters might be counted several times. On the other hand, this methodology may overestimate the overall death rate since respondents, who are obviously alive, are not taken into consideration in the mortality calculation. Trussell and Rodriguez (1990) show that with a random sample from a population, these potential biases cancel each other and this method gives unbiased mortality estimates if mortality rates are not correlated with the number of siblings.

[13]While my data technically go back to the 1960s for some age groups, for comparability across years I start my analysis in 1975 when the oldest women in the sample are 39. I examine fertility for 15-39 year old women. While the changing age distribution is also of concern for mortality calculations, robustness checks using more recent data led to similar qualitative results.

Of course, this assumption does not hold if people in high mortality areas have more children or if children in crowded households are less likely to survive because of the limited resources. However, when I incorporate the adjustments proposed in Gadikou and King (2006) to eliminate these biases my results still hold.[14] Additionally, as stated in Oster (2009), this correlation is more of a concern for child mortality, not for adult mortality. To examine further the potential biases, in Figure 7 I compare mortality rates calculated from sibling histories to the official death data available for Zimbabwe, which is the only country in sub-Saharan Africa in my sample that has official vital registration data. The figure shows that the match between the two sources is very strong, meaning that calculating mortality rates from sibling histories provides quite accurate estimates when the official data is not available.[15]

The theory calls for life expectancy measures since I model forward looking behavior by individuals who incorporate the remaining life span. I convert the age-specific mortality rates to life expectancy measures. Life expectancy is the number of years an individual in a region can be expected to live if he/she experienced the current age-specific death rates of the region throughout his/her life. The notation e(a-b) refers to expected years of life between ages a and b conditional on survival to age a. The exact formulas used for calculation are in Appendix II. Since survivor bias becomes a bigger problem at older ages, I censor life expectancy at age 60.

Constructed life expectancy measures are shown in Table 3 and 4. The tables show that life expectancy both at birth and at age 15 have declined on average among countries in sub-Saharan Africa. Indeed among high HIV/AIDS countries, life expectancy is lower than 30 years ago.

[14]Results are available from author upon request.
[15]See Oster(2009) for more evidence on the reliability of sibling mortality histories.

4 Empirical Analysis and Results

4.1 Effect of Life Expectancy on Fertility

I examine the relationship between fertility and life expectancy as follows:

$$Fertility_{art} = \alpha + \beta LE_{art} + \gamma_a + \lambda_r + \eta_t + \theta_{rt} + \epsilon_{art}, \tag{11}$$

where a refers to age group, r refers to region and t refers to year. Fertility is the number of children born per 1000 women by age group, region, and year. Since in the earlier years of my data I only observe relatively young women (the oldest woman being 39 in 1975) I only include women who are 15-39 years old in the fertility regressions. LE_{art} is the number of average years an individual is expected to live conditional on surviving to age-group a in year t in region r. For a woman of a particular age group, mortality shocks that affect older individuals impact her life expectancy but not mortality shocks that affect younger individuals. While in principle I have annual observations, serial correlation is likely to lead me to understate the standard errors. I therefore use data in five-year intervals corresponding to 1975, 1980, 1985, 1990, 1995, 2000, and 2005. I also aggregate single-year age categories into five 5-year age groups. The regression controls for age group dummies, region fixed effects, year fixed effects as well as region-specific trends.[16]

Results are reported in Table 5. The table shows that for the overall sample, the relationship between adult life expectancy and fertility is negative, which suggests that the horizon effect dominates the general equilibrium wage effect and women respond to increases in life expectancy by having fewer children. How large is the effect? While the relationship is negative, the size of the effect is small. A one year increase in adult life expectancy reduces the annual birth rate by 0.244 percentage points. Over 25 years from ages 15-39, a woman will have 0.061 (=25*.00244) fewer children. Table 4 showed that

[16] I report results where each cell is weighted by number of observations in the cell. Results which do not weight by cell size are qualitatively similar and are not reported.

life expectancy at 15 decreased by an average of two years in my sample. This suggests that total fertility rate may have risen by 0.12 children as a result.

Recently, several papers have examined the effect of HIV/AIDS on fertility. While Young (2005, 2007) finds that HIV/AIDS decreases fertility, papers using newly-available individual level testing data find that regional HIV prevalence representing mortality risk has little measurable effect on fertility (Juhn et al. (2009) and Fortson(2009)). Although I do not directly attempt to test the effect of HIV/AIDS on fertility, in the following section I divide the countries in sub-Saharan Africa by their country-level prevalence using data from UNAIDS/WHO. My two groups are "high" (5 percent or greater) and "low" (less than 5 percent) HIV prevalence countries. The results are reported in columns (2) and (3) of table 5. For both high and low HIV countries, I find a negative significant effect of increasing life expectancy on fertility. In the context of high HIV countries which are experiencing *reductions* in adult life expectancy, this means that women are *increasing* fertility in response to mortality shocks.

My findings on fertility for high HIV countries seem somewhat at odds with the lack of fertility effects documented in the previous papers. There are two potential explanations. The first point is that while I do find a significant effect, the impact of adult life expectancy on fertility is economically small. Second, while previous papers have examined the impact of HIV infection, my measure here is mortality, which is likely to be more correlated with AIDS and advanced stages of the disease. Some researchers have found that HIV prevalence in the community has little impact on sexual behavior suggesting that individuals may lack knowledge of the disease and their own infected status.[17] Uncertainty or lack of knowledge about the consequences of the disease is not likely to be a factor with mortality.

My results differ from Young (2005) which finds a large decline in fertility due to HIV related deaths in South Africa. The results here also differ from Boucekkine et al. (2009)

[17]For example, Oster (2005), using DHS data find little change in sexual behavior since the onset of the epidemic. Luke and Munshi (2006) find that married men in highly infected communities in Kenya have similar numbers of non-marital partners as single men.

which documents a large negative effect of adult mortality on fertility. The difference in my results from the latter paper may stem from the fact that I use within-country cross-region variation in fertility and mortality rates, while Boucekkine et al. (2009) uses country level data.

4.2 Effect of Life Expectancy on Education

I run the following regression covering the years 1975 to 2007 to examine the relationship between education and life expectancy:

$$Education_{cr} = \alpha + \beta LE_{15} + \lambda_r + \gamma_c + \zeta_{cr} + \epsilon_{cr}, \tag{12}$$

where c refers 5-year birth cohorts and r refers to region. Education is the average years of schooling by cohort by region. LE_{15} is the average number of years a 15 years-old is expected to live when the cohort is 5 to 15 years old. The choice of average life expectancy between ages 5 to 15 is to account for the fact that education decision is made during school-going age and not afterwards. Thus, a 30 year old woman who experiences an increase in life expectancy will not increase her own education because she is beyond the age where investments are made. The change in life expectancy will however impact educational investment for her children. Additionally, the above regression includes region and cohort fixed effects and region-specific cohort trends.

Results are shown in Table 6. Columns (1) and (2) show the results for all countries in my sample. Both females and males increase education as life expectancy increases with the size of the effect being larger for males. Intuitively, as the horizon to reap the benefits of the investment lengthens, returns to schooling increases and, on average, individuals go to school for a longer period of time. The coefficients of 0.096 and 0.209 imply that 1 year increase in life expectancy increases education by 0.1 years for females and 0.21 years for males, which approximately correspond to 2% and 3% increases relative to the sample means. These estimates are similar to Jayachandran and Lleras-Muney (2009) which finds that a one-year increase in life expectancy increases schooling by 0.13 years (3%) for females. It is plausible to find a bigger effect for males as it has been established in the literature that under unfavorable conditions and scarcity of resources, household resources are distributed in favor of boys.

In a paper that examines the impact of HIV/AIDS on education, Fortson (2007) finds that regions with higher HIV prevalence experienced relatively larger declines in education over time. My results above are consistent with these findings. In columns (3)-(6), I examine whether the positive impact of life expectancy on education remains even when I look within high and low HIV countries. Columns (3) and (4) show that in low HIV countries, the robust and positive impact of life expectancy on education remains. However, when we I look within high HIV countries, the relationship between life expectancy and education disappears, which suggests that the between variation across high and low HIV countries is important in driving the overall results.

Among high HIV countries, life expectancy at age 15 declined by approximately 4 years from 40.7 in 1990 to 36.9 in 2000. The size of the education effect suggests that average years of schooling could decline by as much as 0.4-0.8 years in these countries. Given that average years of schooling is slightly over 6 years in these countries, and had not increased much since 1975, this is a sizable effect.

4.3 Effect of Life Expectancy on Labor Force Participation

In this section I examine the relationship between labor force participation and adult life expectancy. On the one hand, the horizon effect encourages work and savings as the probability of surviving to old age increases. On the other, the general equilibrium effect of increased population size will reduce wages and decrease the incentive to work. In the case of sub-Saharan Africa where life expectancy is falling over time, this would lead to a rise in wages and individuals will increase labor force participation as long as the substitution effect dominates, i.e. $\sigma < 1$. While examining the impact of life expectancy on wages directly would be the ideal first step, wage data is not available in the DHS. I test the effect of increased life expectancy on the participation decision as follows:

$$LFPR_{art} = \alpha + \beta LE_{15rt} + \eta_r + \lambda_t + \epsilon_{art}, \tag{13}$$

where a refers to age group, r refers to region and t refers to year. Labor force participation is the fraction of people who report to be working. LE_{15rt} is life expectancy at 15 in region r and year t. The regression also includes year and region fixed effects. Since work histories are not available labor force participation is observed only during the survey year. In order to control for region fixed effects, I include in the regressions only those countries where at least two surveys are available. This significantly reduces my sample size relative to fertility and education regressions reported in the previous tables.

Table 7 shows the results for both females and males. As the table shows, life expectancy increases labor force participation among females but not males. The coefficient is marginally significant. When I divide the sample into low and high HIV countries, the results remain for women in high HIV countries but not for women in low HIV countries.

5 Conclusion

There is an on-going debate in the literature on the impact of health improvements and increased life expectancy on development and growth. The current paper contributes to this debate on several grounds. First, I write down a comprehensive general equilibrium model which incorporates endogenous fertility, education, and labor supply. Second, I construct a new panel data set to test the implications of this model. More specifically, I use birth and sibling histories to construct age-specific birth rates and age-specific mortality rates at the country region level in sub-Saharan Africa. Since reliable vital statistics are often not available, the data I construct may be the most accurate data on fertility and mortality available for many of these countries. Since I build the panel from micro data, I can exploit within country regional variation which is not often used in this literature. The data is also unique in terms of the number of surveys (67) and countries (28) covered and span of years it encompasses, 1975-2007. My results suggest that increases in life expectancy reduce fertility, increase education, and increase labor force participation of women (but not men). Overall, my empirical results suggest that in sub-Saharan Africa, increases in life expectancy will have a positive impact on growth through fertility and education and possibly labor supply, but the effect will be small. On the other hand, my results rule out the possibility that recent shocks to adult mortality in high HIV countries will reduce fertility, increase labor productivity, and lead to faster growth.

References

Acemoglu, Daron and Simon Johnson (2007). "Disease and Development: The Effect of Life Expectancy on Economic Growth", *Journal of Political Economy*, 115(6): 925–985.

Ashraf, Quamrul, Ashley Lester, and David Weil (2008). "When Does Improving Health Raise GDP?", *NBER Macroeconomics Annual*, 23: 157–203.

Becker, Gary S., and Robert J. Barro (1988). "Reformulation of the Economic Theory of Fertility", *Quarterly Journal of Economics*, 103(1): 1–25.

Becker, Gary S., Tomas J. Philipson and Rodrigo Soares (2005). "The Quantity and Quality of Life and the Evolution of World Inequality", *American Economic Review*, 95(1): 277–291.

Bicego, George (2008). "Estimating Adult Mortality Rates in the Context of the AIDS Epidemic in sub-Saharan Africa: Analysis of DHS Sibling Histories", *Health Transition Review*, 7.

Bleakley, Hoyt (2007). "Disease and Development: Evidence from Hookworm Eradication in the American South", *Quarterly Journal of Economics*, 122(1): 73–11.

Bloom, David E., and Jeffrey D. Sachs (1998). "Geography, Demography, and Economic Growth in Africa", *Brookings Papers on Economic Activity*, 2:207–273.

Bloom, David E., David Canning, and Jaypee Sevilla (2002). Demographic Dividend: A New Perspective on the Economic Consequences of Population Change. Santa Monica, Calif.: RAND, MR-1274.

Bloom, David E., David Canning, and Jaypee Sevilla (2004). "The Effect of Health on Economic Growth: A Production Function Approach", *World Development*, 32(1): 1–13.

Bloom, David E., David Canning and Gunther Fink (2009). "Disease and Development Revisited", NBER Working Paper No. 15137.

Boucekkine, Raouf, Rodolphe Desbordes and Helene Latzer (2009). "How do Epidemics Induce Behavioral Changes?", *Journal of Economic Growth*, 14(3): 233–264.

Cervelatti, Matteo and Uwe Sunde (2009). "Life Expectancy and Economic Growth: The Role of Demographic Transition", IZA Discussion Paper No. 4016.

Cervelatti, Matteo and Uwe Sunde (2005). "Human Capital, Mortality and Fertility: A Unified Theory of the Economic and Demographic Transition", IZA Discussion Paper, 2905.

Chakraborty, Shanka and Masumi Das (2009). "Death and Capital: Physical and Human Capital Investment under Missing Annuity Markets", Working Paper.

Cordoba, Juan Carlos and Marla Ripoll (2009). "Schooling and Development: The Role of Credit Limits, Fertility and Mortality", Working Paper.

Deaton, Angus (2006). "Global Patterns of Income and Health: Facts, Interpretations, and Policies", NBER Working Paper No. 12735.

Doepke, Matthias (2005). "Child Mortality and Fertility Decline: Does the Barro-Becker Model Fit the Facts?", *Journal of Population Economics*, 18(2): 337–366.

Durand, John D. (1975). "The Labor Force in Economic Development and Demographic Transition", in Leon Tabah, ed., Population Growth and Economic Development in the Third World, 47–78.

Fink, Gunther and Sebastian Linnemayr (2009). "HIV Does Matter for Fertility: Human Capital, Mortality and Family Size", Harvard Public School of Health, mimeo.

Fonseca, Raquel, Pierre-Carl Michaud, Arie Kapteyn and Titus Galama (2009). "The Demand for Health over the Life-Cycle", Working Paper.

Fortson (2009). "HIV/AIDS and Fertility", *American Economic Journal: Applied Economics*, 1(3): 170–194.

Gakidou, Emmanuela and Gary King (2006). “Death by Survey: Estimating Adult Mortality without Selection Bias from Sibling Survival Data”, *Demography*, 43(3): 569–585.

Gallup, John L., Jeffrey D. Sachs, and Andrew D. Mellinger (1999). “Geography and Economic Development”, *International Regional Science Review*, 22(2): 179–232.

Galor, Oded and David N. Weil (1996). “The Gender Gap, Fertility and Growth", *American Economic Review*, 86(3): 374–387.

Goldin, Claudia (1990). Understanding the Gender Gap: An economic History of American Women. New York: Oxford University Press.

Goldin, Claudia (1995). "The U-Shaped Female Labor Force Function in Economic Development and Economic History”, in T. P. Schultz, ed., Investment in Women’s Human Capital and Economic Development. Chicago, IL: University of Chicago Press, 61–90.

Halek, M and J. Eisenhauer (2001). “Demography or Risk Aversion”, *Journal of Risk and Insurance*, 68(1): 1–24.

Hansen, L. P. and K. J. Singleton (1983). “Stochastic Consumption, Risk Aversion, and the Temporal Behavior of Asset Returns”, *Journal of Political Economy*, 91(2): 249–265.

Herlihy, David (1997). The Black Death and The Transformation of the West. Cambridge: Harvard University Press.

Jayachandran, Seema, and Adriana Lleras-Muney (2009). “Life Expectancy and Human Capital Investments: Evidence from Maternal Mortality Declines”, *Quarterly Journal Economics*, 124(1): 349–398.

Juhn, Chinhui, Sebnem Kalemli-Ozcan, and Belgi Turan (2009). “HIV and Fertility in Africa: First Evidence from Population Based Survey”, NBER Working Paper 14248.

Kalemli-Ozcan, Sebnem (2003). “A Stochastic Model of Mortality, Fertility, and Human Capital Investment”, *Journal of Development Economics*, 70(1): 103–118.

Lorentzen, Peter, John McMillan, and Romain Wacziarg (2008). “Death and Development”, *Journal of Economic Growth*,” 13(1): 81–124.

Luke, Nancy, and Kaivan Munshi (2006). “New Roles for Marriage in Urban Africa: Kinship Networks and the Labor Market in Kenya.” *Review of Economics and Statistics*, 88(2):264-282.

Mankiw, N.G. (1985). “Consumer Durables and the Real Interest Rate", *Review of Economics and Statistics*, 67(3): 353–362.

Mankiw N. Gregory and Stephen P. Zeldes (1991). “The Consumption of Stockholders and Nonstockholders”, *Journal of Financial Economics*, 29(1): 97–111.

Miguel, Edward, and Michael Kremer (2004). “Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities”, *Econometrica*, 72(1): 159Ű-217.

Oster, Emily (2005). “Sexually Transmitted Infections, Sexual Behavior, and the HIV/AIDS Epidemic.” *Quarterly Journal of Economics*, 120(2):467–515.

Oster, Emily (2009). “Estimating HIV Prevalence and Incidence in Africa From Mortality Data”, Working Paper, University of Chicago.

Shastry, G. K., and David N. Weil (2003) . “How Much of the Cross-Country Variation in Income is Explained by Health?”, *Journal of the European Economic Association*, 1(2-3): 387–396.

Soares, Rodrigo R. (2005). “Mortality Reductions, Educational Attainment, and Fertility Choice”, *American Economic Review*, 95(3): 580–601.

Soares, Rodrigo R. (2006). "The Effect of Longevity on Schooling and Fertility: Evidence from the Brazilian Demographic and Health Survey", *Journal of Population Economics*, 19(1): 71–97.

Soares, Rodrigo R. and Bruno L. S. Falcao (2008). "The Demographic Transition and the Sexual Division of Labor", *Journal of Political Economy*, 116(6): 1058–1104.

Szpiro, George G. (1986). "Measuring Risk Aversion: An Alternative Approach" *Review of. Economics and Statistics*, 68(1): 156–159.

Tamura, Robert (2006). "Human Capital and Economic Development", *Journal of Development Economics*, 79(1): 26–72.

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

Trussell, James and German Rodriguez (1990). "A Note on the Sisterhood Estimator of Maternal Mortality", *Studies in Family Planning*, 21(6): 344–346.

Weil, David N. (2007). "Accounting for the Effect of Health on Economic Growth", *Quarterly Journal of Economics*, 122(3): 1265–1306.

Young, Alwyn (2005). "The Gift of the Dying: The Tragedy of AIDS and the Welfare of Future African Generations", *Quarterly Journal of Economics*, 120(2): 423–466.

Zhang, Jie, and Junsen Zhang (2005). "The Effect of Life Expectancy on Fertility, Saving, Schooling and Economic Growth: Theory and Evidence", *Scandinavian Journal of Economics*, 107(1): 45–66.

Figure 1: Response of Fertility to Life Expectancy

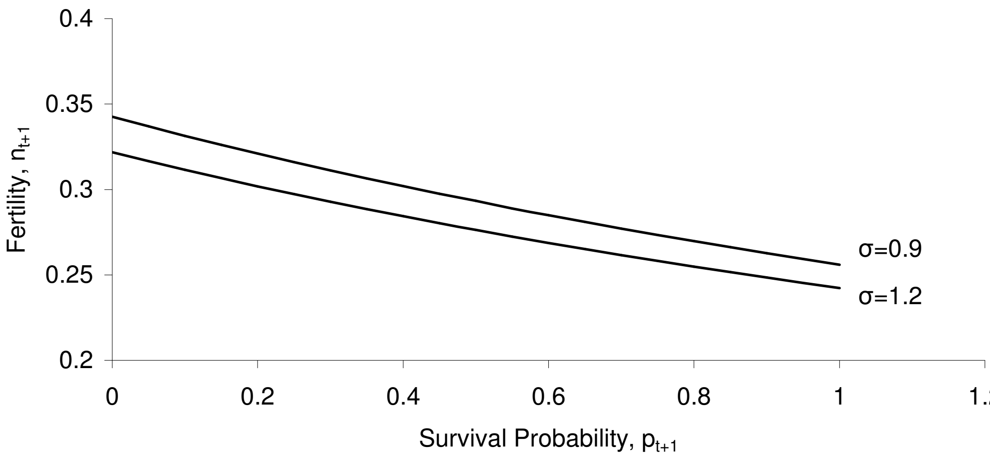


Figure 2: Response of Education to Life Expectancy

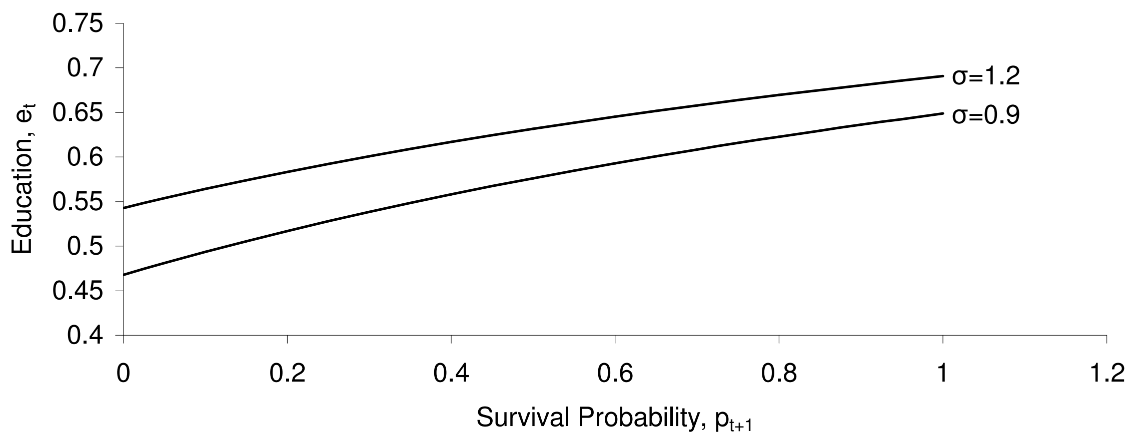


Figure 3: Response of Labor Supply to Life Expectancy

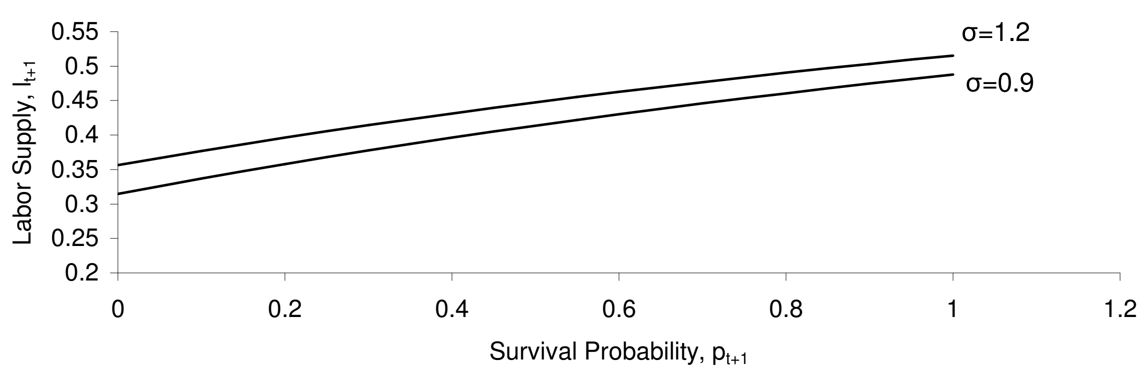


Figure 4: Response of Fertility to Wages

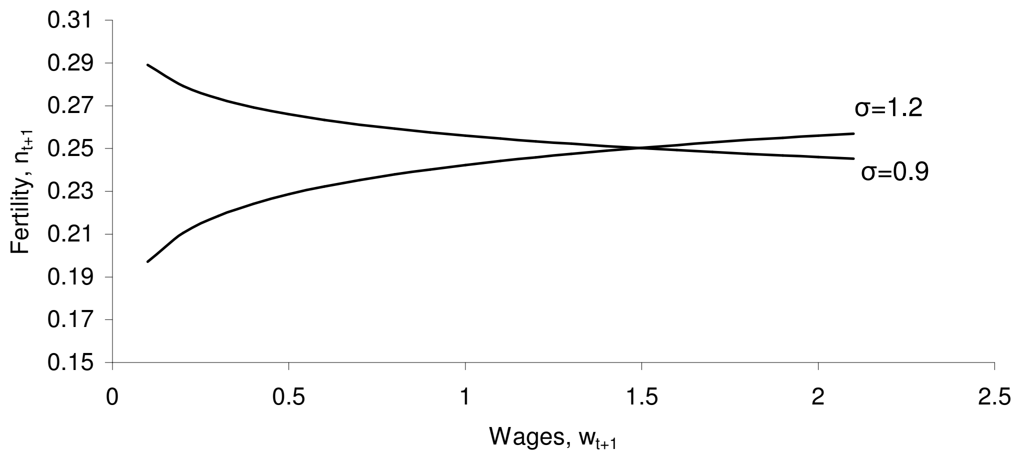


Figure 5: Response of Education to Wages

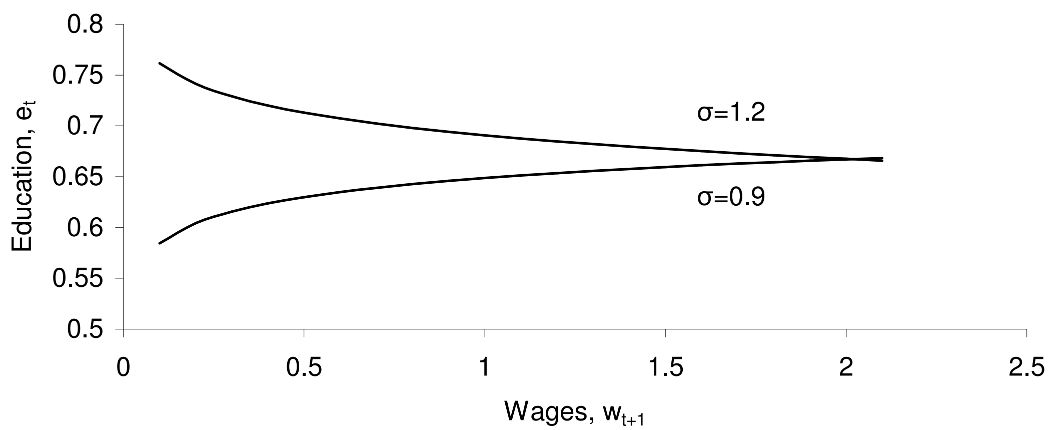


Figure 6: Response of Labor Supply to Wages

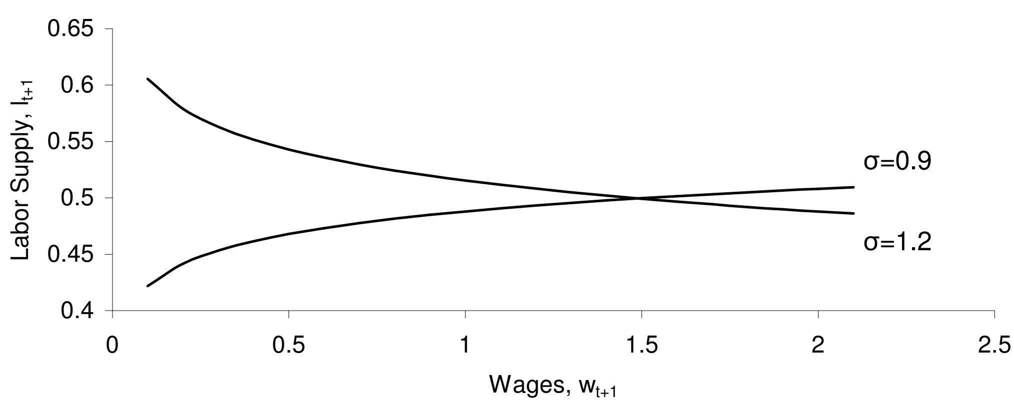
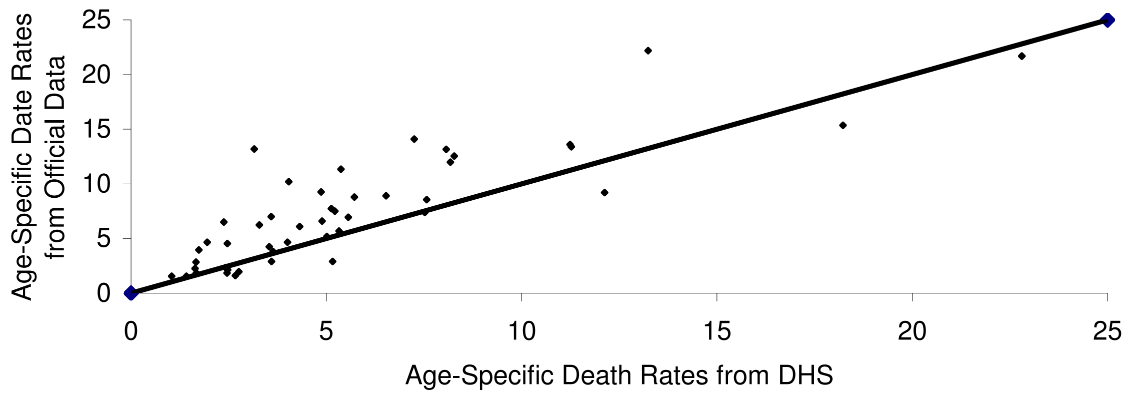


Figure 7: Reliability of Sibling Histories: Zimbabwe



Notes: Official death rates for Zimbabwe for years 1981, 1985, 1989, 1990, 1991 and 1994 from Feeney(2001) are compared to death rates calculated from sibling histories. Age-specific date rates for men and women are calculated for ages 15-24, 25-34, 35-44 and 45-54 and rates are per 1000 population. Line represents the 45-Degree Line.

Table 1: Mean Age-Specific Death Rates

	1975	1980	1990	2000
Ages 0-4	136.67	138.50	150.01	152.25
Ages 5-9	24.38	21.74	19.74	18.27
Ages 10-14	15.63	13.68	12.29	12.56
Ages 15-19	15.10	13.09	13.60	13.57
Ages 20-24	17.00	14.65	16.28	20.72
Ages 25-29	18.73	15.32	19.52	31.45
Ages 30-34	24.23	21.14	27.16	45.24
Ages 35-39	24.69	23.18	27.75	54.50
Ages 40-44	39.49	22.65	36.51	65.56
Ages 45-49	29.73	33.42	39.05	65.44
Average Mortality (0-49)	34.57	31.74	36.19	47.96
Average Adult Mortality (15-49)	24.14	20.49	25.70	42.36

Notes: Average mortality rates across 52 surveys from 28 countries are shown. Death rates are per 1000 population.

Table 2: Mean Age-Specific Death Rates by Gender

	Panel A: Female Age-Specific Death Rates			
	1975	1980	1990	2000
Ages 0-4	126.46	128.68	141.84	146.62
Ages 5-9	23.54	21.33	18.90	17.44
Ages 10-14	14.42	12.29	11.80	12.32
Ages 15-19	14.63	12.69	13.96	14.13
Ages 20-24	15.02	13.04	16.52	22.44
Ages 25-29	16.50	13.76	18.15	34.72
Ages 30-34	26.56	17.68	24.12	43.99
Ages 35-39	18.43	17.01	25.46	50.06
Ages 40-44	33.86	17.97	31.01	54.27
Ages 45-49	44.81	28.60	34.75	56.39
Average Female Mortality (0-49)	33.42	28.31	33.65	45.24
Average Female Adult Mortality (15-49)	24.26	17.25	23.42	39.43
	Panel B: Male Age-Specific Death Rates			
	1975	1980	1990	2000
Ages 0-4	146.07	147.64	157.73	157.53
Ages 5-9	25.14	22.02	20.58	19.11
Ages 10-14	16.69	15.00	12.77	12.81
Ages 15-19	15.48	13.53	13.27	12.99
Ages 20-24	18.63	16.20	16.05	19.04
Ages 25-29	20.83	16.79	21.02	28.19
Ages 30-34	23.37	24.44	30.28	46.51
Ages 35-39	30.74	27.95	29.92	59.24
Ages 40-44	39.81	27.42	42.31	77.26
Ages 45-49	17.02	40.75	43.33	75.13
Average Male Mortality (0-49)	35.38	35.18	38.73	50.78
Average Male Adult Mortality (15-49)	23.70	23.87	28.02	45.48

Notes: Average mortality rates across 52 surveys from 28 countries are shown. Death rates are per 1000 population. Panel A displays the rates for females and panel B displays male mortality rates.

Table 3: Life Expectancy at Birth

	1975	1980	1990	2000
Benin	44.7	46.5	46.5	47.0
Burkina Faso	45.6	46.0	46.3	45.7
Cameroon	44.9	48.4	48.7	43.3
CAR	43.9	47.0	42.6	
CDR	47.8	48.8	46.2	42.6
Chad	45.0	43.5	43.6	43.4
Congo	39.5	51.8	49.4	44.0
Cote d'Ivoire	47.6	49.7	46.4	47.2
Ethiopia	43.1	43.9	43.5	
Gabon	49.1	50.0	51.0	50.8
Guinea	42.3	42.5	42.8	44.4
Kenya	52.1	52.4	51.4	46.5
Lesotho	46.8	48.5	51.2	43.9
Liberia	54.1	53.5	41.3	47.5
Malawi	44.8	46.3	43.1	40.9
Mali	42.1	41.7	42.2	44.9
Mozambique	47.3	46.0	44.7	44.7
Namibia	51.8	52.4	51.1	48.1
Niger	41.2	41.7	40.9	43.9
Rwanda	47.4	45.3	42.0	36.8
Senegal	44.0	45.8	48.4	46.9
South Africa	51.4	52.1	53.0	
Swaziland	52.2	51.5	54.6	44.7
Tanzania	49.1	47.9	47.0	46.1
Togo	45.6	46.1	46.8	
Uganda	45.4	44.2	43.8	43.7
Zambia	50.5	49.2	43.6	39.7
Zimbabwe	52.6	51.9	53.0	46.1
Average	46.8	47.7	46.6	44.7
Low HIV Countries(HIV<=%5)	45.1	46.2	44.7	44.5
High HIV Countries (HIV>%5)	48.8	49.4	48.8	44.9

Notes: Life Expectancy measures are calculated from 52 surveys from 28 countries.

Table 4: Life Expectancy at 15

	1975	1980	1990	2000
Benin	40.5	41.6	41.8	41.0
Burkina Faso	41.0	41.0	41.6	40.7
Cameroon	38.2	42.8	41.7	38.2
CAR	36.8	40.6	37.3	
CDR	41.4	42.1	41.0	38.8
Chad	41.0	39.8	40.7	38.8
Congo	28.8	42.6	39.9	37.7
Cote d'Ivoire	40.7	42.5	39.9	39.4
Ethiopia	38.6	40.0	38.0	
Gabon	40.8	41.5	41.3	40.9
Guinea	39.6	39.9	41.3	40.2
Kenya	42.6	43.0	42.3	38.7
Lesotho	38.4	38.9	41.1	35.3
Liberia	44.3	43.2	36.8	41.3
Malawi	41.3	42.1	39.7	34.2
Mali	40.3	40.2	40.7	41.4
Mozambique	40.6	40.4	41.6	39.0
Namibia	40.8	41.7	40.5	37.4
Niger	40.3	40.3	41.6	41.7
Rwanda	42.0	39.4	37.7	37.2
Senegal	41.1	41.3	41.7	41.4
South Africa	42.2	42.3	42.1	
Swaziland	41.6	40.3	42.0	35.4
Tanzania	42.2	41.3	41.3	38.2
Togo	41.5	42.3	41.8	
Uganda	39.5	39.5	38.3	36.7
Zambia	42.3	42.4	38.7	33.4
Zimbabwe	42.1	41.6	41.7	35.1
Average	40.2	41.2	40.6	38.3
Low HIV Countries(HIV<=%5)	40.1	41.2	40.3	40.0
High HIV Countries (HIV>%5)	40.7	41.3	40.7	36.9

Notes: Life Expectancy measures are calculated from 52 surveys from 28 countries. Life expectancy at 15 is the average expected years of life individuals are expected to live between 15 and 60 conditional on surviving to 15.

Table 5: Effect of Life Expectancy on Fertility: 1975-2005

	All Countries	Low HIV Countries	High HIV Countries
	(1)	(2)	(3)
	Dependent Variable: Age-Specific Birth Rates by Region by Year		
Life Expectancy	-2.442***	-2.202***	-1.544**
	(0.335)	(0.362)	(0.707)
Controls	Region FEs, Year FEs, Region-Specific Time Trends, Age Group FE		
Mean	216	217	215
R^2	0.814	0.822	0.817
N (Region x Year x Age Group)	5971	3096	2875

Notes: Dependent variable is the number of children per 1000 women by age-group by region and by year. Life Expectancy is the average number of years individuals in an age-group are expected to live conditional on surviving to age a. Years used in the regressions are 1975, 1980, 1985, 1990, 1995, 2000 and 2005. Women are grouped into 5 groups according to their ages: 15-19, 20-24, 25-29, 30-34, 35-39. Column (1) includes 28 countries, column (2) includes 15 countries in sub-Saharan Africa with less than 5 % HIV prevalence, and column (3) includes 13 countries in sub-Saharan Africa with more than 5% HIV prevalence. HIV prevalence is as of 2008 and taken from UNAIDS/WHO database. Regressions have region, year and age group fixed effects and region-specific time trends. Regressions are weighted by the number of women by age group by region by year. Standard errors are clustered at region by year level. Asterisks denote significance levels (*=.10, **=.05, ***=.01).

Table 6: Effect of Life Expectancy on Education: 1975-2007

	All Countries		Low HIV Countries		High HIV Countries	
	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: Years of Schooling by Cohort by Region					
LE at 15 when cohort was 5-15	0.096***	0.209***	0.078***	0.211***	-0.003	-0.021
	(0.022)	(0.020)	(0.021)	(0.024)	(0.045)	(0.040)
Linear Cohort x Region	0.002***	0.001	0.000***	0.001***	0.001***	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
Controls	Region FEs, Cohort FEs, Region-Specific Cohort Trends					
Mean	4.33	5.91	3.05	4.84	6.02	7.13
R^2	0.971	0.926	0.960	0.907	0.952	0.909
N (Cohort x Region)	916	859	497	467	419	392

Notes: Dependent variable is the average years of schooling by region by cohort. Life expectancy variable is the number of years a 15 years-old is expected to live when the cohort is 5 to 15 years old. Columns (1) and (2) include 28 countries, columns (3) and (4) include 15 countries in sub-Saharan Africa with less than 5 % HIV prevalence, columns (5) and (6) include 13 countries in sub-Saharan Africa with more than 5% HIV prevalence. HIV prevalence is as of 2008 and taken from UNAIDS/WHO database. 5-year birth cohorts are 1970-1974, 1975-1979, 1980-1984, 1985-1989, and 1990-1994. Regressions are weighted by the population in year-region-sex cell. Standard errors are clustered at region by year level. Asterisks denote significance levels (*=.10, **=.05, ***=.01).

Table 7: Effect of Life Expectancy on Labor Force Participation

	All Countries		Low HIV Countries		High HIV Countries	
	Female	Male	Female	Male	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: Percentage Working by Age Group by Region by Year					
Life Expectancy at 15	0.010*	0.003	0.008	-0.003	0.017*	-0.018
	(0.005)	(0.005)	(0.008)	(0.005)	(0.008)	(0.012)
Controls	Region FEs, Year FEs, Age Group FE					
Mean	0.566	0.710	0.586	0.739	0.540	0.681
R^2	0.819	0.821	0.867	0.829	0.838	0.871
N (Region x Year x Age Group)	2926	2246	1407	1154	1519	1092

Notes: Dependent variable is the proportion of females/males that are working by age group by region by year. Life expectancy at 15 is the number of years a 15 years old is expected to live conditional on surviving to 15. Only countries with more than 1 survey are used in the regressions. Columns (1) and (2) include 20 countries, columns (3) and (4) include 12 countries in sub-Saharan Africa with less than 5 % HIV prevalence, columns (5) and (6) include 8 countries in sub-Saharan Africa with more than 5% HIV prevalence. HIV prevalence is as of 2008 and taken from UNAIDS/WHO database. Regressions are weighted by the population in year-region-age group and sex cell. Standard errors are clustered at region by year level. Asterisks denote significance levels (*=.10, **=.05, ***=.01).

A-1 Appendix I

Using intertemporal budget constraint and considering $C_{t+1} = C_{t+2}$

$$c_{t+1} + p_{t+1}c_{t+2} = e_t h_p l_{t+1} w_{t+1} \tag{A-1}$$

$$c_{t+1} = \frac{e_t h_p l_{t+1} w_{t+1}}{1 + p_{t+1}} \tag{A-2}$$

Using first-order conditions for n_{t+1} and l_{t+1}

$$(1 - v n_{t+1} - l_{t+1})^{-\sigma} = \lambda e_t h_p w_{t+1} \tag{A-3}$$

$$n_{t+1}^{-\sigma} = v \lambda_{t+1} e_t h_p w_{t+1} \tag{A-4}$$

$$n_{t+1}^{-\sigma} = v (\frac{e_t h_p l_{t+1} w_{t+1}}{1 + p_{t+1}})^{-\sigma} e_t h_p w_{t+1} \tag{A-5}$$

$$n = e_t^{\frac{\sigma-1}{\sigma}} w_{t+1}^{\frac{\sigma-1}{\sigma}} l_{t+1} h_p^{\frac{\sigma-1}{\sigma}} v^{-1/\sigma} (p_{t+1} + 1)^{-1} \tag{A-6}$$

Using first-order conditions for e_t and l_{t+1}

$$(1 - e_t)^{-\sigma} = \lambda_{t+1} h_p l_{t+1} w_{t+1} \tag{A-7}$$

$$(1 - e_t)^{-\sigma} = (\frac{e_t h_p l_{t+1} w_{t+1}}{1 + p_{t+1}})^{-\sigma} h_p l_{t+1} w_{t+1} \tag{A-8}$$

$$e_t = (1 + h_p^{\frac{\sigma-1}{\sigma}} l_{t+1}^{\frac{\sigma-1}{\sigma}} w^{\frac{\sigma-1}{\sigma}} (p_{t+1} + 1)^{-1})^{-1} \tag{A-9}$$

Combining Eq.(A-3) and (A-6) and (A-9) yields a single equation for l_{t+1}:

$$1 - l_{t+1} - l_{t+1}[(1 + v^{\frac{\sigma-1}{\sigma}})(1 + w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}} l_{t+1}^{\frac{\sigma-1}{\sigma}} \frac{1}{1 + p_{t+1}})^{\frac{1-\sigma}{\sigma}} w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}} \frac{1}{1 + p_{t+1}}] = 0 \tag{A-10}$$

Using Newton-Raphson iteration method it can be numerically proofed that:

$$\frac{dl_{t+1}}{dp_{t+1}} > 0 \;\; if \;\; \sigma > 0.5 \tag{A-11}$$

and

$$\frac{dl_{t+1}}{dw_{t+1}} < 0 \;\; if \;\; \sigma > 1 \tag{A-12}$$

$$\frac{dl_{t+1}}{dw_{t+1}} > 0 \;\; if \;\; 0.5 < \sigma < 1 \tag{A-13}$$

To find an equation for fertility:

$$n_{t+1}^{-\sigma} = v(1 - vn_{t+1} - l_{t+1})^{-\sigma} \tag{A-14}$$

$$l_{t+1} = 1 - n_{t+1}v - n_{t+1}v^{1/\sigma} \tag{A-15}$$

Combining Eq.(A-10) and (A-15) gives a single equation for n_{t+1} in terms of exogenous variables:

$$1 - (1 - n_{t+1}v - n_{t+1}v^{\frac{1}{\sigma}})[[w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}} \frac{1}{1+p_{t+1}}(1 + w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}} (1 - n_{t+1}v - n_{t+1}v^{\frac{1}{\sigma}})^{\frac{\sigma-1}{\sigma}} \frac{1}{1+p_{t+1}})^{\frac{1-\sigma}{\sigma}}$$
$$(1 + v^{\frac{\sigma-1}{\sigma}})] + 1] = 0 \tag{A-16}$$

Numerical iteration method yields

$$\frac{dn_{t+1}}{dp_{t+1}} < 0 \;\; if \;\; \sigma > 0.5 \tag{A-17}$$

Similarly

$$\frac{dn_{t+1}}{dw_{t+1}} < 0 \;\; if \;\; 0.5 < \sigma < 1 \tag{A-18}$$

$$\frac{dn_{t+1}}{dw_{t+1}} > 0 \;\; if \;\; \sigma > 1 \tag{A-19}$$

Finally to find an equation for education:

$$(1-e_t)^{-\sigma} = \lambda_{t+1} h_p l_{t+1} w_{t+1} \tag{A-20}$$

$$(1-e_t)^{-\sigma} = (\frac{e_t h_p l_{t+1} w_{t+1}}{1+p_{t+1}})^{-\sigma} h_p l_{t+1} w_{t+1} \tag{A-21}$$

$$l = [\frac{(1-e_t)(1+p_{t+1})}{e_t w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}}}]^{\frac{\sigma}{\sigma-1}} \tag{A-22}$$

Combining Eq.(A-6), (A-10) and (A-22) one can obtain the corresponding equation for schooling decision e_t in terms of exogenous variables:

$$1 - [\frac{(1-e_t)(1+p_{t+1})}{e_t w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}}}]^{\frac{\sigma}{\sigma-1}} [1 + [(1+v^{\frac{\sigma-1}{\sigma}})(w_{t+1}^{\frac{\sigma-1}{\sigma}} h_p^{\frac{\sigma-1}{\sigma}} \frac{1}{1+p_{t+1}} e_t^{\frac{\sigma-1}{\sigma}})]] = 0 \tag{A-23}$$

It can be numerically proofed that:

$$\frac{de_t}{dp_{t+1}} > 0 \;\; if \;\; \sigma > 0.5 \tag{A-24}$$

and

$$\frac{de_t}{dw_{t+1}} < 0 \;\; if \;\; \sigma > 1 \tag{A-25}$$

$$\frac{de_t}{dw_{t+1}} > 0 \;\; if \;\; 0.5 < \sigma < 1 \tag{A-26}$$

A-2 Appendix II

A-2.1 Surveys Used:

Table A1 lists the 67 Demographic Health Surveys (DHS) from 28 countries used in the regressions. Datasets are available from Measure DHS, ICF Macro, at www.measuredhs.com.

A-2.2 Age-Specific Death Rate Calculation:

Age-specific death rate is the total number of deaths of a specified age in a region divided by the population of the same age in the same geographic area and multiplied by 1000. For example, to find the mortality rate of 30 years old in 1994 in region A, I divide the number of 30 years-old siblings died in 1994 in region A by the number of 30 years-old siblings alive at the beginning of 1994, and multiply by 1000.

When annual numbers of deaths for specific ages are small ($<$ 10 or 20), calculated age-specific mortality rates may be too unstable or unreliable for analysis. To eliminate this noise and volatility across years, I calculate death rates by taking three-year averages. For example, to find the mortality rate of 30 years old in 1994 in region A, I divide the number of 30 years-old siblings died between 1993 and 1995 in region A by the number of 30 years-old siblings alive between 1993 and 1995. Usage of multiple surveys matched on the regions increases the sibling history information, thus increases the robustness of death rate computations.

A-2.3 Life Expectancy Calculation:

Life expectancy is the number of years an individual is expected to live if he/she experienced the current age-specific death rates throughout his/her life. After age-specific death rates are calculated as explained above, they are used to calculate

Table A-1: Surveys Used in the Paper

Country	Number of Survey Years	Survey Years
Benin	3	2006*, 2001, 1996*
Burkina Faso	3	2003*, 1998*, 1992
Cameroon	3	2004*, 1998*, 1991
Central African Republic	1	1994/1995*
Chad	2	2004*, 1996*
Congo	1	2005*
Cote d'Ivoire	2	2005*, 1994*
Democratic Republic of the Congo	1	2007*
Ethiopia	2	2005*, 2000*
Gabon	1	2000*
Guinea	2	2005*, 1999*
Kenya	4	2003*, 1998*, 1993, 1989
Lesotho	1	2004*
Liberia	1	2007*
Malawi	3	2004*, 2000*, 1992*
Mali	4	2006*, 2001*, 1995/1996*, 1987
Mozambique	2	2003*, 1997*
Namibia	3	2006/2007*, 2000*, 1992*
Niger	3	2006*, 1998, 1992*
Rwanda	2	2005*, 2000*
Senegal	4	2006, 2005*, 1996, 1992*
South Africa	1	1998*
Swaziland	1	2006*
Togo	2	1998*, 1988
Uganda	4	2006*, 2000*, 1995*, 1988
United Republic of Tanzania	3	2004*, 1999, 1996*
Zambia	4	2007*, 2001*, 1996*, 1992
Zimbabwe	4	2005*, 1999*, 1994*, 1988

Notes: In total my dataset consists of 67 surveys from 28 countries. * indicates that the survey has sibling histories and is used in mortality calculations. Although Nigeria 1999 has sibling histories, Nigeria is not used in the study since the quality of the sibling history module is questionable. In all of the surveys listed here sibling histories are over 98% complete, whereas for Nigeria only 68% of the sibling information is complete.

a life table from which one can calculate the probability of surviving to each age. For example, if 10% of a group of siblings alive at age 30 die before reaching to age 31 in 1994, then the age-specific death probability at age 30 in 1994 would be 10%. Life expectancy at age a is then calculated by adding up the survival probabilities at each age. e(a-b) shows the expected years of life between ages a and b conditional on survival to age a. If data is believed to be noisy after an age it can censored at age b. My results are not sensitive to censoring age. Life expectancy formula is as follows:

$$e(a-b) = (\sum_{t=a,a+1,..}^{b} (t+1/2) * (\prod_{\tau=a}^{t-1}(1-q_\tau)) * q_t) + b * (\prod_{\tau=a}^{b-1}(1-q_\tau)) * (1-q_b) - a \tag{A-27}$$

where q_t mortality rate for age t, ${}_tp_a$ is the probability of survival from age a to age t. 1/2 is added to each year assuming, in average, people live half a year at their final age. The term after summation a is subtracted because formula gives the life expectancy beyond age a.

A-2.4 Fertility:

Age-Specific Birth Rates: I use women's retrospective reports of their children in the DHS to reconstruct the number of births per 1000 women at each age in each region in each year. More specifically, to find birth rate of 30 years-old women in region A in year 1994, I divide the total number of births to 30 years-old women in region A in 1994 by the total number of women, regardless of having birth or not, at age 30 in region A in 1994 and multiply by 1000.

Total Fertility Rate: Calculated age-specific birth rates are used to calculate total fertility rate by region by year. More specifically, total fertility rate (TFR) is the average number of births that women in the sample would have by the time they reach age 49 if they were to give birth at the current age-specific fertility rates. It is the sum of the age-specific fertility rates multiplied by five. TFR formula is as follows:

$$TFR_{r,t} = \sum_{a=1}^{49} \frac{Births_{r,t,a}}{Women_{r,t,a}} \tag{A-28}$$

where r is region, t is year and a is age. $Births_{r,t,a}$ is the total number of births to women at age a in region r in year t. Similarly, $Women_{r,t,a}$ is the number of women at age a in region r in year t.