**June 2003**

# The Impact of Life Expectancy in Human Capital Accumulation: AIDS

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***Paper prepared for presentation at the WEAI annual conference, Denver, Colorado, July 11-15, 2003***

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## Abstract

A three period overlapping generations model is developed to investigate the impact of shorter life expectancy due to disease, on human capital investment decisions and income growth. This research is particularly relevant to Sub-Saharan Africa given the dramatic reduction in life expectancy due to HIV/AIDS and the potential lasting effects on growth. Our results indicate that as life expectancy shortens so does schooling inducing a lower growth rate of income. These relationships are even more pronounced for the African continent than for the rest of the world.



**Keywords:** HIV/AIDS, Africa, life expectancy, growth, overlapping generations.

JEL code: O150


## Introduction

Good health is an important component of human well-being. At the same time, as noted by Jeffrey Sachs (2001), improvements in health and life expectancy are likely to contribute to greater economic growth and development. One way in which better health might lead to greater economic growth is through its impact on individual decisions concerning investments in human capital. If individuals can expect to realize returns to investment in education and training over a longer time horizon, they may elect to devote more of their scarce resources to human capital formation. The greater the human capital stock of a country the greater its economic growth is likely to be. Of course, the relationship between health and education runs in both directions. Better health prospects may lead to increased interest in education but education also leads to opportunities and choices that result in better health. Traditionally, it is this second aspect of the relationship that has been emphasized. This paper, however, builds on recent literature emphasizing the impact of health on human capital investments.

The relationship between life expectancy and human capital investments has taken on a new urgency as diseases such as HIV/AIDS have spread. In some African countries, life expectancies have actually declined in recent years as a result of the HIV/AIDS pandemic. Recently, it has been widely reported that there is great potential for HIV/AIDS pandemics on a similar scale to that of Africa in other developing countries, many, such as China and India, with very large populations. Africa has long suffered from diseases such as malaria and tuberculoses and life expectancy at birth has been significantly lower than in Asia or Latin America for some time. In 1965, life expectancy at birth in sub-Saharan Africa was 41 years for males and 43 years for females compared with 49 years and 60 years respectively for all low-income countries and 51 years and 63 years for males and females in China and India (World Bank, 1986). For the period 1995-2000, life expectancy averaged about 49 years in sub-Saharan Africa compared with about 69 for East Asia and Latin America and 64 for all developing countries (UNDP, 2001). The fact that life expectancy in Sub-Saharan Africa has grown slowly and in some cases even declined may provide a partial explanation for the relatively poor economic performance of this region.

This paper is intended to capture the AIDS epidemic's impact on the subsequent human capital accumulation and therefore growth, through shortened life expectancy. We developed a three period overlapping generation model to investigate the effects of increased mortality and shortened life expectancy on human capital investment decisions of representative agents. We briefly review recent efforts to investigate the correlation between human capital investment and health. Then we describe the framework of our model before discussing implications and empirical tests of some parts of the model. The technical specifications and details of the model are appended to the paper.

Although it is recognized that the interaction between health and education may be two-way, traditionally, the dominant causality has been thought to run from education to health. (Grossman, 1973). For a comprehensive review of empirical findings, see Grossman and Kaestner (1997). In terms of policy practices, there are many success stories from industrial countries such as Britain and Japan to newly emerging countries such as the Asian Tigers that attribute their success to policies that emphasize the strategic importance of education. The strategic importance of a population's health, on the other hand, has been ignored. Freeman and Miller (2001) were surprised by the relatively meager accumulation of knowledge about the effects of health on economic growth, suggesting that improved health has rarely been viewed as an effective strategy for increased growth.

The empirical evidence on the correlation between income growth and life expectancy supports the classical view that health is an output of economic growth and development. However, researchers have only been able to show that part of this correlation is accounted for by a causal link running from wealth to health. This suggests that some other factor is at play in accounting for this relationship. Bloom and Canning (2001) argue that health is a form of human capital and therefore an input into the growth process, as well as an output. Bils and Klenow (2000) examine a model with finite-lived individuals in which each generation learns from previous generations and chooses schooling. They asked whether schooling causes growth or the other way around and calibrated versions of two competing models, “schooling to growth” or “growth to schooling”. They found evidence for the latter from the calibration but noted that schooling might be further influencing growth through externalities affecting technology creation and adoption. Though they did not examine the relationship between life span and education time, the equilibrium equation implies that longer life span will lead to more time devoted to education.

Kalemli-Ozcan, Ryder and Weil (1998) examined the role of increased life expectancy in raising human capital investment in the process of economic growth. They developed a continuous time overlapping generation model in which individuals make optimal schooling investment choices in the face of a constant probability of death. They found that mortality decline has significant positive effects on schooling and consumption. Swanson and Kopecky (1999) modeled life expectancy directly with a finite-lifetime continuous time model of human capital acquisitions. The agent allocates t-units of time between work, learning and leisure. Their results suggested that as lifespan increases output per person-hour rises in a concave fashion.

This paper builds on the above literature. To examine how reduction of life expectancy would affect human capital investment decisions and therefore growth, we developed a discrete time overlapping generation model where individuals learn from the old generation and they make a schooling investment decision on two dimensions of human capital, knowing that the human capital acquired from schooling investment will facilitate technological adoption in a later period.

**A Three Period Overlapping Generations Model.**

Kim and Lee (1999) build a two-period overlapping generations model to analyze the effects of technology change on growth rates of income and human capital. Their model includes two dimensions of human capital, referred to as width and the depth. Human capital width represents flexibility, adaptability, and the influence of human capital on the adoption of new technologies. Width determines the adoption cost of a new technology. Human capital depth measures the quality of the human capital stock. The key idea is that the more closely one agent's knowledge is related to the knowledge required for a new technology, the less time the agent spends in adopting the technology. Technical change is stochastic in terms of both its occurrence and its width and depth. Their conclusion is that an increase in technological uncertainty decreases growth rates of income and human capital by lowering efficiencies both in creating new knowledge and in adopting new technologies.

Building on their specifications, we developed a similar model to examine how the risk of premature death would affect investments in human capital and subsequent growth rates. We modified Kim and Lee's model by extending it from a two-period model to a three-period model, and introduced an 'impact' variable of interest to this study: the probability of dying prematurely at the end of the first or the second period. We show that as the probability of surviving the young period increases, the individual tends to increase investment in both width and depth of human capital. If the probability of surviving the adult period increases, given that the individual survived the young period, he tends to invest more in human capital depth while he will reduce his investment in width or flexibility. The growth rate of the economy tends to increase with both of these probabilities. Therefore, lower life expectancy leads to slower growth.

Before explaining the details of the model, the extension to a third period needs to be justified. Kalemi-Ozcan et al. (2000) recognized the limitation of modeling the probability of death as a constant at all ages noting that it is more accurate to allow this probability to vary with a person's life cycle. In general, the probability of death should vary across age groups. For instance, the AIDS epidemic kills more young adults who are more sexually active, than other age groups. If analytical results are sensitive to different age-specific probabilities of dying, we might find support for some policies that target particular age groups. These aspects of the problem cannot be captured in a two-period model.

For this model, human capital plays an essential role in the adoption of new technologies. A representative agent lives at best for three periods, namely, young, adult and old. When he is young, he decides how to allocate his time between work and education. As an adult, he decides how to allocate time between work and technology adoption. When old, he devotes all his time endowment to work earning a wage. The agent faces a probability of dying at the end of the first and second period.

A new and advanced technology is assumed to occur with some probability in each period. The characteristics of the innovations are uniformly distributed along an interval containing all possible new technologies. Adult agents adopt a new technology when a technology shock occurs. The initial structure of the agent's human capital consists of two dimensions: width and depth. The width dimension of human capital refers to the specificity versus the generality of the knowledge acquired. The more general the human capital accumulated, the more flexible and the more able to adopt new technologies the individual is. Human capital depth represents the quality of human capital, which determines the level of technology that can be adopted.

The representative firm employs young, adult and old workers together. The input is human capital only, and the technology is linear, which implies that the human capital of each of the three generations is a perfect substitute for that of the others:

$$y_t = H_{yt} \cdot (1 - l_E) + H_{at} \cdot (1 - l_A) + H_{ot}$$

where $y_t$ is the total output of the economy at period t, $H_{yt}$ is the human capital possessed by the young generation at period t, $H_{at}$ and $H_{ot}$ are that of the adult and old generations respectively, $l_E$ is time devoted to education and $l_A$ is adoption time . The model in this paper is driven by a representative young agent's maximization problem, which guides the width and depth decisions related to his human capital:

$$\max_{N,Q} U(c_{yt}, c_{at}, c_{ot}) = \log c_{yt} + \frac{1}{1+\rho} E(\log c_{at}) + \frac{1}{(1+\rho)^2} E(\log c_{ot})$$

where $U$ is the lifetime expected utility, which depends on consumption in the three periods, respectively denoted by $c_{yt}$, $c_{at}$ and $c_{ot}$, $N$ is knowledge width, $Q$ is knowledge depth, $\rho$ is the rate of time preference and $E$ represents expectations. The explicit solutions to this problem provide optimal investments in the width and the depth of human capital for the first period, expected time devoted to receiving education and equilibrium growth paths for width, depth and income. The explicit solutions along with the first order conditions can be obtained from the authors (also provided in an Appendix to the editors) and are the basis for the theoretical insights and the empirical work in this paper.

The solutions to the above problem indicate that an increase in the probability of not dying at the end of the young period (thus surviving into the adult period) induces higher investment both in the depth and width of human capital stock[1]. An increase in the probability of living to the full length of life, however, increases the relative ratio of depth versus width by increasing the absolute magnitude of depth and decreasing the absolute magnitude of width of human capital[2]. We solved for the equilibrium growth rate of income and expected adoption time by using the fact that in equilibrium the demand for width and depth grow at the same rate. The main findings of this model are:

1. The income growth rate increases with higher life expectancy[3]. Therefore, there can be persistently different growth paths for countries with different life expectancies, even if the occurrence of technological progress is the same for all the countries. The relevance of this result is clearer with a restatement of the motivation of this analysis. Assuming an exogenous technological process and a strong complementarity between technology innovation and human capital, a radical reduction in life expectancy leads to under investment in human capital and thus leads to slow growth. This dimension of the relationship between health, human capital investments and growth may be more significant in places such as sub-Saharan Africa where the HIV/AIDS pandemic may lead to reductions in life expectancy.

2. The adoption time increases with the increases in the probability of technological advance, the probability of surviving the young period, and the conditional probability of living through the three periods if one survives the young period[4]. Therefore, the growth rate of income decreases as the probability of premature dying increases, establishing the main result of this paper. Note that the immediate effect of an epidemic or a persistent war that drastically shortens people's life expectancy is to reduce income due to loss of labor. These effects are not discussed in the model. Rather, our results show that in long run

equilibrium, the slower growth results from a reduction in individual investments in human capital due to a shorter life span.

**Country-level Empirical Relationships.**

**1) Health's Impact on Education Attainment**

One of the behavioral relationships from the model described above[5] establishes that the time an agent devotes to education and technology adoption is negatively related to her probability of premature dying. In an effort to find empirical support for this theoretical relationship, a regression of the following form is estimated:

$$L_{Ei} = a + b(prob_i) + \mu_i$$

where $L_{Ei}$ is the average schooling years for male, female, and total population of age 25 and above in the *ith* country in 1990, obtained from the Barro-Lee dataset of international education attainment and $Prob_i$ is the 1970 mortality rate in the *ith* country for the adult male and female populations obtained from the World Development Indicators dataset (WDI). For the total population regression, since there is no total mortality rate, we used life expectancy obtained from WDI. Two Stage Least Square estimation is used to control for reverse causality. The instrumental variables chosen are the corresponding mortality rate or life expectancy in 1960 obtained from WDI. We include 27 countries from Africa, 22 from Asia, and 19 from Latin America.[6]

Estimates in Table 1 show a significant and negative relationship between mortality rate and schooling years for females and males. These results confirm that the higher the mortality rate, the less investment in human capital people make. The third column indicates that as life expectancy increases so does the number of years in school and therefore the investments in human capital for the whole population.

To see whether the intercepts and elasticities are different for low- and high-income countries (using the World Bank classification), we included a dummy variable and reran the equation above. The results, in the last three columns of Table 1 indicate that developing countries and developed countries have significantly different slopes. For developing countries, increased lifespan and decreased mortality are associated with more years spent in school. The effects are significant for the female and total population though with a smaller magnitude for developed countries while they are insignificant for the male population. The implication is that increases in life expectancy have diminishing effects on schooling time since higher income countries generally enjoy higher life expectancies.

**2) Evidence on Growth Rate and Life Expectancy**

Bloom and Canning (2001) provided an extensive review of the studies that estimated the effect of health status on economic growth. The most common strategy used, according to them, is to run an OLS regression of the growth rate of income from 1965 to 1990 on independent variables from 1965, including the log of life expectancy. (Bloom and Malaney, 1998; Bloom and Sachs, 1998; Bloom and Williamson, 1998; Hamoudi and Sachs, 1999, etc.) To address time-invariant country-specific determinants, panel analysis, instead of cross-section analysis is required. Barro (1996) and Barro and Sala-I-Matin (1995) used 3SLS or SUR with country random effects in their panel studies when dealing with a system of equations. On the whole, the cross-sectional evidence supports a strong and positive impact of increased life expectancy on growth.

We conducted a similar cross-section analysis for 93 countries in the world with the average annual growth rate of GDP per capita from 1977-1998 as the dependent variable, and the log of life expectancy, the dependency ratio (the ratio of dependents to the working age population), openness (the percentage of trade in GDP), the investment ratio, the gross primary enrollment ratio, the gross secondary enrollment ratio, and the political freedom index as the explanatory variables. All the explanatory variables take the values of 1977 to eliminate the potential endogeneity problem. All the observations are obtained from the World Development Indicator Dataset maintained by the World Bank (WDI) except for the freedom index, which is obtained from the Freedom House by averaging the political freedom index and civilian rights index. Results of this regression are found in the second column of Table 2 where we can see that life expectancy has a significant and large impact on subsequent growth of average GDP per capita.

We also estimated an equation relating the impact of life expectancy and the dependency ratio to GDP growth using panel data. The dependent variable is GDP per capita (in logarithms over the periods 1977-1982, 1982-1987, 1987-1992, and 1992-1997), and the explanatory variables are life expectancy (in logarithms at 1977, 1982, 1987, and 1997), dependence ratio, average gross fixed investment annual growth (over the periods 1977-1982, 1982-1987, 1987-1992, and 1992-1997), openness (the percentage of trade to GDP at 1977, 1982, 1987, and 1997), the freedom index, and the enrollment rates of primary schools and secondary schools. This equation is very similar to the one used by McCarthy, Wolf, and Wu (2000) in their analysis on the growth costs of malaria. The observations of the starting years of the five-year periods are chosen to reduce endogeneity problems. The panel includes data for 206 countries for the years of 1977, 1982, 1987, 1992, and 1997.

One way fixed effects models and one way random effects models are used for the estimation. The Hausman random effects test is strongly significant. Instruments are used for life expectancy to control for reverse causality. The instruments used are lagged life expectancy and some geographic data obtained from the dataset compiled by Gallup, Sachs and Mellinger (1999, available for download on CID website). The 2SLS results for the one way fixed effects model and random effects model are shown in the third and fourth columns of Table 2. The effects of life expectancy on GDP per capita are significantly positive, while the effects of the dependency ratio are significantly negative. To the extent that the AIDS epidemic reduces life expectancy and increases the dependency ratio, it will have a significant impact on the level of GDP per capita.

It would be desirable to test whether the sub-Saharan Africa countries differ from other countries in terms of the intercept and elasticities. This can be done by adding sub-Saharan dummy variables to the regression. The results of these regressions are presented in the last two columns of Table 2 and are as expected. There is a large penalty for being a sub-Saharan country; and there is a premium for increased life expectancy for the sub-Sahara Africa countries. Other things equal, a five-year increase in life expectancy would raise per capita GDP about $7-10 (constant 1995 international dollars) more than in the rest of the world, on average. The total benefit of a five-year gain in life expectancy would be about $20-$30 per capita. The sign of the freedom index is expected, as a smaller index number points to a more democratic society. It is noted that the primary school enrollment in fact has no effects on GDP, but secondary school enrollment is significant, though with a small magnitude. The insignificance may suggest that these enrollment ratios are not very good proxies for education attainments.

Overall, the dependency ratio has a large negative effect on GDP per capita as expected. However, the results also suggest that Africa will benefit from a larger dependency ratio, which is very doubtful. Dependency ratios appear to be falling in Africa despite the nature of the HIV/AIDS pandemic. One reason may be that the data do not reflect the full impact of HIV/AIDS as the last year for which data are available is 1997 and the pandemic is likely to affect dependency ratios with a lag. Another reason is that other diseases in sub-Saharan Africa primarily affect the young and old populations actually offsetting the increases in the dependency ratio due to HIV/AIDS.

**Conclusions**

The empirical results reported in the preceding section are consistent with the analytical results derived from the overlapping generations model. While it would be interesting to estimate an empirical model that more directly measures the impact of HIV/AIDS on economic growth, the lag between the effects of the disease on growth and the incidence as reflected in current data makes it impossible to estimate any meaningful relationships. Nevertheless, the analysis does provide substantial evidence that falling life expectancies in Africa as a result of the HIV/AIDS pandemic, as well as the widespread incidence of other diseases, is leading to reduced investments in human capital formation which in turn result in lower human capital stocks and slower growth. The implications of this result are extremely serious. If the spread of HIV/AIDS and other diseases leads to less economic growth in African countries, there will be fewer resources in these countries for use in combating the pandemic. Through the mechanisms identified in this paper, as well as the more obvious connections between disease and economic growth, a vicious cycle could develop in which disease slows growth reducing the ability to control the disease, which becomes more widespread slowing growth even further.

The Global Fund to Fight AIDS, Tuberculoses and Malaria was established in January 2002 by the United Nations to focus contributions from wealthy countries on the fight against these diseases in low-income countries. So far the fund has had to spend more time getting organized than on disbursing the available financial resources. The resources offered by the high-income countries may be inadequate in any case. According to *The Economist* (October 19, 2002), the Global Fund is likely to have financial shortfalls of $2 billion in 2003 and almost $5 billion in 2004. If the analysis in this paper is correct, adequate funding and rapid implementation of the Global Fund's programs is critical if the vicious cycle described above is to be short-circuited. The nature of HIV/AIDS is such that it is very important to undertake effective preventive programs as soon as possible in order to avert an explosion of cases in coming years. Reducing the incidence of these diseases and raising life expectancies are clearly ends in themselves. But, in addition, increased life expectancy has the instrumental value of providing incentives for greater investments in the human capital that contributes significantly to economic growth and human well-being.

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**Table 1. Relationship between Schooling and Mortality Rates or Life Expectancy**

| | Female Average | Male Average School Years | Total Average School Years | Female Average | Male Average School Years | Total Average School Years |
|---|---|---|---|---|---|---|
| **Intercept** | 9.69 (.38) | 10.92(.51) | -8.44(0.70) | 9.27***(0.52) | 9.59***(0.78) | -0.67(3.97) |
| **Dummy** | | | | -0.47(0.60) | 0.11(0.78) | -6.98*(3.75) |
| **Mortality /Lifespan** | -20.21(1.40) | -16.45(1.51) | .23(.01) | -8.12*(3.74) | -3.85(3.79) | 0.13*(0.05) |
| **Dummy*Mortality** | | | | -9.54**(3.37) | -9.80**(3.36) | 0.09*(0.05) |
| **Observation** | 95 | 98 | 107 | 95 | 98 | 107 |
| **R2** | 0.69 | .55 | .79 | 0.73 | 0.62 | 0.80 |

The numbers in parenthesis are the standard error of the parameter estimates before them. Significance level of parameter estimates: *** p-values<0.0001, **p-value<0.01, *p-value<0.1. Numbers in parenthesis are the standard error of the parameter estimates. Observation number refers to number of countries used in the regression.

**Table 2. Regression of log of GDP per capita on log of life expectancy and other relevant variables.**

| | Cross Section | Fixed | Random | Fixed | Random |
|---|---|---|---|---|---|
| **Intercept** | -10.22 (9.05) | -3.311(1.51)* | | | |
| **Africa Dummy** | | | | -.019(.018) | -2.41(.89)** |
| **Life Expectancy** | 4.1 (2.29)** | 2.98 (.36)** | 2.34 (.28) ** | 4.29 (.49) *** | 2.77 (.46) *** |
| **Africa*Life Expectancy** | | | | 1.57(.69)* | 1.81 (.68) ** |
| **Dependency Ratio** | -0.83 (1.85) | -1.77 (.28) ** | -1.58(.24) ** | -1.79 (.31) *** | -1.83 (30) *** |
| **Africa*Dependency** | | | | 1.51 (.50) ** | 1.08 (.52 ) * |
| **Investment Ratio** | -0.036 (0.03) | .0004(.0024) | -.002 (.002) | .003 (.002) * | .00036 (.002) |
| **Freedom** | -0.11 (0.156) | -0.029(.0099) * | -.023 (.009) | -.022 (.008) ** | -.019 (.009) * |
| **Openness** | 0.014 (0.005)** | .0012(.001) | .002 (.0007) * | | |
| **Primary** | -0.002 (0.011) | .0011 (.002) | .0005 (.001) | -.0008 (.001) | -.00037 (.0014) |
| **Secondary** | 0.000075(0.017) | .0165 (.001) ** | .015 (.0014) ** | .014 (.0012) *** | .013 (.0014) *** |
| **Tests** | | Fixed effects <.0001 | Hausman Test .0003 | | |
| **Observation Number** | 93 | 206 | 206 | 105 | 105 |
| **R-Square** | 0.3056 | 0.9597 | 0.6887 | 0.6967 | 0.9874 |

The numbers in parenthesis are the standard error of the parameter estimates before them. Significance level of parameter estimates: *** p-values<0.0001, **p-value<0.01, *p-value<0.1. Numbers in parenthesis are the standard error of the parameter estimates. Observation number refers to number of countries used in the regression.

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[1] Equation (14) in the model appendix.
[2] Appendix equation (15) and (16).
[3] Technically, lower $P_y$ and higher $P*$ in appendix equation (17).
[4] Appendix equation (19).
[5] Equation (19) in the appendix.
[6] 95 Countries used for regression equation:19 High-Income Countries: Austria, Belgium, Canada, Finland, France, Germany, Greece, Ireland, Israel, Italy, Norway, Japan, Netherlands, New Zealand, Spain, Sweden, Switzerland, United Kingdom, United States;27 African Countries: Algeria, Benin, Botswana, Cameroon, Central African Republic, , Congo, Rep., Egypt, Gambia, Ghana, Kenya, Lesotho, Liberia, Malawi, Mali, Mauritius, Mozambique, Niger, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Togo, Tunisia, Uganda, Zambia, Zimbabwe;22 Asia Countries and regions: Afghanistan, Armenia, Bahrain, China, Cyprus, Hong Kong, China, India, Indonesia, Iran, Iraq, Lebanon, Korea, Rep., Kuwait, Malaysia, Nepal, Pakistan, Russian Federation, Philippines, Singapore, Sri Lanka, Thailand;19 Latin American Countries: Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala , Guyana , Haiti ,Honduras ,Panama, Paraguay, Peru, Uruguay, Venezuela, RB, Trinidad and Tobago;5 European Countries: Malta, Bulgaria, Czech Republic, Hungary, Poland, Yugoslavia, FR (Serbia/Montenegro);2 Oceania Countries: Fiji, Papua New Guinea