INVESTING IN HOPE: AIDS, LIFE EXPECTANCY, AND HUMAN CAPITAL ACCUMULATION

Rui Huang[1], Lilyan E. Fulginiti[2] and E.Wesley Peterson[2]

[1]University of California-Berkeley;
[2]University of Nebraska-Lincoln. E-mail: lfulginiti@unl.edu

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.

"…Until the pandemics of AIDS, tuberculosis, malaria and other killer diseases are brought under control in Africa, economic development and political stability will remain crippled. A breakthrough on disease control, conversely, would help unleash a virtuous circle of rising productivity, better education, lower fertility rates – and then lead to further increases in health and prosperity."[i]

Jeffrey D. Sachs, New York Times, July 9, 2003

INTRODUCTION

Good health is an important component of human wellbeing. 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 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.

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, ρ 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 are in the Appendix 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.[ii] 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.[iii] 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:

- The income growth rate increases with higher life expectancy.[iv] 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.
- 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.[v] 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

Though conventional wisdom endorses the idea that causality between health and income runs from income to health, we have developed a theoretical model where the reverse direction is a possibility. Empirically, we will focus on quantifying the effects of heath on human capital investment and one step further, on growth. Endogeneity is an obvious concern and we have dealt with it through the use of instruments (2SLS). We are in the process of implementing a simultaneous system estimation approach that would account for the potential endogeneity and cross section nature of the data set explicitely (random 3SLS).

HEALTH'S IMPACT ON EDUCATION ATTAINMENT

One of the behavioral relationships from the model described above[vi] 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 95 countries in the analysis for females, 98 in the analysis for males, and 107 in the regression for total population.[vii]

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.

Table 1. Relationship between Schooling and Mortality Rates or Life Expectancy (cross-section).

	Female Average School	Male Average School Years	Total Average School Years	Female Average School Years	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)
LDC 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)
LDC Dummy*Mortality				-9.54**(3.37)	-9.80**(3.36)	0.09*(0.05)
Observation Number	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<0.001, **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

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.

Following Barro's lead[viii] and given the availability of panel data on life expectancy we use an instrumented random effects[ix] model to measure the impact of *lagged* life expectancy on educational attainment (94 countries[x] during 1965-1990, five-year intervals.) The instruments are geographic variables obtained from the website of Center for International Development at Harvard University, as described and used in Gallup, Sachs and Mellinger (1999). As Table 2 indicates, we found significant and positive impact of lagged life expectancy on average educational attainment in accordance with the previous cross-country results. As the theory specified, these results support the notion that as life's horizon increases so does expected income and the incentive to further one's education.

Table 2. Relationship between Lagged Life Expectancy and Educational Attainment (random 2SLS, panel).

	Coefficient	**Std. Errors**
Logarithm of life expectancy lagged 5 years	3.94***	0.24
Intercept	-14.86***	0.981
Observation Number	362	
R2	0.75	

Instrumented: logarithm of life expectancy lagged 5 years. Instruments: zpolar wardum zboreal zdestrp zdrytemp zwettemp zsubtrop ztropics zwater are geographic variables defined in Gallup, Sachs and Mellinger (1999). Significance level of parameter estimates:
*** p-values<0.001, **p-value<0.01, *p-value<0.1.

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.). 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[xi] 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 3 where we can see that life expectancy has a significant and large impact on subsequent growth of average GDP per capita.

Table 3. 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	510	510	510	510
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<0.001, **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 4. Regression of Lagged Life Expectancy on Growth RateGDP Per Capita (random 2SLS, panel).

	Coefficient	**Std. Errors**
Logarithm of life expectancy lagged 5 years	-0.277***	0.097
Logarithm of GDP lagged 5 years	-0.066***	0.025
Interaction between lagged logarithm of life expectancy and logarithm GDP	0.017***	0.006
_cons	1.080***	0.393
Number of Observations	405	
R2	0.0429	

Instrumented: Logarithm of life expectancy lagged 5 years, logarithm of GDP lagged 5 years and the interaction between these two variables. Instruments: zpolar zboreal zdestrp zdrytemp zwettemp zsubtrop ztropics zwater open6590 icrg82 tropicar south landarea landlock landlneu airdist newstate icrg82 socialst eu safri sasia transit latam eseasia. All the instrumented variables are from WDI indicator 2001 CD. All the instruments are from the geographical dataset compiled and described by Gallup, Sachs and Mellinger (1999). NewState: The timing of national independence, 0 if before 1914, 1 if between 1914 and 1945, 2 if between 1946 and 1989, and 3 if after 1989. Socialism: A variable equal to 1 if the county was under socialist rule for a considerable period during 1950-1995. Tropicar: The proportion of the country's land area within the geographic tropics.Openness: the proportions of years that a country is open to trade during 1965-1990.Public Institutions: The quality of public institutions.NewState, Socialism, Tropicar , Openness and public institutions are defined and obtained from Gallup, Sachs and Mellinger (1999). Significance level of parameter estimates: *** p-values<0.001, **p-value<0.01, *p-value<0.1.

Further support for this result is obtained from a regression, following Barro again, that uses data on a panel of 89 countries[xii] during the period 1965-1990[xiii], in five-year intervals. The instrumented random 2SLS estimates presented in table 4 support the results of the cross-section regression above and indicate that growth rate of GDP per capital responds positively to increases in one's life horizon.

We also estimated an equation relating the impact of life expectancy and the dependency ratio to the level of GDP per capita using a[10] panel of 105 countries.[xiv] 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 of the growth costs of malaria. The observations of the starting years of the five-year periods are chosen to reduce endogeneity problems.

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 3. 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 3 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-Saharan 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.

Finally, in an effort to more directly establish a relationship between HIV/AIDS statistics and illiteracy as well as growth rates of GDP per capita, the latest HIV prevalence adult rates by country (as of the end of 2001[xv]) are used in a 2SLS cross-sectional regression. We restricted our attention to the 29 sub-Saharan African countries.[xvi] Not surprisingly, we didn't find significant results for the regression of HIV prevalence adult rates in 2001 on contemporaneous GDP growth rates. However, the results are strong and significant for the regression of HIV adult prevalence rates on illiteracy rates, which serves as a reverse measure of human capital attainments. We report the results in Table 5.

Table 5. Regression of HIV adult rates on Illiteracy rates, Sub-Sahara Africa 2001 (2SLS, cross-section.).

	Coefficients	Std. Errors
LogHIVrate	-0.161**	0.056
LogTrade	-0.799**	0.298
LogGDP	-0.127	0.152
_cons	9.676**	3.541
Number obs.	29	
R2	0.12	

Note: Instrumented: Logarithm of Adult HIV rates as of year 2001, logarithm of trade (% of GDP) as of year 2001 and logarithm of GDP in 2001.Instruments: tropicar airdist landlock landlneu zpolar wardum zdestmp zdestrp zdrytemp zwettemp zsubtrop ztropics zwater. Data source: Instrmented variables are from UNAIDS and World Bank. the instruments are from the geodata compiled and described by Gallup, Sachs and Mellinger (1999). Significance level of parameter estimates: *** p-values<0.001, **p-value<0.01, *p-value<0.1.

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 wellbeing.

REFERENCES

Barro, R., 1996. Determinants of Economic Growth: A Cross-Country Empirical Study. NBER Working Paper No. 5698.

Barro, R., Sala-I-Martin, X., 1995. *Economic Growth*, McGraw Hill.

Bils, M, Klenow, P., 2000. Does Schooling Cause Growth? *American Economic Review*, forthcoming.

Bloom, D.,Canning, D., 2000. The Health and Wealth of Nations. *Science*, 287, 1207-9.
Bloom, D., Malaney, P., 1981 Macroeconomic Consequences of the Russian Mortality Crisis. *World Development* 26, 2073-85.
Bloom, D., Sachs, J.D.,1998. Geography, Demography, and Economic Growth in Africa. *Brookings Papers on Economic Activity* 2, 207-295.
Bloom, D., Williamson, J., 1998. Demographic Transitions and Economic Miracles in Emerging Asia. *World Bank Economic Review* 12, 419-55.
CMH, 2001. Macroeconomics and Health: Investing in Health for Economic Development -- Report of the Commission on Macroeconomics and Health. Presented *by* Jeffrey D. Sachs, Chair to the Director-General of the World Health Organization http://www.cid.harvard.edu/cidcmh/CMHReport.pdf
De la Croix, D., Licandro, O., 1999 Life Expectancy and Endogenous Growth. *Economics Letters* 65, 255-263.
Freeman, P., Miller, M., 2001 Scientific Capacity Building to Improve Population Health: Knowledge as a Global Public Good. CMH Working Paper No. WG2:3.
Gallup, J., Sachs, J. and Mellinger, A., Geography and Economic Development, CID Working Paper No.1, March 1999
Grossman, M., 1973. The Correlation Between Health and Education. NBER Working Paper, No. 22.
Grossman, M., Kaestner, R. 1997 Effects of Education on Health. In: Behrman, J. and N. Stancey (Ed.), *The Social Benefits of Education* . The University of Michigan Press, Ann Arbor.
Hadri, K., 2000. Testing for stationarity in heterogeneous panel data. *Econometrics Journal*, 3, 148–161.
Kalemli-Ozcan, S., Ryder, H.E. and Weil, D.N., 2000 Mortality Decline, Human Capital Investment and Economic Growth. *Journal of Development Economics* 62, 1-23.
Kim, Y.J., Lee, J., 1999. Technological Change, Investment in Human Capital, and Economic Growth. CID Working Paper No.29, Harvard.
McCarthy, F.D., Wolf, H. and Wu, Y., 2000. the Growth Costs of Malaria. NBER Working Paper No. 7541.
Sachs, J. D., 2003. "A Rich Nation, a Poor Continent." the *New York Times* (July 9, 2003), page A23.
Swanson, C., Kopecky, K., 1999. Lifespan and Output. *Economic Inquiry* 37, (2) pp 213-225.
The Economist (October 19, 2002) “AIDS: The Next Wave,” pages 75-76.
UNDP (United Nations Development Program), 2001. *Human Development Report 2001*. New York: Oxford University Press.
World Bank, 1986. *World Development Report 1986*. New York: Oxford University Press.

APPENDIX

THE OVERLAPPING GENERATIONS MODEL AND THE ANALYTICAL RESULTS

This is a representative agent model. 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 and earning a wage.

The agent faces a probability of dying at the end of the 1st period and 2nd period, denoted by P_Y and P_A respectively. the relationship between the two probabilities is

$$(1) 1 - P_A = P(l \geq 2t / l \geq t) \cdot (1 - P_Y) \\ = P^* \cdot (1 - P_Y) \qquad (1)$$

Where l denotes life expectancy of the agent, t denotes one period of time, P^* denotes the conditional probability of surviving the end of the 2nd period if the agent doesn't die at the end of first period. Note if $P^*=0$, the agent can at most live up to two periods.

A new and advanced technology a is assumed to occur with a probability of p in each period. the characteristics of a new technology are represented by a point on a continuous technology space of the real line [0,S]. the new technology could occur with a characteristic anywhere between 0 and S on the line, that is, the characteristics of the innovations are uniformly distributed on the interval. Though the characteristic is a random variable, the technology space is known, i.e., S is a parameter denoting the scope of technological innovation. Adult agents adopt a new technology when a technology shock occurs. the initial structure of the agent's human capital consists of two dimensions: with and depth. an agent may have several 'knowledge points' distributed along the technology space [0,S].

The width dimension of human capital is represented by the number of knowledge points possessed by the agent in the interval [0,S] to adopt a new technology, the agent relies on the knowledge point located nearest to the point in [0,S] which characterizes the technological innovation. the more knowledge points an agent has, the more likely it is that he and this close proximity reduces the cost of adoption. Human capital depth represents the quality of human capital. It is assumed that the depth of an agent's human capital determines the level of technology that can be adopted. the agent cannot adopt a new technology if it is beyond the depth of human capital, Q.

An agent is assumed to spend the adoption time of

$$(2) l_A = a \mid x - s \mid A$$

where l_A is the time used for adoption, i.e., the adoption cost; a is a parameter which is an indicator of adoption efficiency, s denotes the location of the knowledge that an agent uses to adopt a technology with a knowledge point x in [0,S], s is located closest to point x among his N number of invested knowledge points. Therefore, he has to devote more adoption time to adopt a higher level of technology, and more time as the distance between his own knowledge and the technology increases. Because his depth of human capital determines the level of technology he can pick up, the adoption time can be written as

$$(2)' l_A = a \mid x - s \mid Q \qquad (2)$$

This specification of adoption cost implies: To adopt a new technology with a higher level, agents will pay a higher adoption cost. and the adoption time cost increases proportionally to the distance between two knowledge points (x and s). Here, this occurs because this distance represents the degree of similarity between these two pieces of knowledge.

To minimize the expected adoption cost, the N knowledge points must be equally distributed over the knowledge space. the strategy of equal spacing is adopted because the characteristic of a technical innovation is a random variable uniformly distributed on the technological space [0,S].

Figure 2 below depicts the relationship between the adoption cost and the location of the characteristics of a new technology represented by x, when an agent has three knowledge points, N=3. N=3 implies that agents invested in three knowledge points at n1, n2 and n3 on the knowledge space [0,S], which are located at S/6, 3S/6 and 5S/6 respectively. Kim and Lee (1999) noted that the structure of this minimization problem is identical to Baumol and Tobin's inventory model of money demand, in which, "N" represents the number of trips to a bank.

Source: Kim and Lee(1999)

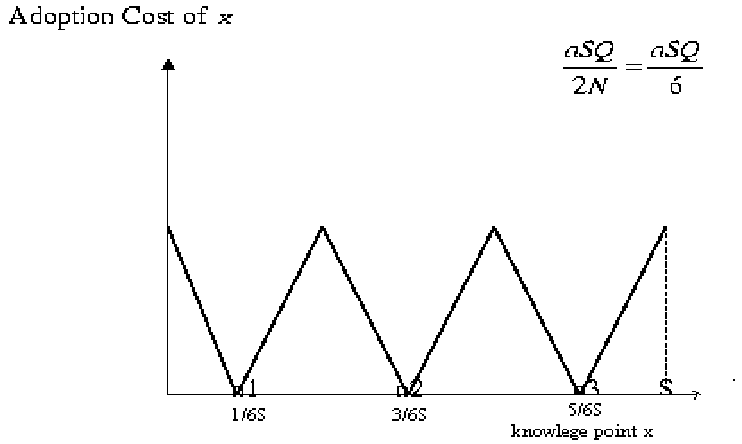

Figure 2. Equal Spacing of Knowledge Points.

After an adult agent adopts a new technology with a level of quality of *Q*, his depth or quality of human capital becomes *Q*, i.e., the human capital is fully embodied into the adopted technology.

$$(3) H_{at} = Q_t \qquad (3)$$

where H_{at} is the human capital stock of adult at time t, Q_t is his depth of human capital at period t. Also assumed is that due to spillover effects, a certain fraction of the technology, once adopted and being currently used, can also be used by young agents without cost. Therefore, the young agents' specific human capital at time t becomes

$$(4) H_{yt} = \delta \overline{Q} \qquad (4)$$

where $\overline{Q}$ denotes the current adult generation's amount of specific human capital and $0 < \delta \leq 1$, is the spillover effect.

A young agent invests an amount of time l_E in education and builds his human capital stock of NQ.
(Education production equation)

$$(5) N_t Q_t = b \cdot l_E \cdot \overline{NQ} \qquad (5)$$

where l_E is the time the agent devotes to receive education, $\overline{NQ}$ is the human capital owned by the current adult generation. the parameter b captures the efficiency of the elder generation in passing their knowledge to the next cohort. This specification implies that the young accumulates his education by spending time in school and pays tuition to the adults or the old agents if no new technology occurs for the current adult generation to compensate for the instructors' opportunity cost. Here we assume that only the individuals with the highest available depth of human capital in a period can be instructors to guarantee that the young can always keep abreast of the frontier of knowledge. the parameter *b* measures the efficiency of human capital formation. (See Kim and Lee(1999) for a discussion of the micro-mechanisms of the education process.) According to Kim and Lee, b>1, which implies that human capital stock can increase over time if the agent invests a certain fraction of her time in education such that bl_E>1. the equation implies that the more education old agents of the previous generation have, the more human capital young agents can accumulate with a fixed time input. in addition, there is a trade-off between *N* and *Q* as the agent cannot increase both simultaneously within a given time.

We proceed now to obtain the human capital stock of the old agent. If the current old agent adopted technology in his adult period and no new technology occurs in his old period, his human capital defines the highest level of human capital of the society, therefore, we assume his human capital to be $(1-\tau_1)Q$, where τ_1 is a depreciation rate in [0,1]. If he adopted in his adult period, but new technology occurs in his old period, his human capital stock becomes $(1-\tau_2)Q$, and $\tau_2 < \tau_1$, is also a depreciation rate. If he had not adopted technology as an adult, but new technology occurred in his old period, then he, like the young cohort, enjoys a spillover effect of the human capital of the current adult. If no new technology occurred in either his adult or old period, all three generations have to share the spilled over human capital stock from the passed away cohort, i.e., $\delta\overline{Q}$. If no new technology occurs in his adult period but occurs in his old period, his human capital is also the spillover effect of the current adult generation, $\delta\overline{Q}$. It is assumed that the spillover effect is not as large as the (depreciated) own human capital. Therefore, the agent is always better off with his own technology adoption than without it whether his technology is outdated by new technology or not.

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

$$(6) y_t = H_{yt} \cdot (1-l_E) + H_{at} \cdot (1-l_A) + H_{ot}$$

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 regardingly. the contribution of each cohort to the total output is the product of their human capital and the time they devote to production. a representative young agent's maximization problem on the width and depth of his human capital is:

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:

$$(6) y_t = H_{yt} \cdot (1-l_E) + H_{at} \cdot (1-l_A) + H_{ot}$$

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. a representative young agent's maximization problem on the width and depth of his human capital is:

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

Where U is the lifetime expected utility, which depends on consumption of three periods, respectively denoted by c_{yt}, c_{at} and c_{ot}.

$$c_{yt} = \delta\overline{Q}(1-l_E) = \delta\overline{Q}(1-\frac{NQ}{bNQ})$$

$c_{at} = (1-l_A)Q$ if he survives and technology occurs.

$c_{at} = \delta\overline{Q}$ if he survives but technology doesn't occur.

$c_{at} = 0$ if he dies at the end of 1st period.

$$l_A = \min_{x\in[0,S]} a|x-s|\cdot Q$$

The adoption cost, measured by adoption time, is proportional to the distance between the knowledge point owned by the individual through schooling nearest to the characteristic of the occurring technology change and the level of technical innovation he adopts.

$c_{ot} = (1-\tau_1)Q$ if he survives and the technology occurs in the adult period but not the old period.

$c_{ot} = (1-\tau_2)Q$ if he survives and a new technology occurs in both the adult and old period.

$c_{ot} = \delta\overline{Q}$ if he survives but no new technology occurs in his old period.

In this case, the current adult generation shares the same human capital with the old generation.

$c_{ot} = 0$ if he dies at the end of 2nd period.

It is assumed that the spillover effect is sufficiently small relative to the depreciation rate of the human capital that the old agent enjoys higher consumption if she adopts technology in her adult period than otherwise. the specifications imply that the level of the human capital of the current adults in the society determine the level of human capital stock.

$$(6)E(\log c_{yt}) = p(1-P_y)\frac{2N}{S}\int_0^{\frac{S}{2N}} \log(Q(1-aQx))dx + (1-p)(1-P_y)\log(\delta\overline{Q})$$
$$= (1-P_y)[p\int_0^S \log(Q(1-aQ\frac{y}{2N}))dy + (1-p)\log(\delta\overline{Q}) \qquad (6)$$

Where p denotes the probability of technological advance, N is the number of knowledge points possessed by the individual through schooling, S stands for the scope of technological space.

The expected utility of the old agent is the probability of living to the old period multiplied by the sum of the expected utility under the different scenarios when technical change occurs or doesn't occur in his adult period or old period, that is:

$$E(\log c_{ot}) = P^*\cdot(1-P_y)[p(1-p)\log[(1-\tau_1)Q]+$$
$$pp\log[(1-\tau_2)Q]+(1-p)p\log\delta\overline{Q}+(1-p)(1-p)\log\delta\overline{Q}]$$
$$= P^*\cdot(1-P_y)p\log Q + constant$$

Following Kim and Lee (1999), we assume that the utility of the second period with the technology adoption is always higher than that without it due to time consistent restrictions on the parameter values of the model so that the adoption of the new technology is always certain. the first period maximization problem is:

$$(7)\max_{N,Q}\log(1-\frac{NQ}{b\overline{NQ}}) + \frac{p(1-P_y)}{1+\rho}\frac{1}{S}\int_0^S \log[Q(1-\frac{aQy}{2N})]dy + \frac{P^*\cdot(1-P_y)p}{(1+\rho)^2}\log Q + constant \qquad (7)$$

As long as p (1-P_y) is not zero, the individual expected utility would always be higher if he adopts technology when it occurs given the assumption of the parameters above, therefore, an interior solution is guaranteed. the FOCs:

$$(8) -\frac{Q}{b\overline{NQ}-NQ} - \frac{p(1-P_y)}{1+\rho}\frac{1}{S}\int_0^S \frac{1}{N-\frac{aQy}{2}}dy$$
$$= -\frac{Q}{b\overline{NQ}-NQ} - \frac{p(1-P_y)}{1+\rho}\frac{1}{N} - \frac{2p(1-P_y)}{(1+\rho)aQS}\log(N-\frac{aSQ}{2}) - \log N) = 0 \qquad (8)$$

$$(9) -\frac{N}{b\overline{NQ}-NQ} + \frac{p(1-P_y)}{1+\rho}\frac{1}{Q} + \frac{p(1-P_y)}{1+\rho}\frac{1}{S}\int_0^S \frac{\frac{-2ay}{2}}{N-\frac{aQy}{2}}dy + \frac{P^*\cdot(1-P_y)p}{(1+\rho)^2}$$
$$= -\frac{N}{b\overline{NQ}-NQ} + \frac{2p(1-P_y)}{1+\rho}\frac{1}{Q} + \frac{2p(1-P_y)N}{(1+\rho)aQ^2S}(\log(N-\frac{aSQ}{2}) - \log N) + \frac{P^*(1-P_y)p}{(1+\rho)^2} = 0 \qquad (9)$$

Multiplying both sides of (8) by N, and both sides of (9) by Q, and subtracting (8) from (9) yields:

$$(3+k)(z-1) = 2\log z \qquad (10)$$

Where $z = 1 - \frac{aSQ}{2N}$, $k = \frac{P^*}{(1+\rho)}$

z is a linear function of the ratio of depth to width. Note that k=0 if P^* =0, and k increases as P^* increases given the discount rate, where P^* is the conditional probability of surviving up to three periods if the agent survives the young period. Hence k can be interpreted as a time value coefficient of future consumption under uncertainty of life expectancy. Equation (10) thus shows a relationship between the probability of premature death and the optimal depth-width ratio of human capital investment. When k=0, the equation is $3/2(z-1) = \log z$, the same equation (10) in Kim and Lee (1999). the addition of a positive k is the result of adding a third period into the model. Since $aSQ/2N$ is by definition not zero, $z \neq 1$. It is easy to see that for each definite value of k in [0,1], there exists a unique solution for z between (0,1) that satisfies equation (10) since the left hand side can be depicted as a straight line through (1,0) and (0, 3+*k*/2) and the right hand side is a usual log curve through (1,0).

An analytical solution of equation (10) is not available since it is non-linear. Using simple computer simulation (EXCEL), we can solve for *z*. Let *z** be the equilibrium *z* that satisfies equation (10). Then, *z** gives the equilibrium ratio of depth to width given the characteristic space of the innovation that has occurred. the simulation shows that *z** declines as k increases, and *z** is between [0.421, 0.2]. Therefore, as *P** increases, i.e., as one is more likely to have a longer life, the optimal ratio of depth to width of human capital acquisition increases. the result is expected since in the old period, the agent is assumed to adopt no technology at all. We would expect a different result if the agent adopts new technology when old.

$$\text{Then } (11)\frac{Q}{N} = \frac{2(1-Z^*)}{aS} \tag{11}$$

Hence, the optimal ratio of depth to width decreases if the uncertainty about the characteristic of the technological advance increases. from (8), (10), and (11), we can solve for *Q* and *N* as:

$$(12)Q = \sqrt{\frac{2(1-z^*)bp(1-P_y)(1+k)\overline{NQ}}{(2+2\rho+(1+k)p(1-P_y))aS}} \tag{12}$$

$$N = \sqrt{\frac{abp(1-P_y)(1+k)S\overline{NQ}}{2(1-z^*)[2+2\rho+p(1-P_y)(1+k)]}} \tag{13}$$

The comparative static results are:

$$\frac{\partial N}{\partial(1-P_y)} > 0 \text{ and } \frac{\partial Q}{\partial(1-P_y)} > 0 \tag{14}$$

$$\frac{\partial N}{\partial P^*} = (1-z^*)(2+2\rho)+(1+k)[2+2\rho+p(1-P_y)]\frac{\partial z^*}{\partial k} < 0 \tag{15}$$

$$\frac{\partial Q}{\partial P^*} = (1-z^*)(2+2\rho)-(1+k)(2+2\rho+(1+k)p(1-P_y))\frac{\partial z}{\partial k} > 0 \tag{16}$$

In equilibrium, as Equation (11) shows, *N*, and *Q* grow at the same rate. in this economy, only adults adopt new technology, therefore, all growth in production comes from the current adults' human capital stock compared with their human capital stock in the young period. Therefore, in equilibrium, $\frac{y}{y} = \frac{Q}{Q}$, i.e., income grows at the same rate as the growth rate of the depth of (current adult's) human capital stock. Therefore, the equilibrium growth rate of income is equal to the growth rate of *Q* and *N*. the equilibrium is a balanced growth path.

Now we have $\frac{N}{N} = \frac{Q}{Q} = 1+g$, where g is the growth rate with a technological advance, i.e., the income growth of an adult (relative to his youth) if he adopts a new technology. from Equation (5), the education time of young agents is $l_E = \frac{NQ}{b\overline{NQ}} = \frac{(1+g)^2}{b}$.

Substituting this into the FOC (8), multiplying by *N*, and using (11):

$$1+g = \sqrt{\frac{p(1-P_y)b(1+k)}{2(1+\rho)+p(1-P_y)}} \qquad (17) \tag{17}$$

It is easy to see that the growth rate increases with (1- P_y) and *P*,* thus with the time devoted to education as the above equation (17) shows.

The expected growth rate of output is,

$$
\begin{aligned}
(18)\ E(1+g) &= (1-P_y)[pp(1+g)+(1-p)p(1+g) \\
&+ (1-p)\delta + P^* p(1-p)(1-\tau_1) + P^* \cdot pp(1-\tau_2) + (1-p)\delta \\
&= (1-P_y)\{pp[1+g+P^*(1-\tau_2)] + 2(1-p)\delta + \\
&p(1-p)[1+g+P^*(1-\tau_1)]\}
\end{aligned}
$$

The expected adoption time is:

$$E(l_A) = \frac{p(1-P_y)}{S}\int_0^S \frac{aQy}{2N}dy = \frac{p(1-P_y)}{2}(1-z^*) \quad (19)$$

From the discussion of equation (10), we know that (1-z*) increases as the conditional probability of living to the old period if surviving the young period (*P*).* from the discussion under equation (10), we know that (1-z*) increases as the conditional probability of living to the old period if surviving the young period (*P*).* Hence, the adoption time increases with the increases in probability of technological advance (p), the probability of surviving the young period ($1-P_y$) and the conditional probability of living through the three periods if one survives the young period (P^*). Hence, the growth rate of income decreases as the probability of premature dying increases, establishing the main result of this paper.

Note that this is the relationship in equilibrium when P_y is stabilized. This implies that, although 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, the effects of which is not discussed in the model. in the long run equilibrium, the slower growth rate is the result of a reduction in the individual investment in human capital due to a shorter life span.

---

[i] From "A Rich Nation, A Poor Continent" by Jeffrey D. Sachs, New York Times, July 9 2003

[ii] Equation (14) in the model appendix.

[iii] Appendix equation (15) and (16).

[iv] Technically, lower P_y and higher P^* in appendix equation (17).

[v] Appendix equation (19).

[vi] Equation (19) in the appendix.

95 Countries used in Table 1 for females: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.

107 Countries used in Table 1 for Total: Algeria, Benin, Botswana, Cameroon, Central African Republic, Congo, Rep., Egypt, Gambia, Ghana, Kenya, Lesotho, Liberia, Malawi, Mali, Mauritius, Mozambique, Niger, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Togo, Tunisia, Uganda, Congo, Dem. Rep., Zambia, Zimbabwe, Barbados, Canada, Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Trinidad and Tobago, United States, Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Uruguay, Venezuela, Afghanistan, Bahrain, Bangladesh, Myanmar, China, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Japan, Korea, Rep., Kuwait, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Syrian Arab Republic, Thailand, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Malta, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, Yugoslavia, Australia, Fiji, New Zealand, Papua New Guinea, Libya, Bulgaria, Romania, Cuba.

[viii] "The one thing that is clear is that fixed-effects procedures lose a lot of information." Barro (1996).

[ix] We can also understand the set of countries we are studying as drawn from a population of all countries and all years.

[x] Afghanistan,Algeria, Argentina, Australia,Austria,Bangladesh,Belgium,Benin,Bolivia, Botswane, Brazil, Cameroon,

Canada,Central African Republic, Chile, Colombia, Zaire, Congo, Costa Rica, Denmark,Ecuador, Egypt, El Salvador,Finland, France, Gambia, Germany, Ghana, Greece, Guatemala, Guinea Bissau, Haiti, Honduras, Hong Kong, Hungary, India,Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Kenya, Kuwait,Lesotho,Liberia,Malawi, Malaysia, Mali, Mauritius, Mexico, Mozambique, Nepal, Netherlands, New Zealand, Nicaragua, Niger Niger, Norway,Pakistan,Panama,Papua New Guinea, Paraguay, Peru, Philippines Poland, Portugal, Rwanda, Senegal, Sierra Leone, Singapore, South Africa, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Syrian Arab Rep., Tanzania, Thailand, Togo, Trinidad & Tobago, Tunisia, Turkey ,Uganda, United Arab Emirates, United Kingdom, United States, Uruguay, Venezuela, Yemen , Zambia, Zimbabwe

[xi] 93 Countries used for second column, Table 3:19 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;4 European Countries: Malta, Bulgaria, Hungary, Poland, ;2 Oceania Countries: Fiji, Papua New Guinea.

[xii] Algeria, Angola ,Argentina, Australia, Austria, Bangladesh, Belgium, Bolivia , Botswana, Brazil, Burkina Faso, Cameroon,Canada,Chile,China, Colombia, Congo, Dem. Rep.,Congo, Rep., Costa Rica,Cote d'Ivoire Denmark,Dominica,Ecuador, Egypt,El Salvador,Ethiopia,Finland,France,Gabon,Gambia, Ghana,Greece,Guatemala Guinea,Guinea-Bissau,Haiti, Honduras, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy Jamaica ,Japan, Jordan, Kenya, Madagascar, Malawi, Malaysia, Mali ,Mexico, Morocco, Mozambique, Netherlands ,New Zealand, Nicaragua, Niger, Nigeria, Norway, Pakistan, Papua New Guinea, Paraguay, Peru,Philippines,Poland,Portugal, Senegal, Sierra Leone, Singapore, South Africa ,Spain, Sri Lanka, Sweden, Switzerland, Syrian Arab Republic,Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey,Uganda ,United Kingdom, United States ,Uruguay, Venezuela, Zambia.

[xiii] We performed panel unit root diagnostic tests on the variabes and nonstationaity was rejected, so we proceed with GLS estimation procedures.

[xiv] Algeria;Angola;Argentina;Australia;Austria;Bangladesh;Belgium;Belize; Benin;Bolivia;Bosnia and Herzegovina; Brazil; Bulgaria; Burundi; Cameroon;Canada;Cape Verde;Central African Republic;Chad;Chile;China; Colombia; Comoros ;Congo, Dem. Rep.;Congo, Rep.;Costa Rica;Cote d'Ivoire; Denmark;Dominican Republic;Ecuador;Egypt; El Salvador; Estonia; Ethiopia; Finland; France; Gabon; Gambia ;Germany; Ghana; Greece; Guatemala;Guinea ;Guinea-Bissau; Guyana; Honduras; Hungary ;Iceland; India; Indonesia; Ireland; Italy; Jamaica; Japan; Kenya; Korea, Rep.; Lesotho; Lithuania; Luxembourg ;Madagascar; Malawi; Malaysia; Mali; Mauritania; Mauritius; Mexico; Morocco; Mozambique;Namibia; Netherlands; New Zealand; Nicaragua; Niger; Nigeria; Norway; Panama; Papua New Guinea; Paraguay; Peru; Philippines; Poland; Portugal; Romania; Senegal; Singapore; Slovenia; South Africa; Spain; Sri Lanka; Sweden ;Switzerland; Syrian Arab Republic; Tanzania; Thailand; Togo; Tunisia; Turkey; Uganda; Ukraine; United Kingdom;United States; Uruguay; Venezuela, RB; Zambia; Zimbabwe

[xv] Figures obtained from the AIDS Epidemic Update 2002 of UNAIDS.

[xvi] Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Dem. Rep.;Congo, Rep.;Cote d'Ivoire, Eritrea, Gambia, Ghana,Guinea-Bissau ,Kenya, Lesotho, Madagascar, Malawi, Mali ,Mauritania, Mozambique, Namibia, Nigeria, Rwanda, South Africa, Sudan, Tanzania, Uganda, Zambia