Male circumcision and AIDS: the macroeconomic impact of a health crisis

Amrita Ahuja • Brian Wendell • Eric Werker

Abstract Theories abound on the potential macroeconomic impact of AIDS in Africa, yet there have been surprisingly few empirical studies to test the mixed theoretical predictions. In this paper, we examine the impact of the AIDS epidemic on African nations through 2005 using the male circumcision rate to identify plausibly exogenous variation in HIV prevalence. Medical researchers have found significant evidence that male circumcision can reduce the risk of contracting HIV. We find that national male circumcision rates for African countries are both a strong predictor of HIV/AIDS prevalence and uncorrelated with other determinants of economic outcomes. Two-stage least squares regressions do not support the hypotheses that AIDS has had any measurable impact on economic growth or savings in African nations. However we do find weak evidence that AIDS has lead to a decline in fertility combined with a slow-down in education gains, as measured by youth literacy, and a rise in poverty, as measured by malnutrition.

1 Introduction

The AIDS epidemic is a humanitarian disaster of massive proportions that has struck sub-Saharan Africa with particular severity. Africa accounts for nearly three quarters of the world's HIV infections, even though it is home to one eighth of the world's population and represents less than one twenty-fifth of worldwide GDP.

A. Ahuja

Harvard Business School, Boston, MA 02163 and Harvard Economics Department, Littauer Center, Cambridge, MA 02138

B. Wendell

Lehman Brothers, 745 Seventh Avenue, New York, NY 10019

E. Werker

Harvard Business School, Boston, MA 02163, Corresponding Author

Infection rates are frightening: in Swaziland, adult HIV prevalence is 33 percent and in several other nations in the "AIDS belt" that runs down southern Africa, one fifth of the adult population is The human impact is staggering: life expectancy in Zimbabwe has fallen more than 20 years in less than two decades. Over the next ten years, AIDS-related illnesses are expected to kill more Africans than all of the wars and natural disasters of the previous five decades (FAO 2003).

The economic impact of AIDS is much less clear. Unlike most diseases, AIDS predominantly affects adults rather than children and the elderly; hence, its economic effects may be particularly severe, especially with regards to decreasing human capital and impeding economic growth (Dixon et al. 2001). The Joint United Nations Programme on HIV/AIDS (UNAIDS) expects that the AIDS epidemic will cause a "growth drag" on GDP per capita in Africa of 0.5 - 1.2 percentage points per year (UNAIDS 2005); similarly, the International Labor Organization (ILO 2004) estimates that GDP growth will decline by 1.1 percentage points per year for the continent as a whole. Other economic studies hypothesize that the decrease in life expectancy brought about by the high prevalence of HIV will reduce incentives for younger Africans to save and to pursue an education, decreasing the availability of both physical and human capital (Ferreira and Pessoa 2003; Bell et al. 2003). However, AIDS may also increase the capital to labor ratio if the reduction in population growth outweighs the reduced savings rate (Over 1992). If it acts like the Black Death did in Europe, AIDS may actually increase per capita income through positive pressure on wages; this in turn would reduce fertility, enabling the wage increase to be sustained (Young 2005(a)). As it turns out, there is not a consensus among empirically-based studies on the link between HIV prevalence rate and economic growth (see Bloom and Mahal 1997; Bonnel 2000; Papageorgiou and Stoytcheva 2008; and Young 2005(a) for the range of perspectives).

A clear understanding of the real impact of AIDS is essential to formulating the appropriate policy response, as this may consist of more than simple prevention and treatment. If AIDS is an economic disaster, and the strength of the economy is instrumental in mitigating the impact of the disease, then strategies targeting economic capabilities in afflicted countries should be a central part of developmental agencies' AIDS programming. Additionally, high AIDS rates should be a serious deterrent to investors. If, on the other hand, AIDS is not an economic disaster, then resources can remain focused on prevention and addressing the undeniable humanitarian consequences of the disease, and economic growth could be fueled by continued investment even where AIDS prevalence is high.

The implications of our analysis also have relevance for the broader debate about the impact of health outcomes on economic output and growth. While microeconomic analyses have demonstrated beyond reasonable doubt that improved health leads to improved economic outcomes at the individual level (Strauss and Thomas 1998; Miguel and Kremer 2004; Schultz 2002), there is far less certainty about the economic impact of altering health at the macroeconomic level. Although the correlation between health and both output and growth at the macro level is undisputed, debate remains as to whether there is a causal relationship running from health to wealth. The majority opinion seems to be that improving health does lead to increased wealth and growth (Gallup and Sachs 2001; World Health Organization 2001; Bloom and Canning 2005; Weil 2005; Lorentzon et al. 2005). This view has been challenged by recent studies suggesting that improving health may have a negative impact on GDP per capita, (Acemoglu and Johnson 2006), that the net impact of a health crisis may also be positive (Young 2005(a)) or that the impact may be heterogeneous across countries, with a small negative impact which is concentrated in poorer countries (Papageorgiou and Stoytcheva 2008). Understanding the economic impact of AIDS, the most visible contemporary health crisis of macroeconomic proportions, is a crucial piece of this puzzle.

Measuring the impact of the AIDS epidemic (or health outcomes more broadly) is by no means straightforward. Cross-country comparisons are subject to omitted-variable bias since unobservable factors—such as the “responsibility” of the government or the “prudence” of the population—that affect AIDS (health) may also have an independent impact on the dependent variable. Reverse causality is another valid concern as many dependent variables (income and nutrition levels, for example) may also influence national AIDS rates, as people change their behavior in response to the epidemic, which can lead to different infection rates (Kremer 1996). Additionally, measurement error plagues most AIDS studies regardless of the dependent variable, an especially salient worry given the recent controversy over national HIV rates; classical measurement error can lead to attenuation bias where the magnitude of the coefficient is underestimated. In order to combat these identification problems, we instrument for HIV prevalence using the male circumcision rate.

Suggesting that male circumcision practices can be used to predict AIDS rates is hardly a novel idea. Indeed, the link between male circumcision and HIV prevalence has been debated in the medical literature for at least 20 years and was exploited as an instrument by Breirova (2002) in a paper examining the impact of AIDS on education in Kenya. The causal nature of this link has recently been established beyond reasonable doubt via three separate randomized and blindly evaluated trials in South Africa (Auvert et al. 2005), Kenya (Bailey et al. 2007) and Uganda (Gray et al. 2007), which showed that circumcision reduced a man's risk of infection from HIV by between 48 and 60 percent.[1,2] Results were so clear-cut that all three trials were halted after an interim review of data. The World Health Organization and UNAIDS recently recommended that "promoting male circumcision should be recognized as an additional, important strategy for the prevention of heterosexually acquired HIV infection in men" (UNAIDS/WHO 2007).

In this paper we argue that, in addition to having a causal protective effect on HIV infection rates, male circumcision in Africa does not co-vary at the national level with any salient omitted variables, such as initial income, initial life expectancy, or modernity, and that the coefficient of male circumcision on HIV/AIDS remains large and significant even after controlling for religion and ethnicity. We then use graphing and fixed-effect panel regressions (which are extremely effective in predicting changes in

---

1 Risk reduction was 60 percent in the South African trial (Auvert et al., 2005), 53 percent in Kenya (Bailey et al., 2007), and 48 percent in Uganda (Gray et al., 2007).

2 While the causal protective impact of male circumcision on HIV infection is now established, there is less clarity on the mechanism through which it works (see Szabo and Short, 2000 for an overview of proposed mechanisms). A leading theory is that uncircumcised males in less sanitary environments are more likely to get chancroid infections that cause genital sores. Since these chancroid sores catalyze the transmission of the HIV virus through increased blood exposure, uncircumcised men would have a higher likelihood of transmitting and receiving the AIDS virus (Caldwell and Caldwell, 1996). Steen (2001) notes that chancroids are particularly important in catalyzing HIV transmissions in countries with high AIDS prevalence and that male circumcision reduces chancroid infections. A more direct theory states that the vascular prepuce (foreskin removed in male circumcision) contains a high concentration of Langerhans cells which are a known target cells for HIV transmission (Hussain and Lehner, 1995). Other sexually transmitted infections that can increase the risk for HIV infection are also more prevalent among uncircumcised males, supporting the argument for this mechanism (Moses et al., 1998).

mortality that have characterized the epidemic) to estimate the impact of AIDS on economic measures between 1980 and 2005. We also estimate a cross-sectional cross-country regression of growth between 1990 and 2005 to corroborate our findings on the impact of AIDS on economic output.

Turning to our results, we find that AIDS has not had a measurable impact on several key economic variables in Africa. Specifically, HIV rates do not have a significant effect on GDP per capita or savings rates. Our conservative reading of the data indicates that the statistical likelihood that AIDS has had *any* negative effect on African GDP per capita is only two fifths. We find suggestive, though hardly conclusive, evidence that AIDS may have led to a decrease in fertility. We also find weak evidence that youth literacy levels increased more slowly than they would have in the absence of AIDS, suggesting that HIV may decrease investment in education. Finally, we find evidence indicating that the AIDS epidemic has led to an increase in malnutrition, which we interpret as supporting the hypothesis that the epidemic has contributed to the persistence of poverty in Africa.

The rest of this paper is organized as follows. In Section 2, we describe the instrument, examine the first stage of AIDS on circumcision, and subject the instrument to various robustness checks. In Section 3, we detail the empirical methodology. In Section 4, we examine the impact of AIDS on a variety of economic outcomes. Section 5 concludes.

2 Male circumcision and AIDS in Africa

There is high variation in male circumcision practices both across and within countries in Africa. In primarily Muslim North Africa, male circumcision is treated as a religious ritual prescribed by Islamic hygienic laws, while many sub-Saharan tribes incorporate male circumcision as a component of initiation rituals into manhood. Linguistic evidence indicates that male circumcision practices among the Bantu peoples of sub-Saharan African predate colonial influences (Marck 1997). Moreover, available accounts suggest that male circumcision remains a powerful tradition in many African cultures (Mandela 1994; Saitoti 1988). It is conceivable that some tribes may have altered male circumcision behavior since tribal practices were last surveyed; however, since we use circumcision data that predates the AIDS epidemic, any effects that the epidemic has had on circumcision will not taint our results.

Even though the medical community is no longer unsure of circumcision's causal impact on HIV infection in Africa, to justify using male circumcision as an instrument for HIV prevalence we must establish that it does not co-vary with important omitted variables that could impact the outcomes of the regression. The remainder of this section describes the male circumcision rate estimates and then argues that they are a good predictor of HIV prevalence rates at the national level as well as uncorrelated with major determinants of economic performance.

2.1 Estimates of circumcision

The first attempt to gauge national circumcision rates in Africa, using a methodology based on knowledge of circumcision rates by tribe, produced estimates for a subset of the countries (Bongaarts et al. 1989). A decade later, Halperin and Bailey (1999) grouped African nations into broad groups of high (>80 percent) and low (<20 percent) male circumcision prevalence. The authors combined data on tribal composition of each country with the knowledge of tribal circumcision practices to create national level estimates for many African countries. Shelton (2002) expanded this dataset to increase coverage and added a middle circumcision group (20-80 percent). These estimates form our primary instrument.

To examine the validity of the estimates, we built our own estimates based on ethnographic data on circumcision practices at the tribal level and demographic breakdowns of countries by tribe. Appendix A.1 provides a detailed description of our methodology. Appendix A.2 compares the estimates of Halperin and Bailey and Shelton (henceforth H/B) with ours. Ascribing values of 1 through 3 for low through high circumcision rates, there is a high correlation (0.82) between our approximations and the measures generated by H/B. Convinced that the H/B measures are sound, we use these independently-constructed measures as our primary instrument; our own estimates serve as a useful cross-check.

2.2 AIDS on circumcision

To examine the strength of the first stage of the estimation, we test how well national male circumcision rates predict HIV prevalence levels in African nations. Our dependent variable, the national AIDS/HIV prevalence rate in 1997 (percent of adults age 15-49), is from the UNAIDS/WHO *1998 Report on the global HIV/AIDS epidemic*.[3] We only use the single year as the estimation methods have changed over time, so UNAIDS recommends against comparing estimates across time.[4] We use 1997 AIDS prevalence rates as, of the years available, this one provides the most extensive coverage. Additionally, since HIV/AIDS is a disease which progresses slowly, we prefer to use infection rates from earlier in the epidemic; the biggest effects of infections in the mid nineties would be felt toward the end of our study period.[5]

The average national prevalence rate across the countries in Africa in 1997 was 6.5 percent, ranging from less than 0.1 percent in Morocco to 25.8 percent in Zimbabwe.[6]

Fig. 1 HIV/AIDS and male circumcision

Figure 1 plots the HIV/AIDS prevalence rate against the male circumcision category, revealing an obvious negative correlation.[7] The first column of Table 1 expresses this figure in regression coefficients. We find a large, negative effect of circumcision on AIDS that is statistically significant at the one-percent level. To interpret the coefficient, we perform the following thought experiment: going from a low-

---

[3] Appendix C provides a summary of sources for data used in this paper.

[4] http://www.unaids.org/Unaids/EN/Resources/Epidemiology/How+do+UNAIDS_WHO+arrive+at+estimates.asp, point 2.

[5] The correlation between AIDS prevalence in 1997 and prevalence and deaths from the disease in more recent years is very high, as recorded in Appendix B.1.

[6] There has been controversy over whether the WHO numbers are overestimates (Donnelly, 2004). If the prevalence rates are systematically overestimated by a constant proportion, then (a) the signs and significance of the coefficients are correct, but (b) the size of the impact of the explanatory variables in the first stage will be overestimates while (c) the size of the impact of HIV/AIDS in the second stage will be an underestimate. If the prevalence rates are simply measured with a lot of error, then the need for instrumental variable regressions becomes all the more crucial.

[7] Appendix A.3 shows an analogous plot of the AIDS rate against our linear male circumcision rate estimates.

circumcision country (male circumcision rate below 20 percent) to a mid-range country (circumcision rate between 20 percent and 80 percent), the predicted decrease in AIDS prevalence is about 8 percentage points; going from a low-circumcision country to a high-circumcision country (circumcision rates above 80 percent) predicts a decrease in AIDS prevalence of 14 percentage points. Cognizant of the criticism that the observed correlation between circumcision and AIDS may be driven by confounding factors, we include a number of key control variables in the two following regressions.[8]

Column 2 includes controls for the log of GDP per capita, the log of population density, the percentage of the population living in urban areas, the adult literacy rate, and the Polity2 score that measures the level of democracy in the country (where -10 is a perfect autocracy and 10 is a perfect democracy), all measured in 1980. We use values from 1980 as these predate the epidemic and thus cannot be contaminated by reverse causality. Certainly population density and urban residence may have effects on the HIV prevalence rate in the country independent of male circumcision, and GDP per capita and Polity2 may have important effects on the ability of the government to combat the epidemic. The coefficient on the high male circumcision rate retains its significance and remains large and meaningful at 11 percent. The coefficient on the intermediate circumcision rate variable decreases a little to about 5 percent, and is now not significant at conventional levels. Among the controls, only the log of population density has a significant effect on the HIV prevalence rate. In column 3 we include three additional ethnic, religious, and linguistic controls: the ethnolinguistic fractionalization, the fraction Muslim, and the fraction of the population from a Bantu-speaking tribe. As expected, Muslim countries have lower AIDS rates; however, the coefficients on the H/B variables remain similar in magnitude and significance to estimates without the controls for ethnicity. Strikingly, the impact of going from low- to high-circumcision on the AIDS rate is larger than the impact of the Muslim variable (which includes circumcision as well as behavioral norms).

---

[8] We do not control for health expenditures because it is higher in high-HIV countries perhaps due to medical expenses. We also do not control for other STIs which could obfuscate the relationship between circumcision and AIDS.

Table 1 Predicting HIV/AIDS rates with male circumcision

	Dependent Variable: % of adults 15-49 living with HIV/AIDS in 1997				
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS
H/B circumcision 20%-80%	-8.156	-5.167	-6.08	-5.253	-5.443
	[2.481]***	[3.622]	[4.079]	[3.254]	[3.618]
H/B circumcision 80%-100%	-14.151	-11.264	-9.565	-11.051	-8.826
	[2.167]***	[3.119]***	[3.167]***	[3.544]***	[3.347]**
ln(GDP per capita, PPP, Int. $2000), 1980		-0.187	1.853	2.041	2.589
		[1.486]	[1.616]	[1.826]	[1.638]
ln(Population Density), 1980		-1.202	-1.189	-1.433	-1.717
		[0.494]**	[0.516]**	[0.828]*	[0.748]**
Polity 2 Score, 1980		0.221	0.095	0.16	0.1
		[0.137]	[0.159]	[0.163]	[0.161]
Adult Literacy Rate, 1980		0.113	0.042	0.07	-0.007
		[0.091]	[0.088]	[0.095]	[0.099]
% Population Urban, 1980		-0.041	-0.048	0.014	0.026
		[0.087]	[0.065]	[0.088]	[0.088]
% Muslim			-6.245		-7.479
			[2.520]**		[3.055]**
% population from Bantu-speaking tribe			0.311		-1.496
			[3.244]		[2.620]
Ethnolinguistic Fractionalization, 1985			3.117		1.638
			[3.590]		[3.561]
Northern Africa				-5.546	-2.072
				[2.576]**	[2.860]
Eastern Africa				3.319	5.13
				[4.174]	[3.404]
Central Africa				0.46	-1.281
				[2.124]	[1.936]
Southern Africa				-1.834	-0.347
				[5.427]	[5.572]
F statistic on H/B variables	27.35	8.5	5.87	7.26	5.00
P (>F)	0.0000	0.0017	0.0098	0.0045	0.0206
Observations	48	31	31	31	31
R-squared	0.66	0.74	0.82	0.83	0.88

White standard errors in brackets.
* significant at 10%; ** significant at 5%; *** significant at 1%

Columns 4 and 5 introduce regional controls to make sure the circumcision/HIV correlation is not driven by differences in regional averages of both variables (West Africa is the omitted region). Even as North Africa has the predicted negative coefficient (AIDS is much less prevalent in North Africa), the magnitude of the circumcision variables are largely unchanged from columns 2 and 3, though the significance falls slightly in column 5. Additionally, we ran variations including controls for the percent Muslim squared as well as the percent Bantu squared (unreported). The coefficients on circumcision were basically unaffected.

To ensure that idiosyncrasies in the H/B male circumcision rate estimates were not responsible for the results, we ran the same regressions using our own estimates of male circumcision rates, reported in Appendix A3. We found that the coefficient estimates were comparable, though the linear circumcision rate lost size and significance once percent Muslim was included as a control. Going from a fully uncircumcised to fully circumcised country predicts a 15 percentage point reduction in AIDS prevalence, which is similar to the 14 percentage point reduction entailed by moving from the lowest to the highest H/B circumcision category.

To confirm that our results do not arise from idiosyncrasies in the measurement of HIV/AIDS prevalence, we ran the same regressions using HIV/AIDS prevalence in 2001, HIV/AIDS prevalence in 2005 and the death rate from HIV/AIDS in 2005 as dependent variables. Results from the main specification are reported in Appendix B.2. The coefficient estimates are similar to those obtained using HIV/AIDS prevalence in 1997 as the dependent variable.

At first glance, then, the first-stage results demonstrate that male circumcision rates are a powerful and robust predictor of HIV prevalence for African nations.

2.3 Validity of the instrument

It is difficult to imagine a direct impact of circumcision on economic growth, but perhaps the national circumcision rate may act as a proxy for important omitted variables that may have an independent effect on the dependent variable in the two-stage regression. To address this concern, we test whether major potential omitted variables differ systematically across high- and low-circumcision countries. In addition, our preferred empirical specification (discussed in the following section) includes fixed effects in order to control for any time-invariant unobservable factors.

A possible concern is that the male circumcision rate is positively correlated with characteristics that are conducive to economic growth. To test this hypothesis, in Table 2 we divide the sample of countries into three groups corresponding to those whose H/B circumcision rate estimates lie below 20 percent (low), between 20 percent and 80 percent (medium), and above 80 percent (high) and measure the three groups' means for a variety of country characteristics from 1980, before the AIDS epidemic had taken off. We find that initial GDP per capita is very similar across high-, medium-, and low-circumcision countries. Life expectancy is marginally higher in low male-circumcision countries, and infant mortality is considerably lower—in other words, circumcision is associated with worse health outcomes before AIDS took off. The fertility rate is again very similar across the three groups of countries. High-circumcision countries do have a higher domestic savings rate in 1980, suggesting that these countries might be financially more forward-looking; however the result is far from statistically significant. And there is an equally weak difference in the level of democracy in 1980 between high- and low-circumcision countries, suggesting that circumcised countries were characterized by more autocratic governments; however, this result is also not statistically significant.

The most statistically-significant differences across the two groups of countries were in the share of population living in urban areas (circumcised countries were more urban) and in literacy rates (circumcised countries were less literate). Hence we run the gamut of regressions of Section IV controlling for initial literacy and urban population and the results do not change appreciably. We additionally control for infant mortality rates, since the differences between the high and low circumcision groups are large and significant at the 10 percent level; once again this makes little difference to the results.

We also check whether the "modernity" of the population differs across high- and low-circumcision countries. After all, populations that adopt one new technology may be more likely to adopt other ones which could be conducive to economic growth. Table 1 reports the means by circumcision of the number of radios, vehicles, televisions and telephones per 1000 population.[9] The differences are minor and tell a mixed story: high circumcision countries tend to have fewer vehicles and phones but more radios and televisions than low circumcision countries. None of the differences are significant.

Even if male circumcision is correlated with neither typical preconditions for economic growth nor the adoption of newer technologies, it may be correlated with the level of risky sexual behavior of a given population. The channel from sexual prudence to economic performance is nebulous, and (incomplete) data on risky behavior are only available from the mid-1990s, well after the epidemic had taken off. That said, we report the differences in the available measures of risky sexual behavior between high- and low-circumcision countries at the end of Table 1. We use two measures of risky sexual behavior, and have data for both men and women for around half the countries in Africa. The first measure is whether adults report high-risk sexual activity, defined as sex with a non-regular, non-cohabiting partner, within the last year. There is little difference between low and high circumcision countries in terms of likelihood of engaging in high risk activities for both men and women. The second measure is whether adults report using a condom at their last high-risk sexual activity. Across both men and women, more people in low-circumcision countries report using condoms during high risk sex, not surprising given that condom use may be an outcome of the AIDS epidemic.

While some differences do exist across high- and low-circumcision countries for some variables, the fact remains that the most important economic and health variables—initial income and life expectancy—are quite similar across the three groups of countries. In other words, if characteristics associated with male circumcision could have a causal impact on economic and health outcomes, it seems quite clear that those characteristics had had little effect as of 1980 when AIDS was beginning to spread. Certainly the circumcision-stratified three populations are not otherwise identical, but pre-existing tribal practices with regard to circumcision have had a massive effect on the spread of AIDS without being overtly correlated with any major determinant of growth. On the whole it is not implausible to use male circumcision as an exogenous instrument for HIV prevalence.

[9] Data on vehicles are for 1996, the earliest year for which they are available

Table 2 Summary statistics by level of circumcision

	Male Circumcision Rate <20%			***Male Circumcision Rate 20-80%***			***Male Circumcision Rate > 80%***		
	Mean	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**	**Mean**	**Std. Dev.**	**N**
Log (GDP per capita, PPP, Int. $2000)	7.46	0.81	9	7.44	0.93	7	7.36	0.65	22
Gross Domestic Savings, % GDP	6.86	25.38	9	5.63	16.52	8	14.39	20.03	24
Adult Literacy Rate, Total*	55.10	14.79	9	36.61	20.22	8	34.00	14.29	19
Youth Literacy Rate, Total*	69.49	15.41	9	50.37	20.88	8	50.42	20.69	19
Fertility Rate	6.81	0.85	9	6.57	0.76	9	6.60	0.76	29
Birth Rate, crude (per 1,000 people)	45.37	6.46	9	45.81	4.41	9	46.11	4.68	30
Death Rate, crude (per 1,000 people)	14.21	5.14	9	16.56	3.02	9	18.12	5.14	29
Mortality Rate, infant (per 1,000 live births)	99.04	31.13	9	112.11	25.96	9	122.96	36.56	29
Life Expectancy at Birth	49.58	4.31	9	47.45	3.92	9	46.54	6.57	30
% of Population Undernourished	26.11	6.94	9	34.25	17.65	8	31.63	17.95	24
Urban Population, % Total*	16.97	11.02	9	22.88	14.65	8	30.85	15.40	30
Log (Population Density)	3.05	1.84	9	2.83	0.81	9	2.76	1.19	29
Log (Population)	14.73	0.99	9	16.31	0.79	9	15.13	1.40	30
Polity 2 (Democracy) Score	-4.63	6.67	8	-5.22	5.02	9	-5.38	4.69	29
Vehicles per 1000 Inhabitants, 1996	35.92	28.58	8	25.14	48.30	8	25.33	43.54	30
Main Line Telephones per 1000 Inhabitants, 1980	8.76	8.89	8	8.84	18.79	8	5.05	4.79	19
TV Sets per 1000 Inhabitants, 1980	3.42	4.59	8	17.59	25.38	9	11.81	17.55	27
Radios per 1000 Inhabitants, 1980	81.61	57.59	9	113.13	97.83	9	117.78	81.24	29
% Engaging in High Risk Sex, Male	30.81	17.12	7	40.20	28.04	7	31.53	20.04	16
% Engaging in High Risk Sex, Female	14.19	10.77	7	13.21	12.19	7	12.24	14.24	16
% Using Condoms when Engaging in High Risk Sex, Male	54.90	22.54	5	36.64	21.75	5	30.32	23.17	15
% Using Condoms when Engaging in High Risk Sex, Female	25.75	12.40	4	19.07	16.55	7	17.30	18.03	16
% of adults 15-49 living with HIV/AIDS in 1997*	16.97	6.44	9	8.82	4.12	9	2.82	3.07	30

*Means of groups with Male Circumcision Rate <20% and Male Circumcision Rate > 80% are significantly different at the 5% level

3 Empirical strategy

The overarching principle we follow is to use the most transparent and simple framework that still addresses concerns of omitted variable bias, reverse causality, and measurement error. Our analysis for each outcome variable follows two basic procedures.

The first procedure consists of two parts. First, we divide the sample into two groups of countries: those with high HIV/AIDS prevalence in 1997 (above six percent) and those with low HIV/AIDS in 1997 (below six percent).[10] For countries with complete data in the years 1980, 1985, 1990, 1995, 2000, and 2005 if available, we plot the average of the outcome variable by high and low AIDS over the time period. (It is important to note that this is not a causal test of the impact of AIDS on the dependent variable: since we use the AIDS rate in 1997, it is possible that the path of the dependent variable could have influenced the AIDS rate. Nonetheless, the plots should reveal the correlational patterns of AIDS and economic indicators in Africa.

We complement this with a similar set of graphs that divide countries based on their male circumcision rate (rather than their HIV/AIDS rate) to illustrate the evolution of macroeconomic variables divided by the exogenous component of HIV. In keeping with our main instrument, we divide our sample into three groups of countries: those with male circumcision rates greater than 80 percent, between 80 and 20 percent, and less than 20 percent. Analogously to before, we plot the average of the outcome variable by the three different male circumcision rate categories.

The second procedure rigorously tests the visual story revealed by the plots. Specifically, we run panel regressions on the outcome variable over the years 1980, 1985, 1990, 1995, 2000, and 2005 if available, and across the countries for which data are available for every time period. The panel includes country and year fixed effects to control for any time-invariant, country-specific factors as well as secular changes in the level of the dependent variable across the continent. To measure the impact of AIDS, we

---

[10] Six percent was chosen as the cutoff level because it occurs at a natural break in the data: the highest AIDS rate below this level is 4.9 percent (Cameroon) and the lowest rate above this level is 7.2 percent (Burkina Faso).

interact the AIDS rate in 1997 with dummy variables for the years 1990, 1995, 2000, and 2005; we do not expect AIDS to have made a significant impact on the economy before 1990. Given the controversy surrounding the measurement of the AIDS rate, and our decision to use a single year of AIDS data, we do not want to interpret this measure as the actual AIDS rate. Rather, we interpret it as a proxy for the true level of AIDS that exists in a particular country during a particular year.

For example, the measure of AIDS in Kenya in 1997 from the dataset we use is 11.6 percent. In 2004 new household data released suggest that only 6.7 percent of adults were infected; UNAIDS responded by revising their estimate to 9.3 percent (Donnelly 2004).[11] This could imply that the true AIDS rate in the year 2000 may be lower than the 1997 estimates. So long as the ratio of the true AIDS rate to the 1997 measured AIDS rate is known and reasonably consistent across countries,[12] the measure of AIDS that we use is sufficient to calculate the true relationship between AIDS and economic outcomes.

Specifically, the estimation equation is the following:

$$(1)\quad y_{it} = \alpha + \beta_1 * AIDS97_i * 1990_t + \beta_2 * AIDS97_i * 1995_t + \beta_3 * AIDS97_i * 2000_t + \beta_4 * AIDS97_i * 2005_t + \gamma_1 * \boldsymbol{X}_i * 1990_t + \gamma_2 * \boldsymbol{X}_i * 1995_t + \gamma_3 * \boldsymbol{X}_i * 2000_t + \gamma_4 * \boldsymbol{X}_i * 2005_t + \delta_1 * \boldsymbol{\mu}_i + \delta_2 * \boldsymbol{\nu}_t + \varepsilon_{it}$$

where $\boldsymbol{\mu}_i$ is a vector of country fixed effects and $\boldsymbol{\nu}_t$ is a vector of year dummies. The variable $\boldsymbol{X}$ is a control variable that might otherwise be omitted and correlated with the instrument. Thus the coefficients of interest are β_1, β_2, β_3, and β_4—the interaction terms between our measurement of the AIDS rate and the year dummies. The control periods are 1980 and 1985 when the epidemic was still in its infancy.

It is important to note that for inference, we rely on the fact that if the “true” elasticity of AIDS is constant over the time period over study, then our reported coefficients will be increasing in magnitude from 1990 to 2005 for outcomes on which

---

11 Kenya is not the only country where the original estimates have been criticized as too high. Household data from Zambia, Malawi, and South Africa also suggest that the UNAIDS estimates may have been too high (Donnelly, 2004).

12 This would be the case if discrepancies between the true and estimated AIDS rate arose from a common cause, such as limitations in the prevalence estimation methodology that is used across all countries.

AIDS does have an impact. Suppose the true elasticity of an outcome with respect to AIDS is ψ, then we would expect that:

$$\beta_1 = \psi * \frac{AIDS90_i}{AIDS97_i} \qquad \beta_2 = \psi * \frac{AIDS95_i}{AIDS97_i} \qquad \beta_3 = \psi * \frac{AIDS2000_i}{AIDS97_i} \qquad \beta_4 = \psi * \frac{AIDS2005_i}{AIDS97_i}$$

Continuing with the Kenya example, suppose *AIDS97* is measured at 11.6 percent, but the true levels were 4 percent, 6 percent, 9 percent and 12 percent in 1990, 1995, 2000 and 2005 respectively. Then we would expect β_4 to be about 1.3 times as high as β_3, twice as high as β_2, and three times as high as β_1. Hence, in addition to the signs on the coefficients of interest, we also use the trends in their magnitudes as a reality check on whether or not AIDS affects each outcome variable.

Because we believe that an OLS estimate of AIDS on many economic outcomes may suffer from reverse causality and omitted variable bias, and due to the controversy surrounding the measurement of HIV prevalence rates, we instrument for *AIDS97* using the male circumcision rate. Our primary specification uses the H/B measurements, although we also use our linear circumcision rate estimates as a robustness check in Appendix A.4. As a further robustness check, we also confirm in Table B.3 that results remain unchanged when using alternate measures of HIV/AIDS. Results (unreported) are also unchanged when any single country is dropped from the regression.

To understand the impact of AIDS on GDP, we also include a cross-sectional growth regression following, as closely as possible given data limitations, the basic regression framework of Barro (1999). Specifically, we regress the dependent variable, economic growth over the period 1990-2005, on the AIDS rate in 1997 (which is meant to proxy for the average AIDS rate over the period 1990-2005), as well as a number of control variables including initial income, fertility, infant mortality, primary school enrollment, democracy, and also fixed factors such as percent Muslim, percent Bantu, and ethnolinguistic fractionalization:

$$(3) \quad \ln(y_{i,\,2005}/y_{i,\,1990}) = \alpha + \beta * AIDS97_i + \gamma * \boldsymbol{X}_i + \varepsilon_i$$

where $\boldsymbol{X}_i$ are the host of control variables. As before, we instrument for *AIDS97* with male circumcision. Consistent with the growth literature, we instrument for initial income with income five years previous and for infant mortality with infant mortality ten years previous.[13] We also run a robustness check on the validity of the instrument by regressing growth between 1975 and 1985 (the closest pre-AIDS period with data coverage) on the AIDS rate in 1997. We check to confirm that we do not observe any "false effects" on growth in the earlier period; these would have to come from omitted variables correlated with the instrument as AIDS prevalence was negligible in this period.[14]

4 The impact of AIDS

This section reports the results of the empirical strategy taken to the African data. In the first sub-section we focus on the impact of the epidemic on mortality, revealing that our methods are effective in predicting the expected adverse health impact. Following that we analyze the impact of AIDS on economic growth. In addition, we discuss the extent to which it affects three major determinants of growth: savings, fertility, and education. The final sub-section presents preliminary evidence on the effects of the epidemic on poverty and destitution.

4.1 AIDS and health

The best understood impact of AIDS is its effect on health. In the absence of treatment, it can fairly quickly claim the lives of its victims. A study in Uganda begun in 1990 among randomly-selected HIV-positive individuals reported a median time of 4.3 years before progression to full-blown AIDS (Morgan et al., 1997). Assuming a reasonably uniform distribution of progression to AIDS among the sample group, this implies that the median group member was already about halfway to AIDS. The median

---

[13] Although growth regressions often use infant mortality five years previous as an instrument, for many developing countries infant mortality rates are reliably measured only once every ten years

[14] We run a further robustness check by dropping one country at a time from the regression, to ensure that our results do not arise from the effects of outliers. Results (unreported) remain similar to those from the specification including all countries.

survival time among individuals who had AIDS was 9.3 months. In other words, from the time of contraction of the HIV virus, a typical victim in Uganda could expect to survive around nine years. With prevalence rates in some countries in the double digits, this predicts a dramatic reduction in life expectancy and increase in death rates.

Figure 2a maps the average crude death rate[15] over the period 1980-2005 by countries whose 1997 HIV/AIDS prevalence rates were high (above 6 percent) and low (below 6 percent). In 1980, high-AIDS countries actually had a lower crude death rate, by about 3.1 deaths per thousand, a figure equal to 17 percent of deaths per thousand in low AIDS countries. Both experienced reductions in crude death rates through 1985. By 1990 the picture changes dramatically. While low-AIDS countries continued to experience reductions through 2005, the death rates in high-AIDS countries rose, such that by 2005 the crude death rate was significantly higher in high-AIDS countries by about 4.2 deaths per thousand per year, or about 30 percent of deaths per thousand, than in low-AIDS countries.

Figure 2b, which provides a similar map of crude death rates but groups countries by male circumcision rates, tells a similar story. Countries with low male circumcision rates (and hence high average HIV/AIDS rates) went from out-performing to underperforming countries with high male circumcision rates (and hence low average HIV/AIDS rates) in terms of crude death rates over the period 1980 to 2005.

Fig. 2a Crude death rate 1980-2005, by AIDS rate

Fig. 2b Crude death rate 1980-2005, by male circumcision rate

Table 3 tests this relationship using the more precise econometric methodology described previously. Controlling for country and year fixed effects, column 1 reports the coefficients on the interaction between the measured AIDS rate in 1997 and dummies for the years 1990, 1995, 2000, and 2005. As can be seen from the estimates, the

[15] Although life expectancy (Acemoglu and Johnson, 2006; Bloom et al., 2004), adult mortality (Lorentzen et al., 2005) and adult survival rates (Bloom and Canning, 2005; Weil, 2005) are the measures more commonly used in this literature, we prefer to use infant mortality and crude death rates as they are directly measured rather than modeled. In developing economies, where detailed tables of death by age do not exist, life expectancy, mortality, and adult survival rates are typically generated from infant mortality rates and crude death rates based on country-specific models.

coefficients are all positive and highly statistically significant, and they increase as the epidemic matures. This is consistent with the interpretation of the coefficients described in equation 2—that the typical country has experienced a growth in its HIV/AIDS prevalence rate, so if the true elasticity of crude death rates with respect to AIDS is constant across time, by using a single measure of AIDS we should observe changes in the measured coefficients. The magnitude of the coefficient for the year 2005 relative to the baseline period of 1980 and 1985 is 0.64. In other words, one extra percentage point in the HIV/AIDS prevalence rate in 1997 predicts an increase in annual crude death rate by the year 2005 of 0.64 deaths per thousand per year.

Table 3 HIV/AIDS and crude death rates

	Dependent Variable: Death Rate, Crude (per 1000 people)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	IV	IV	IV	IV	IV	IV
HIV/AIDS Rate in 1997 * 1990	0.141	0.228	0.21	0.327	0.181	0.266	0.18
	[0.062]**	[0.129]*	[0.121]*	[0.183]*	[0.103]*	[0.144]*	[0.150]
HIV/AIDS Rate in 1997 * 1995	0.289	0.374	0.343	0.402	0.338	0.393	0.288
	[0.066]***	[0.116]***	[0.107]***	[0.155]**	[0.103]***	[0.128]***	[0.132]**
HIV/AIDS Rate in 1997 * 2000	0.508	0.555	0.518	0.419	0.56	0.523	0.427
	[0.074]***	[0.102]***	[0.103]***	[0.105]***	[0.100]***	[0.100]***	[0.117]***
HIV/AIDS Rate in 1997 * 2005	0.642	0.694	0.658	0.464	0.73	0.63	0.55
	[0.106]***	[0.145]***	[0.149]***	[0.146]***	[0.141]***	[0.138]***	[0.170]***
F Statistic on AIDS-year interactions	15.08	9.38	9.18	6.36	8.77	8.62	4.49
P (>F)	0	0	0	0.0006	0	0	0.0038
F Statistic on first stage instrument		22.61	26.85	13.8	28.88	21.37	13.54
P (>F)		0	0	0	0	0	0
GDP per capita in 1980*year interactions			Yes				
Adult Literacy in 1980*year interactions				Yes			
Urban Population Share in 1980*year interactions					Yes		
Infant Mortality Rate in 1980*year interactions						Yes	
% Muslim*year interactions							Yes
Observations	294	282	246	210	276	282	282
R-squared	0.89	0.88	0.89	0.89	0.89	0.9	0.89

Robust standard errors in brackets clustered on countries. All specifications include country and year fixed effects. HIV/AIDS instrumented with the H/B variables.
* significant at 10%; ** significant at 5%; *** significant at 1%

Column 2 repeats the same specification, this time instrumenting for the AIDS rate with male circumcision. The results are similar, though the coefficients are larger in magnitude. This is consistent with the existence of measurement error in the AIDS rate leading to attenuation bias in the OLS results. The size of the coefficient on the year 2005 has increased to about 0.69. For a country which had had the mean adult HIV/AIDS prevalence rate across high-AIDS countries of about 13 percent, this would suggest an increase of just under 9 deaths per thousand per year. The average crude death rate in 1980 in high- and low-AIDS countries was about 16 deaths per thousand people. Hence, this represents an increase of over 50 percent in the number of deaths per thousand each year for high-AIDS countries on average.[16]

Columns 3 through 7 include controls for the interaction of potential omitted variables (correlated with the instrument) with the year dummies for 1990, 1995, 2000, and 2005. We control for initial income in column 3, which might have an independent effect on the change in life expectancy; we control for initial adult literacy, urban population, and infant mortality (the three variables most correlated with the instrument) in columns 4, 5, and 6 respectively; we control for percent Muslim in column 7. None of the controls change the results appreciably.

Fig. 3a Infant mortality rate 1980-2005, by AIDS rate

Fig. 3b Infant mortality rate 1980-2005, by male circumcision rate

Figures 3a and 3b and Table 4 conduct similar analyses using infant mortality rate rather than crude death rate as the outcome variable. Although AIDS is predominantly an adult disease, it is also expected to lead to an increase in infant mortality. Between 20 and 50 percent of infants born to women with HIV are infected during pregnancy, delivery, or breastfeeding (De Cock et al. 2000), and of these about a third will die before their first

[16] The increase in deaths due to HIV/AIDS seems low given infection rates. If average infection rate is about 13 percent, or 130 in 1000, and the disease kills everyone it infects within ten years, then on average about 13 people per year, rather than 9, should be dying from AIDS, assuming that the distribution of infection is uniform across the previous ten years. That the increase in deaths is lower than expected seems to suggest either that the rate of infection has been growing over the previous ten years (so that a higher share of people are currently in early stages of infection), that current HIV/AIDS prevalence estimates are too high, or that adult infection rates are higher than for the population at large. Most likely, all three issues are at play.

birthday (Newell et al. 2004).[17] We also conducted similar analyses using life expectancy as the dependent variable (unreported). The results are very similar, suggesting that AIDS has had a large effect on mortality, regardless of how it is measured.

Table 4 HIV/AIDS and infant mortality rates

	Dependent Variable: Mortality Rate, Infant (per 1,000 live births)						
	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV	(7) IV
HIV/AIDS Rate in 1997 * 1990	0.508	0.525	0.499	1.051	0.372	0.624	-0.11
	[0.305]	[0.367]	[0.368]	[0.504]**	[0.408]	[0.389]	[0.426]
HIV/AIDS Rate in 1997 * 1995	1.013	1.107	1.019	1.631	0.909	1.151	0.117
	[0.344]***	[0.432]**	[0.420]**	[0.627]**	[0.465]*	[0.466]**	[0.490]
HIV/AIDS Rate in 1997 * 2000	1.668	1.799	1.692	2.017	1.687	1.682	0.588
	[0.384]***	[0.506]***	[0.503]***	[0.784]**	[0.524]***	[0.554]***	[0.611]
HIV/AIDS Rate in 1997 * 2005	1.987	2.201	2.077	2.231	2.122	2.007	0.899
	[0.469]***	[0.603]***	[0.599]***	[0.931]**	[0.609]***	[0.649]***	[0.736]
F Statistic on AIDS-year interactions	5.43	3.38	3.1	1.84	3.27	2.55	1.06
P (>F)	0.0012	0.0173	0.0271	0.145	0.0204	0.0532	0.3872
F Statistic on first stage instrument		21.38	23.86	12.84	26.05	19.94	10.79
P (>F)		0	0	0.0001	0	0	0.0002
GDP per capita in 1980*year interactions			Yes				
Adult Literacy in 1980*year interactions				Yes			
Urban Population Share in 1980*year interactions					Yes		
Infant Mortality Rate in 1980*year interactions						Yes	
% Muslim*year interactions							Yes
Observations	225	215	185	165	210	215	215
R-squared	0.95	0.95	0.95	0.94	0.95	0.95	0.95

Robust standard errors in brackets clustered on countries. All specifications include country and year fixed effects. HIV/AIDS instrumented with the H/B variables.
* significant at 10%; ** significant at 5%; *** significant at 1%

While this exercise reveals little new information about the disease, it does serve as a robustness check on the instrument and empirical strategy more generally. The

[17] Several studies also document that the AIDS epidemic has lead to increases in childhood (under-5) mortality (Hill et al., 2001, Crampin et al., 2003; Walker et al., 2002).

instrument has strong predictive power, and the estimations confirm the intuition behind the picture presented in the popular press and in Figure 2a.

4.2 Is AIDS an economic disaster?

The bulk of economic literature on the impact of AIDS in Africa predicts a frightening set of scenarios.[18] The first channel economists focused on was a reduction in the savings rate caused by AIDS-related expenditures (Over 1992). With reasonable assumptions including a boon to growth from a reduction in the population growth rate, Over estimates a net negative effect on growth rates of around a third of a percentage point for African economies worst hit by the epidemic. This may be sensitive to whether the country is an open economy, in which case reduced foreign direct investment and increased capital outflows can exacerbate the negative effects of AIDS (Haacker 2002), or whether market inefficiencies such as unemployment are lessened, in which case the negative effect of AIDS is diminished (Cuddington 1993). Similarly, savings may fall through the drastically lower life-expectancy rates. The shortened expected lifespan reduces incentives to save, which prohibits the capital accumulation central to models of economic growth (Arndt and Lewis 2000). In a general equilibrium model, Arndt and Lewis predict that the income level in 2010 will be 7 percent lower in South Africa as a result of AIDS. Following the lines of that argument, the shortened lifespan also diminishes incentives for individuals to invest in education since the payoff to human capital investments decreases with falling life-expectancy (Ferreira and Pessoa 2003). Ferriera and Pessoa predict a long-run drop in per-capita income of one quarter, driven in part by a reduction in schooling of one half. Several studies (e.g. Case et al. 2004; Evans and Miguel 2004; Yamano and Jayne 2004) also highlight the reduction in schooling that could come from orphaning of children due to AIDS.

This literature is not without its optimistic outliers. Studies by ING Barings (2000) and the Bureau for Economic Research (2000) predict a positive impact of AIDS on the South African economy. These have been criticized by Acott (2000) for their demographic projections and by Gaffeo (2003) for the primary channel of growth

---

[18] See Gaffeo (2003) for a review of the literature.

increase being through a higher demand for AIDS-related expenditures. Most recently, Alwyn Young (2005a) has argued that AIDS may not be the economic disaster (in terms of per capita income) forecast as above. In his simulation of the South African economy, AIDS reduces the labor supply, putting positive pressure on the real wage which, in turn, lowers fertility (thus sustaining the rise in real wage). This effect should counteract the disease's negative impact on the accumulation of human capital among orphans, leaving the economy with higher per capita output than in a no-AIDS scenario.

The negative impact of AIDS on population growth will be even stronger if fertility is reduced due to fear of mother-to-child transmission, longer abstinence, widowhood, reduced fecundity, increased condom use, and the desire to not leave progeny as orphans. However, AIDS could perversely increase fertility if families desire to have more children in response to a higher expected mortality per child, if women reduce breastfeeding in an effort to prevent transmission of the disease to a child, or if women reduce post-partum abstinence to discourage the husband from extra-marital sex that increases his risk of acquiring HIV (Ntozi 2001). Evidence suggests that HIV-positive women have lower pregnancy rates than women who are not HIV-positive (Gray et al 1998; Desgrees du Lou et al. 1998; Zaba and Gregson 1998), though the net impact on fertility (including the fertility-increasing behavioral response on the part of non HIV-positive women) cannot be determined from these studies. The extensive analysis of Young (2005 (b)) based on DHS surveys of 27 sub-Saharan African countries with wide-spread epidemics strongly suggests that the disease is causing a fertility decline by reducing the demand for children. There are also studies which point in the opposite direction, most forcefully Kalemli-Ozcan (2006), which finds that the epidemic leads to an increase in fertility due to a precautionary demand for children, and this could be reversing Africa's demographic transition.

Surprisingly, there are few cross-country empirical studies on the macroeconomic effects of AIDS on output and growth. The most widely-cited is Bloom and Mahal (1997), which looks at the impact from 1980-92 across 51 developing and industrial countries. Bloom and Mahal do not find a statistically significant relationship between AIDS and economic growth. Papageorgiou and Stoytcheva (2008) extend the sample of Bloom and Mahal and pay attention to concerns about endogeneity as they regress the level of output per capita on HIV/AIDS infection rates for almost 90 countries using panel data techniques in an extended Solow framework. They find that HIV/AIDS has a negative impact on growth, which is statistically significant but small. Interestingly, they find that negative effects are concentrated in Africa and Latin America, for infections in the high-productivity 16-34 age-group. Bonnel (2000) regresses growth from 1990-97 on AIDS in 1994-97 for approximately 80 developing countries and finds a negative impact of AIDS on growth that is statistically significant for the square of the log of the HIV/AIDS prevalence rate. Dixon et al.(2001) perform dynamic panel regressions from 1960-98 on African economies where HIV enters the growth equation only through health capital. They conclude that the impact of HIV for low-AIDS countries is minimal, and for high-AIDS countries is unclear. In a similar exercise, McDonald and Roberts (2006) find that each percentage point in HIV prevalence lowers per capita income by 0.59 percent. Mahal (2004), while arguing that overall the evidence for a macroeconomic impact of AIDS is still weak, provides some support for this result. His simulations suggest that the impact of AIDS will be high in Botswana and South Africa, but negligible in South and South-West Asia. In our view, it seems appropriate to worry about omitted variable bias and measurement error more than previous studies have done.

To keep the estimations transparent we first graph average GDP per capita over the period 1980-2005 in Africa by high- and low-AIDS countries in Figure 4a. Several observations follow. First, there was not any consistent increase in per capita income in Africa until the period 1995-2005, which shows a similar increase for high- and low-AIDS countries. Second, high-AIDS countries start and end marginally richer. Third, the period over which low-AIDS countries meaningfully outperformed high-AIDS countries was 1980-85, before the disease took hold, indicating the slight catching up done by low-AIDS countries does not seem to be a result of their avoiding the epidemic. The graphs in Figure 4b, plotting GDP per capita over the same period by male circumcision rate category, again provides no evidence that high male circumcision rate countries outperform low male circumcision countries as the AIDS epidemic progresses. If anything, low circumcision countries have done particularly well relative to high circumcision countries in the 1995-2000 period, by which time the epidemic was deeply rooted.

Fig. 4a GDP per capita 1980-2005, by AIDS rate

Fig. 4b GDP per capita 1980-2005, by male circumcision rate

For a causal model of the impact of AIDS on economic growth we turn to Table 5. The first column is an OLS regression of the log of GDP per capita on country and year fixed effects as well as the interaction of the AIDS rate in 1997 with year dummies for 1990, 1995, 2000, and 2005. The coefficients are essentially zero. Of course, as we have argued, there may be biases in this estimate. The three main potential sources of bias are: measurement error, which if classical predicts that OLS will lead to attenuation bias on the impact of AIDS on GDP per capita; omitted variable bias (the most obvious one being that countries who succumb to AIDS probably do not manage their economy well either, and the effects of this mismanagement accumulate over time) predicts that OLS would incorrectly ascribe to AIDS a negative impact from this omitted variable on GDP per capita; and reverse causality, which could go either way, depending on how income affects the spread of AIDS (which seems to be slightly positive according to most specifications in Table 2).

The next six columns instrument for the AIDS rate using male circumcision. The coefficients increase somewhat but remain very close to zero, and the inclusion of control variables introduces some noise into the regressions but does not change the results appreciably. The coefficient on the interaction between the AIDS rate in 1997 and the dummy for the year 2005 is 0.003 (column 2) and is statistically indistinguishable from zero. If the measurement were correct, this would imply that an exogenous increase in the prevalence rate in 1997 of one percentage point is associated with an *increase* in GDP per capita in the year 2005 of around 0.3 percent over and above what it would have been without AIDS since the period 1980-85.

To estimate the average impact of the disease in the decade 1995-2005 relative to 1980-1990, we ran the regressions discussed above with interactions of the AIDS rate in 1997 and the male circumcision variables with year dummies replaced by their interaction with a dummy taking the value 1 in 1995, 2000 and 2005, and the value 0 in other years (results not reported). This is the simplest regression to represent the “differences-in-differences” of the epidemic on the affected countries. The coefficient on

Table 5 HIV/AIDS and GDP per capita

	Dependent Variable: ln(GDP per capita, PPP, Int. $2000)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	IV	IV	IV	IV	IV	IV
HIV/AIDS Rate in 1997 * 1990	0.001	0.003	0.003	0.002	0.002	0.003	0.007
	[0.007]	[0.007]	[0.007]	[0.007]	[0.007]	[0.007]	[0.009]
HIV/AIDS Rate in 1997 * 1995	0.001	0.004	0.004	-0.002	0.004	0	0.011
	[0.008]	[0.009]	[0.009]	[0.010]	[0.009]	[0.009]	[0.014]
HIV/AIDS Rate in 1997 * 2000	0.002	0.006	0.006	-0.001	0.008	0.001	0.022
	[0.011]	[0.012]	[0.012]	[0.013]	[0.012]	[0.011]	[0.016]
HIV/AIDS Rate in 1997 * 2005	-0.001	0.003	0.003	-0.004	0.004	-0.001	0.023
	[0.013]	[0.013]	[0.013]	[0.015]	[0.013]	[0.013]	[0.019]
F Statistic on AIDS-year interactions	0.78	0.48	0.48	0.48	0.58	0.28	0.81
P (>F)	0.5436	0.7493	0.747	0.7487	0.6825	0.8866	0.5284
F Statistic on first stage instrument		22.84	28.64	16.71	34.67	23.09	12.26
P (>F)		0	0	0	0	0	0.0001
GDP per capita in 1980*year interactions			Yes				
Adult Literacy in 1980*year interactions				Yes			
Urban Population Share in 1980*year interactions					Yes		
Infant Mortality Rate in 1980*year interactions						Yes	
% Muslim*year interactions							Yes
Observations	228	222	222	186	216	222	222
R-squared	0.95	0.95	0.95	0.96	0.96	0.95	0.95

Robust standard errors in brackets clustered on countries. All specifications include country and year fixed effects. HIV/AIDS instrumented with the H/B variables.
* significant at 10%; ** significant at 5%; *** significant at 1%

the interaction of the AIDS rate in 1997 with the post-1995 dummy was again about 0.003. While this point estimate is consistent with the “optimistic” views of AIDS, it is not precisely measured. If we consider the 90-percent confidence level for a one-percent HIV/AIDS increase, GDP per capita would be no lower than -1.2 percent and no higher than 1.9 percent. For Africa as a whole, where the mean AIDS rate (weighted by population in 2000) is just under 6 percent, this implies that at worst, 2000 GDP per capita would be 7 percent lower than it would have been in the absence of AIDS. At the optimistic end, GDP per capita could be as much as 11 percent higher than it would have been without the epidemic. We interpret the results as being unable to reject the null hypothesis that AIDS has no impact on per capita wealth. However, while this means our estimates are still consistent with the least pessimistic (0.5 percent growth drag) of the UNAIDS (2005) and ILO (2004) assessments of the impact of HIV/AIDS on economic growth in Africa, they do rule out the more pessimistic assessments. Our analysis of the data indicates that the statistical likelihood that the impact of AIDS on growth in Africa has been negative is about 35 percent.

We test this same hypothesis using a standard growth regression framework. Figure 4c graphs the partial correlation of growth in African countries from 1990-2005 against HIV-AIDS prevalence in 1997, filtering for the 1990 values of infant mortality, adult literacy, the log of fertility and the log of GDP per capita. The graph provides no evidence that low AIDS countries outperform those with high AIDS rates during this period. Figure 4d graphs the same outcome variable with the same filters against male circumcision rate categories. Again, we see no evidence that high circumcision rate countries underperformed those with low circumcision rates from 1990 to 2005.

Fig. 4c Partial Correlation of GDP per Capita Growth 95-05 and HIV/AIDS Rate 1997

Fig. 4d Partial Correlation of GDP per Capita Growth 95-05 and male circumcision

Table 6 provides results from a formal causal growth regression model. Since we are regressing growth over the period 1990-2005 on the AIDS rate in 1997, which we interpret as the average AIDS rate over the period, this regression should estimate the elasticity of economic growth with respect to AIDS. As it is a cross-sectional regression we are unable to control for unobservable time-invariant country characteristics, but the two-stage least squares specification should address that concern. The second column reports the OLS results, controlling for initial GDP per capita, fertility, infant mortality, and adult literacy. We chose these controls to recreate as closely as possible the typical growth regressions while modifying the controls (for example choosing adult literacy rather than secondary education) only when data coverage demanded. Consistent with the panel regression in Table 5, a higher AIDS rate predicts a higher level of growth in GDP per capita, with the coefficient from column 2 remaining non-significant. The coefficient is approximately -0.005, indicating that a one-percentage point increase in the AIDS rate is associated with an decrease in the log of GDP per capita over fifteen years of 0.005 (column 2)—approximately equal to a fall in the growth rate of 0.5 percent over fifteen years or about 0.03 percent per annum. Projected on the control period of 1975-85, the AIDS rate in 1997 is essentially zero in the base OLS specification.

The next six columns instrument for the AIDS rate with male circumcision, gradually adding additional controls. These specifications also instrument for initial income with income five years previously, and infant mortality with the same measure from ten years previously. The coefficient on the AIDS rate remains small and positive across columns three to eight while the noise with which it is measured increases slightly; hence it remains statistically insignificant. The results are directionally consistent with those from the fixed effects specification on income levels, although they predict a slightly larger effect on income. Column 4 is our preferred specification, and here the coefficient on income is 0.003 with a standard error of 0.015. Hence, over the 15- year period 1990-2005 (rather than the 22.5 year period from 1980-85 to 2005 that is captured in the fixed effects specification), a country with a 1 percent HIV/AIDS prevalence rate should see about a 0.3 percent increase in income over and above what it would have had if its prevalence rate were zero. Standard errors also remain large: a 90-percent confidence interval predicts that 2005 income would be decreased by no more than 2.3 percent and increased by no more than 2.8 percent over the decade and a half. Here, the probability that the epidemic has had a negative impact on growth is 42 percent. We repeat specifications 4 and 6 additionally controlling for North Africa (unreported) and the coefficient on AIDS is essentially unchanged.

4.3 Savings, fertility, and education

While AIDS may not have had a measurable impact on economic growth through 2005, it remains possible that it has had an effect on the determinants of economic growth thus affecting future economic performance. Testing the notion that the AIDS epidemic skews incentives to save, we examine how AIDS rates have impacted the change in gross domestic savings as a percent of GDP. Figure 5a plots the savings rate over the period 1980-2005 by high- and low-AIDS countries. From the graph it is apparent that low-

Table 6 Growth in GDP per capita, 1990-2005

I. Primary Regression (Growth 1990-2005)	Dependent Variable: GDP per Capita Growth 1990-2005							
	(1) OLS	(2) OLS	(3) IV	(4) IV	(5) IV	(6) IV	(7) IV	(8) IV
% of adults 15-49 living with HIV/AIDS in 1997	-0.002	-0.005	0.002	0.003	0	0.014	0.014	0.024
	[0.008]	[0.013]	[0.009]	[0.015]	[0.016]	[0.021]	[0.018]	[0.022]
ln(GDP per capita, PPP, Int. $2000), 1990		-0.111		-0.209	-0.2	-0.264	-0.386	-0.375
		[0.103]		[0.154]	[0.147]	[0.158]	[0.173]**	[0.241]
ln(Average Fertility, 1987-1992)		-0.452		-0.815	-0.819	-0.764	-0.968	-1.213
		[0.340]		[0.532]	[0.534]	[0.571]	[0.557]*	[0.849]
Infant Mortality Rate, 1990		-0.001		-0.001	-0.002	-0.001	-0.001	0.002
		[0.003]		[0.003]	[0.004]	[0.004]	[0.004]	[0.006]
Adult Literacy Rate, 1990		0		-0.002	-0.002	0.001	0.002	0
		[0.005]		[0.006]	[0.006]	[0.007]	[0.008]	[0.010]
% Popluation Urban, 1990					-0.002	-0.003	-0.003	-0.003
					[0.006]	[0.006]	[0.005]	[0.005]
% population from Bantu-speaking tribe						-0.159	-0.174	-0.291
						[0.200]	[0.192]	[0.231]
% Muslim						0.297	0.306	0.384
						[0.253]	[0.220]	[0.230]
Ethnolinguistic Fractionalization, 1985							-0.004	0.045
							[0.231]	[0.270]
Polity 2 Score, 1990							0.021	0.014
							[0.017]	[0.018]
Average Terms of Trade, 1990-2002								-0.004
								[0.004]
Observations	44	35	42	32	32	32	32	29
R-squared	0	0.14		0.05	0.08	0.07	0.11	0.04

Robust standard errors in brackets. HIV/AIDS is instrumented with the H/B variables. Ln(GDP) is instrumented with the value from five years lagged; infant mortality is instrumented with the value from ten years lagged.
* significant at 10%; ** significant at 5%; *** significant at 1%

II. First Stage	Dependent Variable: % of adults 15-49 living with HIV/AIDS in 1997							
	(1) N/A	(2) N/A	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
H/B circumcision 20%-80%			-8.156	-3.919	-4.504	-5.17	-7.89	-11.514
			[2.493]***	[2.894]	[2.707]	[2.966]*	[3.392]**	[2.571]***
H/B circumcision 80%-100%			-14.221	-10.815	-12.376	-11.284	-13.005	-13.854
			[2.188]***	[2.454]***	[2.968]***	[3.076]***	[2.980]***	[2.375]***
F statistic on H/B variables			26.84	14.37	10.22	7.54	10.05	19.22
P (>F)			0	0.0001	0.0006	0.0032	0.001	0.0001
Observations			42	32	32	32	32	29
R-squared			0.67	0.74	0.76	0.8	0.82	0.87

Robust standard errors in brackets. Includes same controls from Primary Regression.
* significant at 10%; ** significant at 5%; *** significant at 1%

III. Control Regression (Growth 1975-1985)	Dependent Variable: GDP per Capita Growth 1975-1985							
	(1) OLS	(2) OLS	(3) IV	(4) IV	(5) IV	(6) IV	(7) IV	(8) IV
% of adults 15-49 living with HIV/AIDS in 1997	0.007	0.001	0.009	0.001	-0.007	-0.017	-0.032	-0.022
	[0.010]	[0.016]	[0.010]	[0.017]	[0.017]	[0.038]	[0.030]	[0.025]
Observations	35	27	35	27	27	27	27	27
R-squared	0.03	0.17	0.03	0.14	0.03		0.43	0.52

Robust standard errors in brackets. AIDS is instrumented with the H/B variables. Ln(GDP) is instrumented with the value from five years lagged; infant mortality is instrumented with the value from ten years lagged. All regressions contain the same controls as in panel I.
* significant at 10%; ** significant at 5%; *** significant at 1%

AIDS countries are better, but less consistent savers. Both groups experienced an uptick in savings beginning in 1995. Figure 5b, which plots the same savings rates split by male circumcision rate category again shows high-circumcision rate countries save more than low-circumcision rate countries, but shows no discernable differences in saving rate trends between the two sets of countries.

Fig. 5a Savings (% of GDP) 1980-2005, by AIDS Rate

Fig. 5b Savings (% of GDP) 1980-2005, by male circumcision rate

Table 7 tests the relationship between HIV/AIDS prevalence and savings more formally. The results are generally very noisy: both the OLS and the IV results indicate

Table 7 HIV/AIDS and savings

	Dependent Variable: Gross Domestic Savings, % GDP						
	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV	(7) IV
HIV/AIDS Rate in 1997 * 1990	-0.024	0.015	-0.015	0.076	-0.222	0.127	0.248
	[0.198]	[0.235]	[0.241]	[0.291]	[0.239]	[0.249]	[0.379]
HIV/AIDS Rate in 1997 * 1995	-0.096	-0.077	-0.098	-0.122	-0.193	-0.059	-0.289
	[0.194]	[0.302]	[0.309]	[0.374]	[0.285]	[0.334]	[0.401]
HIV/AIDS Rate in 1997 * 2000	-0.154	-0.005	-0.033	-0.291	-0.195	0.008	0.204
	[0.237]	[0.452]	[0.448]	[0.520]	[0.391]	[0.510]	[0.762]
HIV/AIDS Rate in 1997 * 2005	-0.26	-0.197	-0.203	-0.528	-0.263	-0.233	-0.142
	[0.262]	[0.530]	[0.523]	[0.656]	[0.436]	[0.607]	[0.761]
F Statistic on AIDS-year interactions	0.31	0.16	0.17	0.27	0.24	0.29	0.96
P (>F)	0.8711	0.9568	0.9532	0.8914	0.9132	0.8797	0.4413
F Statistic on first stage instrument		24.57	29.5	15.86	44.14	22.66	14.43
P (>F)		0	0	0	0	0	0
GDP per capita in 1980*year interactions			Yes				
Adult Literacy in 1980*year interactions				Yes			
Urban Population Share in 1980*year interactions					Yes		
Infant Mortality Rate in 1980*year interactions						Yes	
% Muslim*year interactions							Yes
Observations	198	192	192	156	186	192	192
R-squared	0.84	0.84	0.85	0.85	0.85	0.85	0.84

Robust standard errors in brackets clustered on countries. All specifications include country and year fixed effects. HIV/AIDS instrumented with the H/B variables.
* significant at 10%; ** significant at 5%; *** significant at 1%

that savings may have fallen as a result of AIDS, but the standard errors in the coefficient estimates prevent any conclusions being drawn.

We similarly find no significant effect on fertility of the AIDS epidemic in Africa, although most of our results indicate negative point estimates. Figure 6a depicts the crude birth rate over the period 1980-2005 by high- and low-AIDS countries. Both groups of countries exhibit a decline over the period, with a slightly higher decline among high-AIDS nations, who start at a slightly higher level and end at a slightly lower level. Figure 6b, which plots the same data split by male circumcision rate categories, also picks up the trend: low-circumcision countries experience a larger drop in their crude birth rate.

Fig. 6a Crude birth rate 1980-2005, by AIDS rate

Fig. 6b Crude birth rate 1980-2005, by male circumcision rate

Panel regressions in Table 8 suggest the potential negative effect that AIDS might have on fertility. The coefficient in both OLS in the first column and IV in the next column are negative, but the results are not statistically significant. In a specification that controls for the interaction between adult literacy and the year dummies, however, the coefficient is positive. The specifications which control for urban population and percent Muslim interacted with the year dummies flip signs again and are both strongly negative. Since these specifications were included to control for variables that were correlated with the instrument, rather than for any structural reason, we do not wish to stress these results. Broadly, our regressions do find suggestive, if not overwhelming, evidence that the AIDS epidemic may have contributed to reduced fertility in affected nations.
There is equally weak evidence that the AIDS epidemic might have affected educational attainment in Africa. Figure 7a depicts youth literacy rates, our measure of education with the broadest coverage, over the period 1980-2000 for high- and low- AIDS countries. (Data from 2005 are unavailable.) Although youth literacy rates in low-AIDS countries are lower than those in high-AIDS countries, youth literacy has grown more where AIDS rates are low. This is clearer in Figure 7b, where one can see that youth literacy has grown faster in high-male circumcision countries than in low circumcision ones.

Table 8 HIV/AIDS and birth rates

	Dependent Variable: Crude Birth Rate (per 1,000 people)						
	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV	(7) IV
HIV/AIDS Rate in 1997 * 1990	-0.03	-0.053	-0.085	0.163	-0.142	0.029	-0.208
	[0.077]	[0.082]	[0.075]	[0.142]	[0.083]*	[0.096]	[0.092]**
HIV/AIDS Rate in 1997 * 1995	-0.046	-0.094	-0.122	0.251	-0.221	0.028	-0.321
	[0.105]	[0.115]	[0.115]	[0.171]	[0.119]*	[0.132]	[0.139]**
HIV/AIDS Rate in 1997 * 2000	-0.09	-0.141	-0.168	0.217	-0.296	-0.005	-0.404
	[0.114]	[0.125]	[0.128]	[0.182]	[0.130]**	[0.142]	[0.156]**
HIV/AIDS Rate in 1997 * 2005	-0.119	-0.153	-0.188	0.162	-0.319	-0.021	-0.433
	[0.110]	[0.130]	[0.130]	[0.193]	[0.132]**	[0.149]	[0.170]**
F Statistic on AIDS-year interactions	1.82	1.44	1.28	0.86	4.04	0.39	3.6
P (>F)	0.1396	0.2372	0.293	0.4974	0.0069	0.8114	0.0121
F Statistic on first stage instrument		23.19	27.69	15.04	29.76	22.02	13.57
P (>F)		0	0	0	0	0	0
GDP per capita in 1980*year interactions			Yes				
Adult Literacy in 1980*year interactions				Yes			
Urban Population Share in 1980*year interactions					Yes		
Infant Mortality Rate in 1980*year interactions						Yes	
% Muslim*year interactions							Yes
Observations	300	288	252	216	282	288	288
R-squared	0.92	0.91	0.93	0.94	0.92	0.93	0.92

Robust standard errors in brackets clustered on countries. All specifications include country and year fixed effects. HIV/AIDS instrumented with the H/B variables.
* significant at 10%; ** significant at 5%; *** significant at 1%

Fig. 7a Youth literacy rate 1980-2000, by AIDS rate

Fig. 7b Youth literacy rate 1980-2000, by male circumcision rate

The panel regressions of Table 9 confirm this relationship. The coefficient on AIDS interacted with year dummies for 1990, 1995 and 2000 is always negative in OLS (column 1) and IV (column 2), and the magnitude of the coefficient increases from 1990 to 2000 as would be expected if the true AIDS rate was also increasing over that time period. The coefficient is also significant at the 10-percent level in most specifications for AIDS interacted with 1990 and 1995 dummies. It loses significance in 2000 as the standard error increases more than the coefficient increases. When we include controls for the 1980 value of adult literacy interacted with year dummies for 1990, 1995 and 2000 (column 4), the coefficient becomes smaller in magnitude and loses significance across all years, suggesting that what we are seeing may in fact be a catch-up effect driven by lower initial values rather than the direct effect of AIDS on education.

Table 9 HIV/AIDS and youth literacy

	Dependent Variable: Youth Literacy Rate (%)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	IV	IV	IV	IV	IV	IV
HIV/AIDS Rate in 1997 * 1990	-0.101	-0.168	-0.177	-0.092	-0.185	-0.184	-0.301
	[0.069]	[0.089]*	[0.096]*	[0.108]	[0.113]	[0.090]**	[0.126]**
HIV/AIDS Rate in 1997 * 1995	-0.177	-0.263	-0.279	-0.064	-0.298	-0.265	-0.485
	[0.105]*	[0.137]*	[0.145]*	[0.147]	[0.175]*	[0.137]*	[0.196]**
HIV/AIDS Rate in 1997 * 2000	-0.225	-0.3	-0.323	-0.044	-0.365	-0.305	-0.597
	[0.147]	[0.197]	[0.207]	[0.192]	[0.258]	[0.192]	[0.275]**
F Statistic on AIDS-year interactions	1.08	1.56	1.5	0.92	1.06	1.67	2.51
P (>F)	0.3714	0.2171	0.2332	0.4411	0.3797	0.193	0.0759
F Statistic on first stage instrument		18.35	20.51	11.87	18.54	18.35	7.73
P (>F)		0.00	0.00	0.0001	0.00	0.00	0.0018
1980*year interactions			Yes				
Adult Literacy in 1980*year interactions				Yes			
Urban Population Share in 1980*year interactions					Yes		
Infant Mortality Rate in 1980*year interactions						Yes	
% Muslim*year interactions							Yes
Observations	180	170	160	170	170	170	170
R-squared	0.98	0.98	0.98	0.99	0.98	0.98	0.99

Robust standard errors in brackets clustered on countries. All specifications include country and year fixed effects. HIV/AIDS instrumented with the H/B variables.
* significant at 10%; ** significant at 5%; *** significant at 1%

To summarize, despite a host of interesting and economically sound mechanisms through which the AIDS epidemic could severely hinder economic growth in Africa, the empirical data only weakly support any of the proposed hypotheses. AIDS does not seem to be affecting economic growth, savings, or fertility. While the disease does seem to be reducing the rate at which youth literacy is increasing, this may be due to a simple catch-up effect. As such, our findings are most aligned with those of Acemoglu and Johnson (2006) and Young (2005(a)) in finding little support for a positive causal impact of health on economic growth. While Acemoglu and Johnson focus on diseases which predominantly affect children, this paper, in line with Young's work, suggests that there is little support even for worsening adult health leading to poorer economic outcomes in Africa. It should be noted, however, that the relatively recent nature of the epidemic combined with the lengthy incubation period of the virus could cause the effects to be delayed. Moreover, even as the epidemic has been around at a substantial level for at least fifteen years, the behavioral effects from changing norms may take another decade or two to lead to changes in economic outcomes. As more and better data are produced, these theoretical predictions should be retested, and future empirics could be more consistent with the pessimistic models.

4.4 AIDS and poverty

Although the AIDS epidemic does not seem to be adversely affecting average GDP per capita, it could still lead to an increase in poverty. In fact, this is the outcome that most research predicts (Bloom et al. 2001; UNAIDS 2006; Greener 2004; Whiteside 2002; UNAIDS/World Bank 2001). While some of this pessimism stems from expectations that AIDS will decrease economic growth (Greener 2004), even in the absence of this effect, researchers suggest that other mechanisms make it plausible that poverty will increase as a result of the disease. Individuals and families affected by AIDS face increased risk of poverty through loss of jobs, additions to the family of relatives orphaned by AIDS, and increases in medical and funeral expenses. However, it is not clear that these will lead to a net increase in the poverty rate. In general, whether or not AIDS increases poverty at a national level will depend on how the decline in fortunes of families with AIDS affects the fortunes of other families, especially poor families, not directly affected by AIDS.

The empirical evidence on the impact of AIDS on poverty remains scarce, particularly at a macro level. Booysen (2003) follows cohorts of families with and without an HIV-affected member over time and finds that families with an affected member are more likely to experience income variations and chronic poverty, and that

HIV-related outcomes such as mortality, morbidity, and orphaning play a role in explaining socio-economic mobility of households. While informative, the study is based on a relatively small sample and is essentially a micro-level comparison. At a country level, Greener (2004) performs simulations for Botswana, trying to take into account household level expenditure and income effects of AIDS infection, and finds that AIDS will lead to a 5-7 percent increase in the incidence of poverty, with the effects worst for those in the lowest income quartile. Salinas and Haacker (2006) perform simulations for four countries in Africa, taking into account changes in earnings and expenses for households as well as general equilibrium effects on the wage rate, and find that AIDS increases poverty incidence in all four countries and widens the poverty gap in two countries. These increases are beyond their predictions of what would result simply from reduced growth. While these country-level analyses are instructive, they do rely on strong assumptions, and may not generalize to other countries.

We would like to perform a direct analysis of the effect of AIDS on poverty but the national-level data on poverty rates which would enable this do not exist.[19] Instead, we use a measure of malnutrition as a proxy for poverty. We do not use the standard measure of malnutrition, which is based on measures of weight for height and height for weight, as both of these can be influenced directly by the biological course of the disease. Instead, we use a measure from the World Food Programme (WFP), calculated by comparing the total number of calories available in a region from local food production and trade with the minimum caloric requirements for the population. Since caloric requirements are a function of population demographics, specifically age and gender characteristics, the WFP calculates the minimum per capita caloric requirements uniquely across countries. Combining demographic characteristics of the population with estimates of the food distribution across income levels for each nation, the WFP estimates the percentage of the population whose food intake falls below the minimum threshold in each country (FAO 2000). While not a perfect measure of poverty, we believe this is a reasonable proxy that captures a dimension of poverty with negative spillovers on human

[19] Only a handful of African countries have poverty data from the mid 1980s or earlier. Only 14, 22, and 17 countries provide poverty estimates in the 5-years centered on 1990, 1995 and 2000 respectively (World Development Indicators).

capital, not to mention humanitarian importance.[20] With malnutrition rates (as well as with poverty) there would be concern about reverse causality; hence, our instrumental-variable approach is particularly useful here.

Figure 8a depicts the undernourishment rate from 1980-2000 by high- and low-AIDS countries. Both sets of countries begin the period with malnutrition rates around 30 percent. For low-AIDS countries, this declines steadily over the next twenty years; however, for high-AIDS countries, it increases until the mid 1990s and begins to decline only after that, when economic growth across the continent picks up. Figure 8b, which shows undernourishment by male circumcision category, tells a similar story. Undernourishment declined steadily in countries with high male circumcision, whereas it increased until the mid 1990s in countries with medium and low circumcision rates.

Fig. 8a Malnutrition rate 1980-2000, by AIDS rate

Fig. 8b Malnutrition rate 1980-2000, by male circumcision rate

The regressions in Table 10 confirm these results. The coefficient in both OLS in column (1) as well as for IV in columns 2 to 6 are positive, significant, and increasing in magnitude and significance from 1990 to 1995, although they remain roughly constant from 1995 to 2000. The increase in the magnitude of the coefficient over time generally supports the hypothesis that the increase in malnutrition (and, by implication, poverty) is being driven by the increasing prevalence of AIDS. However, that this effect seems to characterize the 1980-1995 period more than the 1990-2000 period leads us to interpret this as suggestive rather than conclusive evidence.

---

[20] There is a small literature that examines the relationship between AIDS and malnutrition. See, for example, FAO (2003), Haddad and Gillespie (2001), and de Waal and Whiteside (2003).

Table 10 HIV/AIDS and malnutrition

Dependent Variable: % of Population	Dependent Variable: % of Population Undernourished (1) OLS	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV	(7) IV
HIV/AIDS Rate in 1997 * 1990	0.933	0.848	0.914	0.694	1.073	0.887	0.181
	[0.378]**	[0.467]*	[0.515]*	[0.912]	[0.541]*	[0.505]*	[0.655]
HIV/AIDS Rate in 1997 * 1995	1.07	1.21	1.253	1.181	1.415	1.297	0.668
	[0.371]***	[0.523]**	[0.576]**	[1.127]	[0.554]**	[0.586]**	[0.795]
HIV/AIDS Rate in 1997 * 2000	0.923	1.202	1.247	1.252	1.466	1.29	0.793
	[0.330]***	[0.520]**	[0.576]**	[1.099]	[0.549]**	[0.582]**	[0.780]
F Statistic on AIDS-year interactions	2.94	1.9	1.68	0.48	2.57	1.71	0.54
P (>F)	0.04	0.15	0.19	0.70	0.07	0.18	0.6581
F Statistic on first stage instrument		17.53	22.07	11.46	19.86	17.53	11.29
P (>F)		0	0	0	0	0	0.0001
GDP per capita in 1980*year interactions			Yes				
Adult Literacy in 1980*year interactions				Yes			
Urban Population Share in 1980*year interactions					Yes		
Infant Mortality Rate in 1980*year interactions						Yes	
% Muslim*year interactions							Yes
Observations	164	160	152	132	156	160	167
R-squared	0.75	0.73	0.74	0.76	0.76	0.73	0.78

Robust standard errors in brackets clustered on countries. All specifications include country and year fixed effects. HIV/AIDS instrumented with the H/B variables.
* significant at 10%; ** significant at 5%; *** significant at 1%

5 Conclusion

The empirical results presented in this paper are consistent with early studies that showed the AIDS epidemic having minimal impact on economic growth as well as recent work suggesting that disease more generally has little impact on macroeconomic growth. Although future data may align with the various predictions of economic disaster that some theoretical papers have put forward, those fears do not seem to have taken root as of 2005.

Additionally, we put forth the notion of using male circumcision rates as an instrument for HIV prevalence. As one might imagine given recent evidence from randomized trials, the ability of national male circumcision rates to predict AIDS levels in African nations is strong and robust, and circumcision rates appear uncorrelated with the usual predictors of growth. Therefore it is not implausible to suggest that the male circumcision rate can be used as an instrumental variable for economists exploring the impact of AIDS in Africa when concerns of causality and measurement error arise.

Africa is struggling on many fronts, and there are many who see the AIDS epidemic as the knockout punch that will ensure that the continent cannot grow out of its present state of poverty. Yet economic growth across the continent has reached five percent recently (OECD, 2005). This paper has argued that the impact of the epidemic on growth has not been as large as most have feared. It appears to be that other economic factors—institutions, politics, and macroeconomic stability—remain more significant barriers to Africa's growth. If these factors can be kept in check for a significant length of time, we believe AIDS will not prevent Africa's economic expansion in the medium run. Nevertheless, given the potential negative impact of the disease on education and poverty, prudent governments of high-AIDS countries should target their poorer citizens with educational and nutritional outreach in order to preserve the long-run growth potential of their populations.

Acknowledgements We would like to thank Faisal Ahmed, David Cutler, Guenther Fink, Edward Glaeser, Larry Katz, Michael Kremer, Sulekha Patel, Rebecca Thornton, David Weil and workshop participants at Brown Economics, Harvard Economics, Harvard Business School, Harvard Statistics, and the Northeast Universities Development Consortium for valuable comments and advice, as well as Joanna Beinhorn, Jennifer Cervone, Katherine Laurence, and James Zeitler for excellent research assistance. The usual disclaimer applies.

Appendix

A.1 Methodology for Constructing Male Circumcision Rate Estimates

To examine the validity of the male circumcision rate data from Halperin and Bailey (1999) and Shelton (2002), we build our own estimates based on ethnographic data on circumcision practices at the tribal level (largely from Murdock, 1967) and demographic breakdowns of countries by tribe.[21] With the binary assumption that male circumcision was either universal or absent for any given tribe, we estimate a male circumcision rate for each country.[22] For example, for Kenya:

KENYA'S TRIBAL BREAKDOWN		
Tribe	**Percent of Population (Alesina et al., 2003)**	**Male Circumcision (Murdock 1967)**
Kikuyu	22	Y
Luhya	14	Y
Luo	13	N
Kalenjin	12	Y
Kamba	11	Y
Kisii	6	Y
Meru	6	?
other African	15	?
non-African	1	?

21 The demographic breakdowns by tribe are from the dataset generated by Alesina et al. (2003), accessible at http://www.stanford.edu/~wacziarg/downloads/fractionalization.xls.

22 We thank John Caldwell for this suggestion.

From the above chart, we estimate that 65 percent of Kenyan males are circumcised while 13 percent are not circumcised. The remaining 22 percent are unknown, so we assume a 0.5 probability that any unknown male is circumcised, which is close to the continental average. Thus, mapping the ethnographic data on national demographic breakdowns, we estimate the male circumcision rate for Kenya to be $(1*0.65) + (0.5*0.22) + (0*0.13) = 0.76$. We apply the same methodology to estimate male circumcision rates for all countries in continental Africa as well as Madagascar and Comoros.

A.2 Male Circumcision Rate Estimates

Country	Male Circumcision Rate	Halperin/Bailey
Angola	0.66	>80%
Burundi	0.02	<20%
Benin	0.84	>80%
Burkina Faso	0.81	20%-80%
Botswana	0.06	<20%
Central African Rep.	0.67	20%-80%
Cote d'Ivoire	0.46	20%-80%
Cameroon	0.63	>80%
Congo	0.70	>80%
Comoros	0.98	>80%
Djibouti	0.94	>80%
Algeria	1.00	>80%
Egypt	1.00	>80%
Eritrea	0.95	>80%
Ethiopia	0.76	-
Gabon	0.93	>80%
Ghana	0.42	>80%
Guinea	0.83	>80%
Gambia	0.90	>80%
Guinea-Bissau	0.91	>80%
Equat. Guinea	0.86	>80%
Kenya	0.76	>80%
Liberia	0.70	>80%
Libya	0.99	>80%
Lesotho	0.00	<20%
Morocco	1.00	>80%
Madagascar	0.95	>80%
Mali	0.95	>80%
Mozambique	0.12	20%-80%
Mauritania	0.78	>80%
Malawi	0.17	<20%
Namibia	0.15	<20%
Niger	0.92	>80%
Nigeria	0.81	>80%
Rwanda	0.10	<20%
Sudan	0.47	20%-80%
Senegal	0.89	>80%
Sierra Leone	0.88	>80%
Somalia	0.93	>80%
Swaziland	0.50	<20%
Chad	0.64	>80%
Togo	0.93	>80%
Tunisia	1.00	>80%
Tanzania	0.44	20%-80%
Uganda	0.15	20%-80%
South Africa	0.35	20%-80%
Zaire	0.70	20%-80%
Zambia	0.12	<20%
Zimbabwe	0.10	<20%

A.3 Predicting AIDS Rates with Male Circumcision Rate

	Dependent Variable: % of adults 15-49 living with HIV/AIDS in 1997				
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS
Male circumcision rate	-15.528	-11.153	-3.752	-8.722	0.454
	[2.514]***	[3.000]***	[4.847]	[4.490]*	[6.626]
ln(GDP per capita, PPP, Int. $2000), 1980		1.566	3.064	2.672	3.193
		[1.613]	[1.982]	[2.149]	[1.948]
ln(Population Density), 1980		-1.224	-1.561	-1.478	-2.388
		[0.696]	[0.751]**	[0.991]	[0.959]***
Polity 2 Score, 1980		0.03	0.04	0.011	0.109
		[0.191]	[0.210]	[0.215]	[0.229]
Adult Literacy Rate, 1980		0.127	0.058	0.054	-0.033
		[0.081]	[0.076]	[0.102]	[0.096]
% Popluation Urban, 1980		-0.134	-0.153	-0.037	-0.057
		[0.091]	[0.085]	[0.104]	[0.108]
% Muslim			-8.854		-12.22
			[2.840]**		[4.008]***
% population from Bantu-speaking tribe			2.504		2.027
			[3.586]		[3.811]
Ethnolinguistic Fractionalization, 1985			-0.479		-0.5
			[3.768]		[4.197]
Northern Africa				-4.65	0.703
				[2.839]	[3.845]
Eastern Africa				5.373	7.257
				[4.681]	[3.539]**
Central Africa				-0.023	-2.901
				[3.199]	[2.073]
Southern Africa				2.365	2.873
				[7.016]	[6.408]
F-statistic	38.14	13.82	0.60	3.77	0
P (>F)	0	0.001	0.4556	0.066	0.9462
Observations	49	31	31	31	31
R-squared	0.57	0.65	0.75	0.73	0.83

White standard errors in brackets.
* significant at 10%; ** significant at 5%; *** significant at 1%

A.4 2SLS Estimates Using Continuous Male Circumcision Rate

	(1) IV	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV	(7) IV
	ln(GDP per capita, PPP, Int. $2000)	Gross Domestic Savings, % GDP	Crude Birth Rate, Per Thousand	Crude Death Rate, Per Thousand	Infant Mortality Rate	Youth Literacy Rate, Total	% of Population Undernourished
HIV/AIDS Rate in 1997 * 1990	0.003	-0.096	-0.014	0.271	0.525	-0.116	0.971
	[0.007]	[0.230]	[0.105]	[0.125]**	[0.367]	[0.107]	[0.507]*
HIV/AIDS Rate in 1997 * 1995	0.006	0.033	-0.024	0.437	1.107	-0.195	1.049
	[0.010]	[0.331]	[0.149]	[0.109]***	[0.432]**	[0.164]	[0.563]*
HIV/AIDS Rate in 1997 * 2000	0.01	0.181	-0.05	0.624	1.799	-0.17	0.842
	[0.013]	[0.507]	[0.164]	[0.105]***	[0.506]***	[0.238]	[0.571]
HIV/AIDS Rate in 1997 * 2005	0.012	-0.057	-0.054	0.757	2.201		
	[0.015]	[0.576]	[0.168]	[0.159]***	[0.603]***		
F Statistic on AIDS-year interactions	0.32	0.55	0.46	11.53	3.38	1	1.35
P (>F)	0.8657	0.6971	0.7668	0	0.0173	0.4066	0.2736
F Statistic on first stage instrument	30.86	32.34	31.77	30.67	21.38	26.76	25.63
P (>F)	0	0	0	0	0	0	0
Observations	222	192	294	288	215	175	160
R-squared	0.95	0.84	0.91	0.88	0.95	0.98	0.74

Robust standard errors in brackets clustered on countries. All specifications include country and year fixed effects.

HIV/AIDS instrumented with (continuous) male circumcision rate.

* significant at 10%; ** significant at 5%; *** significant at 1%

B.1 Table of Correlations Between Different Measures of HIV/AIDS Prevalence

Measures of HIV/AIDS Prevalence	**% of adults 15-49 living with HIV/AIDS in 1997**	**% of adults 15-49 living with HIV/AIDS in 2001**	**% of adults 15-49 living with HIV/AIDS in 2005**	**% of Population dying from HIV/AIDS in 2005**
% of adults 15-49 living with HIV/AIDS in 1997	1			
% of adults 15-49 living with HIV/AIDS in 2001	0.8854	1		
% of adults 15-49 living with HIV/AIDS in 2005	0.8366	0.9409	1	
% of Population dying from HIV/AIDS in 2005	0.8626	0.9552	0.9701	1

Number of Observations: 39

B.2 Predicting Different Measures of HIV/AIDS with Male Circumcision

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
Dependent Variable:	% of adults 15-49	% of adults 15-49	% of adults 15-49	% of adults 15-49	% of population	% of population
H/B circumcision 20%-80%	-14.521 [4.087]***	-6.626 [4.306]	-9.467 [3.733]**	-4.312 [6.127]	-0.479 [0.165]***	-0.229 [0.245]
H/B circumcision 80%-100%	-19.91 [3.777]***	-9.641 [3.467]**	-15.147 [3.194]***	-8.954 [4.458]*	-0.725 [0.148]***	-0.419 [0.185]**
ln(GDP per capita, PPP, Int. $2000), 1980		3.023 [2.684]		2.225 [2.581]		0.052 [0.109]
ln(Population Density), 1980		-3.13 [0.955]***		-1.915 [0.717]**		-0.088 [0.033]**
Polity 2 Score, 1980		0.11 [0.201]		-0.049 [0.250]		-0.001 [0.011]
Adult Literacy Rate, 1980		0.233 [0.109]**		0.174 [0.088]*		0.009 [0.004]**
% Popluation Urban, 1980		-0.217 [0.096]**		-0.091 [0.097]		-0.003 [0.004]
% Muslim		-7.13 [4.425]		-4.691 [3.607]		-0.2 [0.164]
% population from Bantu-speaking tribe		-0.591 [4.098]		0.047 [4.957]		0.034 [0.202]
Ethnolinguistic Fractionalization, 1985		-0.544 [4.007]		1.443 [4.560]		0.059 [0.195]
F statistic on H/B variables P (>F)	16.41 0.0000	4.15 0.0353	14.93 0.0000	5.25 0.0147	16.26 0.0000	5.1 0.0162
Observations R-squared	40 0.62	27 0.92	46 0.58	31 0.86	46 0.6	31 0.82

White standard errors in brackets.
* significant at 10%; ** significant at 5%; *** significant at 1%

B.3 2SLS Estimates of Main Outcome Variables using Various Measure of HIV/AIDS

Measure of HIV/AIDS:	***Aids Prevalence in 2001***			***Aids Prevalence in 2005***			***Death Rate from Aids in 2005***		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	IV	IV	IV	IV	IV	IV	IV	IV	IV
Dependent Variable:	ln(GDP per capita, PPP, Int. $2000)	Crude Death Rate, Per Thousand	% of Population Under - nourished	ln(GDP per capita, PPP, Int. $2000)	Crude Death Rate, Per Thousand	% of Population Under- nourished	ln(GDP per capita, PPP, Int. $2000)	Crude Death Rate, Per Thousand	% of Population Under- nourished
HIV/AIDS Rate * 1990	0.002	0.163	0.657	0.003	0.215	0.845	0.068	4.478	17.617
	[0.005]	[0.113]	[0.443]	[0.006]	[0.149]	[0.550]	[0.135]	[3.082]	[10.987]
HIV/AIDS * 1995	0.003	0.259	0.886	0.004	0.353	1.189	0.08	7.343	24.789
	[0.007]	[0.111]**	[0.509]*	[0.008]	[0.160]**	[0.647]*	[0.177]	[3.152]**	[12.929]*
HIV/AIDS Rate * 2000	0.005	0.379	0.886	0.006	0.522	1.196	0.135	10.854	24.93
	[0.008]	[0.068]***	[0.488]*	[0.010]	[0.131]***	[0.632]*	[0.219]	[2.404]***	[12.629]*
HIV/AIDS Rate * 2005	0.003	0.478		0.003	0.654		0.078	13.621	
	[0.010]	[0.069]***		[0.012]	[0.143]***		[0.259]	[2.709]***	
F Statistic on AIDS-year interactions	0.41	19.09	1.11	0.46	7.21	1.24	0.48	8.8	1.33
P (>F)	0.7993	0	0.3582	0.7643	0.0001	0.3095	0.7467	0.0001	0.2777
F Statistic on first stage instrument	14.41	13.97	9.58	11.9	12.44	8.29	13.1	13.52	9.23
P (>F)	0.0000	0.0000	0.0005	0.0001	0.0001	0.001	0.0001	0	0.0005
Observations	192	240	136	222	270	156	222	270	156
R-squared	0.94	0.89	0.68	0.95	0.87	0.71	0.95	0.88	0.72

Robust standard errors in brackets clustered on countries. All specifications include country and year fixed effects. HIV/AIDS instrumented with (continuous) male circumcision rate.
* significant at 10%; ** significant at 5%; *** significant at 1%

C Table of Variables Used and Data Sources

Variable Description	Source
GDP per capita, PPP, Int. $2000	WDI (2006)
Gross Domestic Savings, % GDP	WDI (2006)
Adult Literacy Rate, Total	WDI (2005)
Youth Literacy Rate, Total	WDI (2005)
Birth Rate, crude (per 1,000 people)	WDI (2006)
Fertility Rate	WDI (2005)
Death Rate, crude (per 1,000 people)	WDI (2006)
Mortality Rate, infant (per 1,000 live births)	WDI (2006)
Life Expectancy at Birth	WDI (2005)
Population	WDI (2005)
Urban Population, % Total	WDI (2005)
% of adults 15-49 living with HIV/AIDS in 1997	UNAIDS/WHO (1998)
% of adults 15-49 living with HIV/AIDS in 2001	UNAIDS (2004)
% of adults 15-49 living with HIV/AIDS in 2003	UNAIDS/WHO (2006)
% of adults 15-49 living with HIV/AIDS in 2005	WHO (2008)
% of population dying from AIDS in 2003	UNAIDS/WHO (2006), WDI(2005) & WDI(2008)
% of population dying from AIDS in 2005	WHO(2008), WDI(2005) & WDI(2008)
Male circumcision rate	Ahuja, Wendell, Werker (2008)
H/B circumcision rate 20%-80%	Shelton (2002)
H/B circumcision rate 80%-100%	Shelton (2002)
% Muslim	Alesina et all. (2003)
% population from Bantu-speaking tribe	Ahuja, Wendell, Werker (2008)
Ethnolinguistic Fractionalization, 1985	Roeder (2001)
Polity 2 (Democracy) Score	Marshall and Jaggers (2002)
Terms of Trade Index	WDI (2005)
Main Line Telephones per 1000 Inhabitants	WDI (2005)
Radio Sets per 1000 inhabitants	WDI (2005)
Vehicles per 1000 Inhabitants	WDI (2003)
% Engaging in High Risk Sex, Male	UNAIDS (2004)
% Engaging in High Risk Sex, Female	UNAIDS (2004)
% Using Condoms when Engaging in High Risk Sex, Male	UNAIDS (2004)
% Using Condoms when Engaging in High Risk Sex, Female	UNAIDS (2004)
% of Population Undernourished	UN Common Database (2006)

References

Acemoglu, D. & Johnson, S. (2006). *Disease and Development: The Effect of Life Expectancy on Economic Growth.* Cambridge, MA: MIT, mimeo.

Acott, D. (2000). *The Economic Impact of AIDS in South Africa: A Critique of the Demographic Methods Used in the ING-Barings Report of April 2000, and their Implications.* Cape Town: University of Cape Town (mimeo).

Alesina, A., Devleeschauwer, A., Easterly, W., Kurlat, S., & Wacziarg, R. (2003). Fractionalization. *Journal of Economic Growth,* 8(2), 155-194.

Arndt, C., & Lewis, J.D. (2000). The Macro Implications of HIV/AIDS in South Africa. *Africa Region Working Paper Series*. Washington, DC: The World Bank. No. 9.

Auvert, B., Taljaard, D., Lagarde, E., Sobngwi-Tambekou, J., Sitta, R., & Puren, A. (2005). Randomized Controlled Intervention Trial of Male Circumcision for Reduction of HIV Infection Risk: The ANRS 1265 Trial. *PLOS Medicine,* 2(11), 1112-1122.

Bailey, R.C., Moses, S., Parker, C.B., Agot, K., Maclean, I., Krieger, J.N., et al. (2007). Male circumcision for HIV prevention in young men in Kisumu, Kenya: a randomised controlled trial. *The Lancet,* 369(9562), 643–656.

Barro, R. (1999). *Determinants of Economic Growth.* Cambridge, MA: MIT Press.

Bell, C., Devarajan, S., & Gersbach, H. (2003). *The Long-run Economic Costs of AIDS: Theory and an Application to South Africa.* Mimeo.

Bloom, D.E., & Canning, D. (2005). Health and Economic Growth: Reconciling The Micro and Macro Evidence. *Freeman Spogli Institute for International Economics Working Paper Series*.

Bloom, D.E., Canning, D., & Sevilla, J. (2004). The Effect of Health on Economic Growth: A Production Function Approach. *World Development,* 32(1), 1-13.

Bloom, D.E., & Mahal, A. (1997). Does the AIDS Epidemic Threaten Economic Growth? *Journal of Econometrics,* 77(1), 105-124.

Bloom, D.E., River Path Associates, & Sevilla, J. (2001). Health, Wealth, AIDS and Poverty, *HIV/AIDS and Development in the Asia Pacific Ministerial Conference,* The Australian Government Overseas AIDS Program. http://www.ausaid.gov.au/publications/pdf/health_wealth_poverty.pdf

Bongaarts, J.P. Way, R.P., & Conant, F. (1989). The relationship between male circumcision and HIV infection in African populations. *AIDS*, 3, 383-377.

Bonnel, R. (2000). *HIV/AIDS: Does it Increase or Decrease Growth in Africa?* Washington, DC: World Bank (mimeo).

Booysen, F. le Roux. (2003). *Poverty Dynamics and HIV/AIDS Related Morbidity and Mortality in South Africa.* Conference paper presented at Empirical Evidence for the Demographic and Socio-Economic Impact of AIDS, University of KwaZulu-Natal.

Breirova, L. (2002). *AIDS and Education in Kenya.* Cambridge, MA: MIT (mimeo).

Bureau for Economic Research. (2001). The Macroeconomic Impact of HIV/AIDS in South Africa. *Economic Research Note No. 10.* Stellenbosch: Bureau for Economic Research.

Caldwell, J., & Caldwell, P. (1996). The African AIDS Epidemic. *Scientific American,* 274, 62-68.

Case, A., Paxson, C., & Ableidinger, J. (2004). Orphans in Africa: Parental Death, Poverty, and School Enrollment. *Demography,* 41(3), 483-508.

De Cock, K.M., Fowler, M.G., Mercier, E., de Vincenzi, I., Saba, J., Hoff, E., et al. (2000). Prevention of mother-to-child HIV transmission in resource-poor countries: translating research into policy and practice. *JAMA*, 283(9), and.

Crampin, AC, Floyd, S., Glynn, J.R., Madise, N., Nyondo, A., Khondowe, M.M., et al. (2003). The long-term impact of HIV and orphanhood on the mortality and physical well-being of children in rural Malawi. *AIDS*, 17(3), 389-97.

Cuddington, J.T. (1993). Further Results on the Macroeconomic Effects of AIDS: The Dualistic Labor-Surplus Economy. *World Bank Economic Review,* 7(3), 403-417.

Desgrees du Lou, A., Msallati, P., Ramon, R., Noba, V., Viho, I., Dabis, F., et al. (1998). HIV-1 infection and reproductive history: a retrospective study among pregnant women, Abidjan, Cote D'Ivoire, 1995-1996. *Journal of STD & AIDS*, 9, 452-456.

Dixon, S., McDonald, S., & Roberts, J. (2001). AIDS/HIV and Development in Africa. *Journal of International Development*, 13, 411-426.

Donnelly, J. (2004) Kenya Study Suggests Fewer may have AIDS. *Boston Globe*, 15 Jan 2004.

Evans, D., & Miguel, E. (2004). Orphans and schooling in Africa: a longitudinal analysis. *BREAD Working Paper* 056.

FAO. (2000). *The State of Food Insecurity in the World 2000*. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO. (2003). Food insecurity and HIV/AIDS: when short-term emergencies intersect a long-wave crisis. In *The State of Food Security in the World 2003* (pp 10-13). Rome, Italy: Food and Agricultural Organization of the United Nations.

Ferreira, P.C., & Pessoa, S.D. (2003). The Long-Run Economic Impact of AIDS. Working Paper. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=411782. 10 Feb 2003.

Gaffeo, E. (2003). The Economics of HIV/AIDS: A Survey. *Development Policy Review*, 21, 27-49.

Gallup, J.L., & Sachs, J.D. (2001). The Economic Burden of Malaria. *American Journal of Tropical Medicine and Hygiene*, 64(1, 2)S, 85-96.

Gray, R.H., Wawer, M.J., Serwadda, D., Sewankambo, N., Li, C., Wabwire-Mangen, F., et al. (1998). Population-based study of fertility in women with HIV-1 infection in Uganda. *Lancet*, 351(9096), 98-103.

Gray, R.H., Kigozi, G., Serwadda, D., Makumbi, F., Watya, S., Nalugoda, F., et al. (2007). Male circumcision for HIV prevention in men in Rakai, Uganda: a randomised trial. *The Lancet*, 369(9562), 657–666.

Greener, R. (2004). Chapter 5: The Impact of HIV on Poverty and Inequality. In M. Haacker (Ed.), *The Macroeconomics of AIDS and Poverty*. IMF.

Haacker, M. (2002). The Economic Consequences of HIV/AIDS in Southern Africa. *IMF Working Paper* 02/38. Washington, DC: IMF.

Haddad, L., & Gillespie, S. (2001). Effective Food and Nutrition Policy Responses to HIV/AIDS: What We Know and What We Need to Know. *Journal of International Development*, 13, 487-511.

Halperin, D.T., Bailey, R.C. (1999). Male circumcision and HIV infection: 10 years and counting.” *Lancet*, 354(9192), 1813-15.

Hill, K., Bicego, G., & Mahy, M. (2001). Childhood Mortality in Kenya: An Examination of Trends and Determinants in the Late 1980s to Mid-1990s. *Johns Hopkins Population Center Working Paper.*

Hussain, L.A., & Lehner, T. (1995). Comparative investigation of Langerhans' cells and potential receptors for HIV in oral, genitourinary and rectal epithelia. *Immunology*, 85(3), 475-484.

ING Barings. (2000). *Economic Impact of AIDS in South Africa. A Dark Cloud on the Horizon.* London: ING Barings South African Research.

International Labour Office. (2004). *HIV-AIDS and Work: Global Estimates, Impact and Response.* Geneva: The ILO Programme on HIV/AIDS and the World of Work

Kalemli-Ozcan, S. (2006). AIDS, Reversal of the Demographic Transition and Economic Development: Evidence from Africa. *NBER working paper* 12181.

Kremer, M. (1996). Integrating Behavioral Choice into Epidemiological Models of the AIDS Epidemic. *Quarterly Journal of Economics*, 111(2), 549-573.

Lorentzon, P., McMillan, J., & Wacziarg, R. (2005). Death and Development. *NBER working paper* 11620.

Mahal, A. (2004). Economic Implications of Inertia on HIV/AIDS and Benefits of Action. *Economic and Political Weekly*, March 6.

Mandela, N. (1994). *Long Walk to Freedom*. New York: Little, Brown and Co.

Marck, J. (1997). Aspects of male circumcision in sub-equatorial African cultural history. *Health Transition Review*, 7, 357-59.

Marshall, M.G., & Jaggers, K. (2002). *Polity IV Dataset*. [Computer file; version p4v2002] College Park, MD: Center for International Development and Conflict Management, University of Maryland.

McDonald, S., & Roberts, J. (2006). AIDS and Economic Growth: A Human Capital Approach. *Journal of Development Economics*, 80, 228-250.

Miguel, E., & Kremer, M. (2004). Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities. *Econometrica*, 72(1), 159-217.

Morgan, D., Maude, G.H., Malamba, S.S., et al. (1997). HIV-1 progression and disease-defining disorders in rural Uganda. *The Lancet*, 350(9073), 245-250.

Moses, S., Bailey, R.C., & Ronald, A.R. (1998). Male circumcision: Assessment of health benefits and risks. *Sexually Transmitted Infections*, 74(5), 368-373.

Murdock, G.P. (1967). *Ethnographic Atlas.* Pittsburgh, PA: University of Pittsburgh Press.

Newell M.L., Coovadia, H., Cortina-Borja, M., Rollins, N., Gaillard, P., & Dabis, F. (2004). Mortality of infected and uninfected infants born to HIV-infected mothers in Africa: a pooled analysis. *The Lancet*, 364(9441).

Ntozi, J.P.M. (2001). *Impact of HIV/AIDS on Fertility in Sub-Saharan Africa.* United Nations Economic and Social Council.

OECD Observer. (2005). *Africa's Economy: Aid and Growth.* July 2005.

Over, M. (1992). *The Macroeconomic Impact of AIDS in Sub-Saharan Africa.* Washington, DC: The World Bank (mimeo).

Papageorgiou, C., & Stoytcheva, P. (2008). *What Is the Impact of AIDS on Cross-Country Income So Far? Evidence from Newly Reported AIDS Cases.* Washington, DC: International Monetary Fund, Research Department (mimeo).

Roeder, P.G. (2001). Ethnolinguistic Fractionalization (ELF) Indices, 1961 and 1985. <http//:weber.ucsd.edu\~proeder\elf.htm>. Accessed 9 September 2003.

Saitoti, T.O. (1988). *The Worlds of a Maasai Warrior: An Autobiography*. Berkeley, CA: University of California Press.

Salinas, G., & Haacker, M. (2006). HIV/AIDS: The Impact on Poverty and Inequality. *IMF Working Paper* 06/126. Washington, DC: IMF.

Schultz, T.P. (2002). Wage Gains Associated with Height as a Form of Health Human Capital. *The American Economic Review*, 92(2), 349-353.

Shelton, J. (2002). Male Circumcision and National HIV Infection Rates. *Jim Shelton's Pearls*. Johns Hopkins Bloomberg School of Public Health. http://www.jhuccp.org/pearls/.

Steen, R. (2001). Eradicating Chancroid. *Bulletin of the World Health Organization*, 79(9), 818-26.

Strauss, J., & Thomas, D. (1998). Health, Nutrition, and Economic Development, *Journal of Economic Literature,* 36, 766-817.

Szabo, R., & Short, R.V. (2000). How does male circumcision protect against HIV infection? *British Medical Journal*, 320, 1592-1594.

UNAIDS. (2005). *UNAIDS Questions & Answers.* http://www.unaids.org/epi/2005/doc/docs/en/QA_PartI_en_Nov05.pdf#search=%22aids%20growth%200.5%204%20Africa%20site%3Aunaids.org%22**.** Accessed 10 October 2006.

UNAIDS. (2006). *Report on the Global AIDS Epidemic*. http://www.unaids.org/en/HIV_data/2006GlobalReport/default.asp. Accessed 1 October 2006.

UNAIDS/WHO. (1998). *Report on the global HIV/AIDS epidemic.* http://www.who.int/emc-hiv/global_report/index.html. Accessed 10 February 2004.

UNAIDS/WHO. (2004). *Report on the global AIDS epidemic.* http://www.unaids.org/bangkok2004/report.html.

UNAIDS/WHO. (2007). *New Data on Male Circumcision and HIV Prevention: Policy and Programme Implications*. http://www.who.int/hiv/mediacentre/MCrecommendations_en.pdf.

UNAIDS/World Bank. (2001). *AIDS, Poverty Reduction and Debt Relief: A Toolkit for Mainstreaming HIV/AIDS Programmes into Development Instruments.* http://data.unaids.org/Publications/IRC-pub02/JC536-Toolkit_en.pdf#search=%22World%20Bank%202001%20AIDS%20Poverty%20Tool%20Kit%22. Accessed 1 October 2006.

United Nations Common Database. http://unstats.un.org/unsd/cdb/cdb_help/cdb_quick_start.asp. Accessed April 2006.

de Waal, A., & Whiteside, A. (2003). 'New Variant Famine': AIDS and Food Crisis in Southern Africa. *The Lancet,* 362, 1234-37.

Walker, N., Schwartlander, B., & Bryce, J. (2002). Meeting international goals in child survival and HIV/AIDS. *The Lancet*, 360(9329), 284-289.

Weil, D.N. (2005). Accounting for the Effect of Health on Growth. *NBER working paper* 11455.

Whiteside, A. (2002). Poverty and HIV/AIDS in Africa. *Third World Quarterly*, Special Issue, Global Health and Governance, 23(2), 313-332.

World Bank. (2003) *World Development Indicators 2003.* Dataset. Washington, DC: The World Bank Group.

World Bank. (2005) *World Development Indicators 2005.* Dataset. Washington, DC: The World Bank Group.

World Bank. (2006) *World Development Indicators 2005.* Dataset. Washington, DC: The World Bank Group.

World Bank. (2008) *World Development Indicators 2005.* Dataset. Washington, DC: The World Bank Group.

World Health Organization. (2001). *Macroeconomics and Health: Investing in Health for Economic Development*. http://www3.who.int/whosis/cmh.

World Health Organization. (2008). *WHO Global Health Atlas.* http://www.who.int/globalatlas/. Accessed 14 July 2008.

Yamano, T. & Jayne, T.S. (2004). Working-age adult mortality and primary school attendance in rural Kenya. *Tegemeo Institute of Agricultural Policy and Development Working Paper* 005/2004.

Young, A. (2005a) The Gift of the Dying: The Tragedy of AIDS and the Welfare of Future African Generations. *Quarterly Journal of Economics.* 120, 243-266.

Young, A. (2005b) *In Sorrow to Bring Forth Children: Fertility Amidst the Plague of HIV.* Chicago, IL: University of Chicago, Graduate School of Business, mimeo.

Zaba, B., & Gregson, S. (1998). Measuring the impact of HIV on fertility in Africa. *AIDS*. 12, Supplement, 1, S41-50.

Figure 1: HIV/AIDS and Male Circumcision

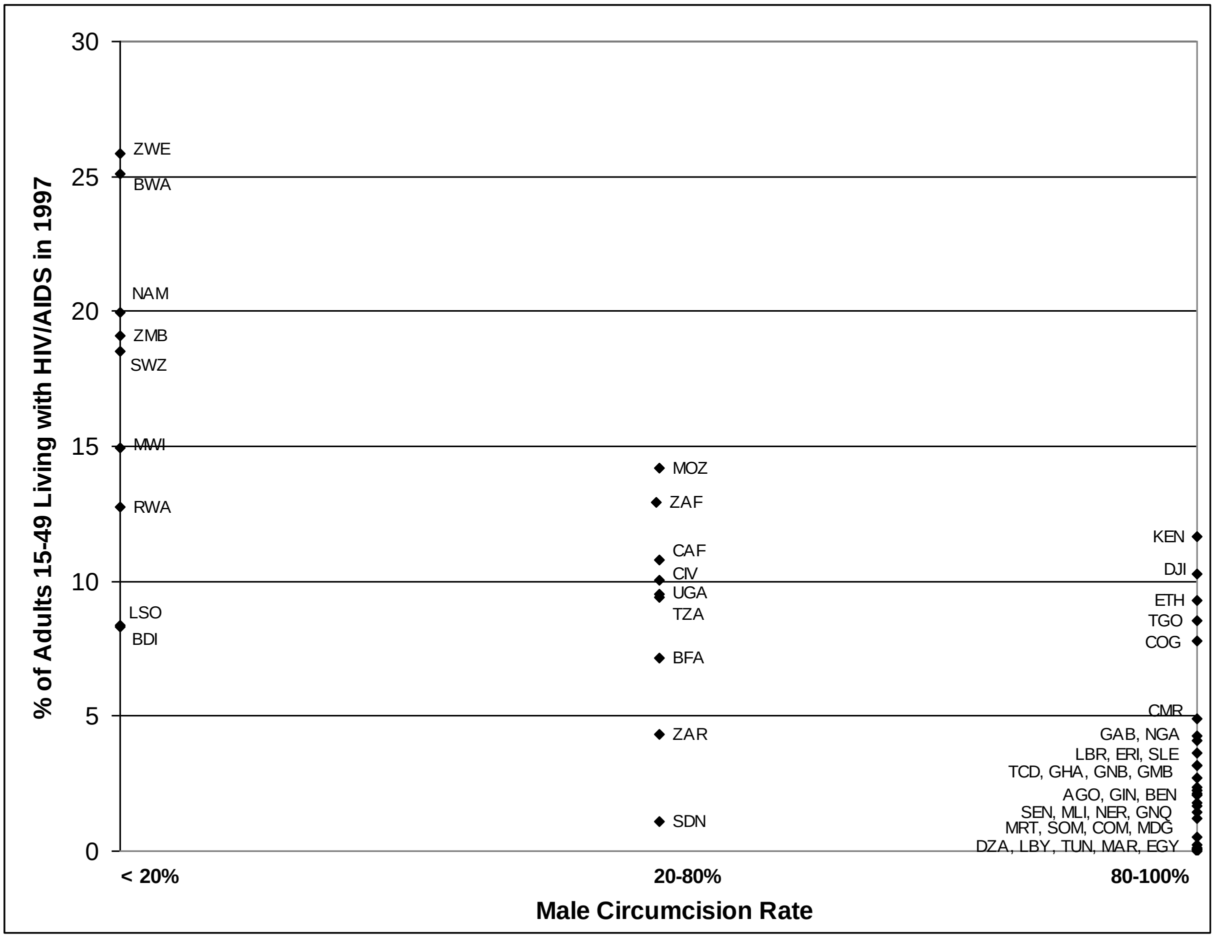


Figure 2a: Crude Death Rate 1980-2005, by AIDS Rate

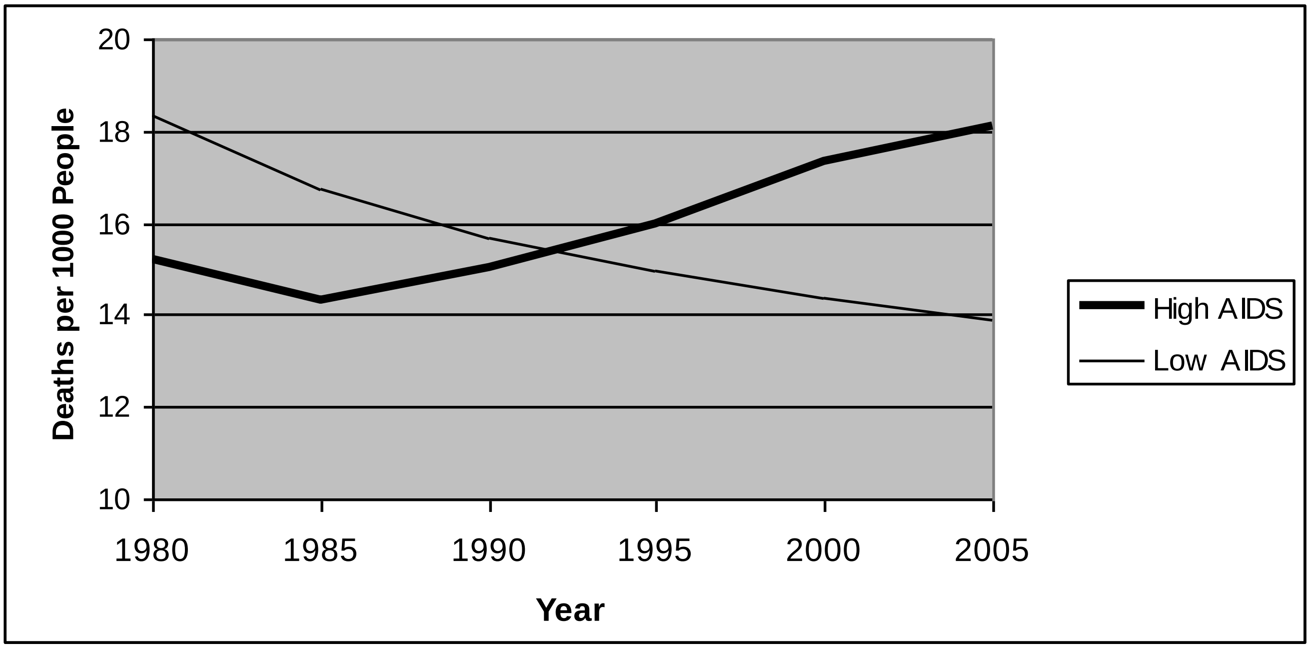


Figure 2b: Crude Death Rate 1980-2005, by Male Circumcision Rate

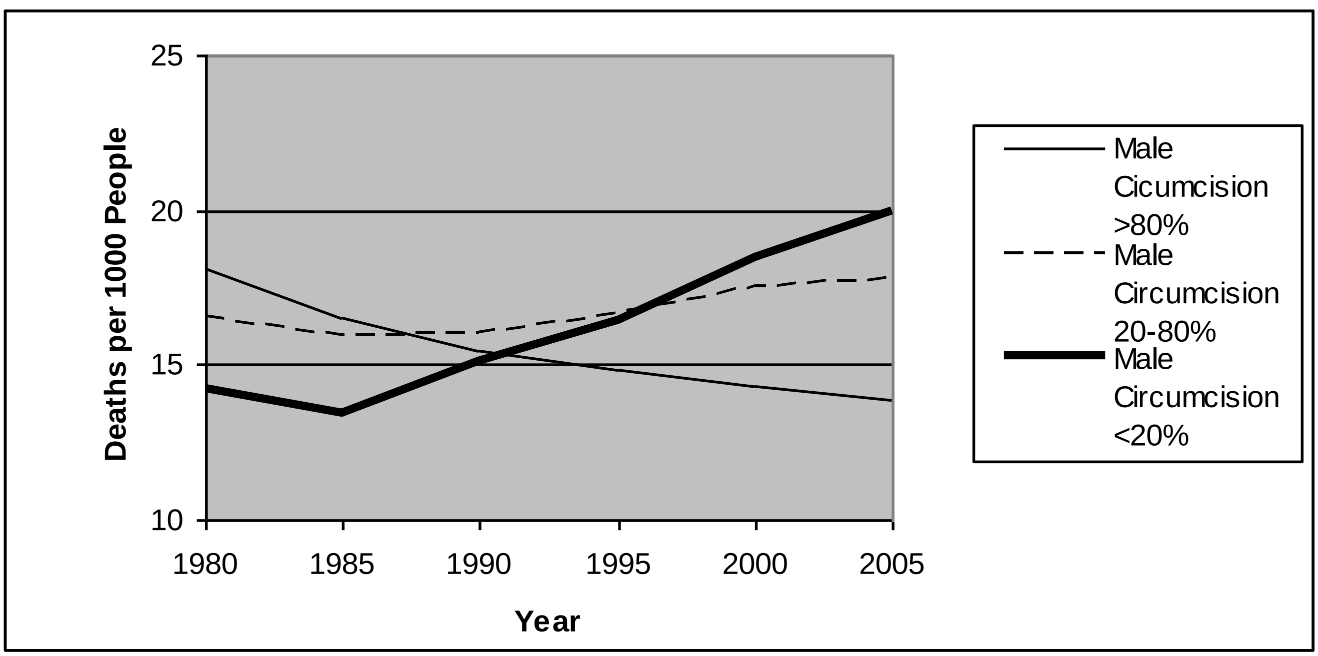


Figure 3a: Infant Mortality Rate 1980-2005, by AIDS Rate

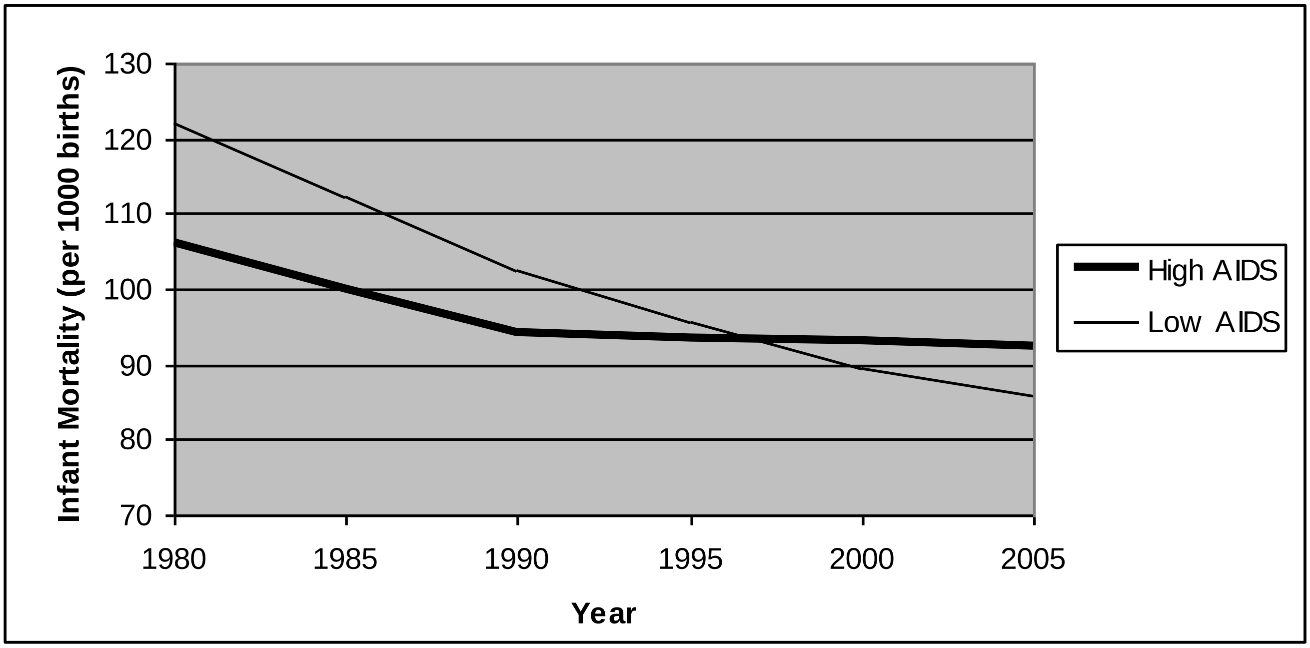


Figure 3b: Infant Mortality Rate 1980-2005, by Male Circumcision Rate

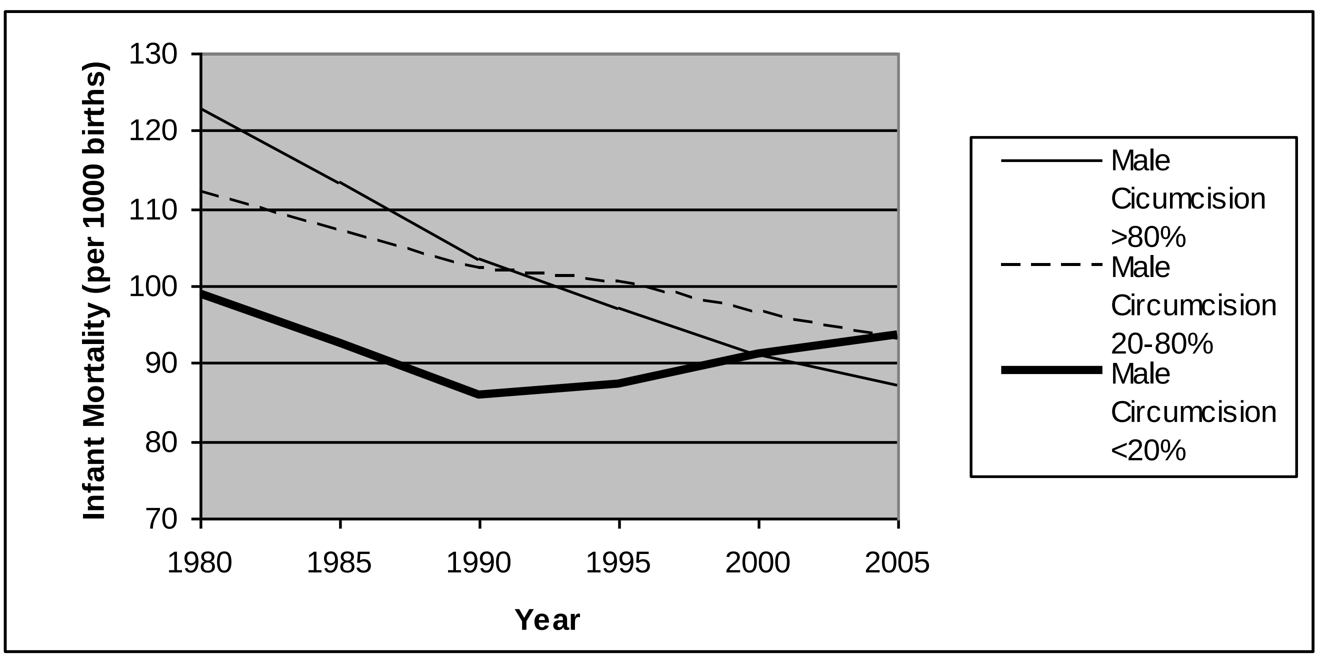


Figure 4a: GDP per capita 1980-2005, by AIDS Rate

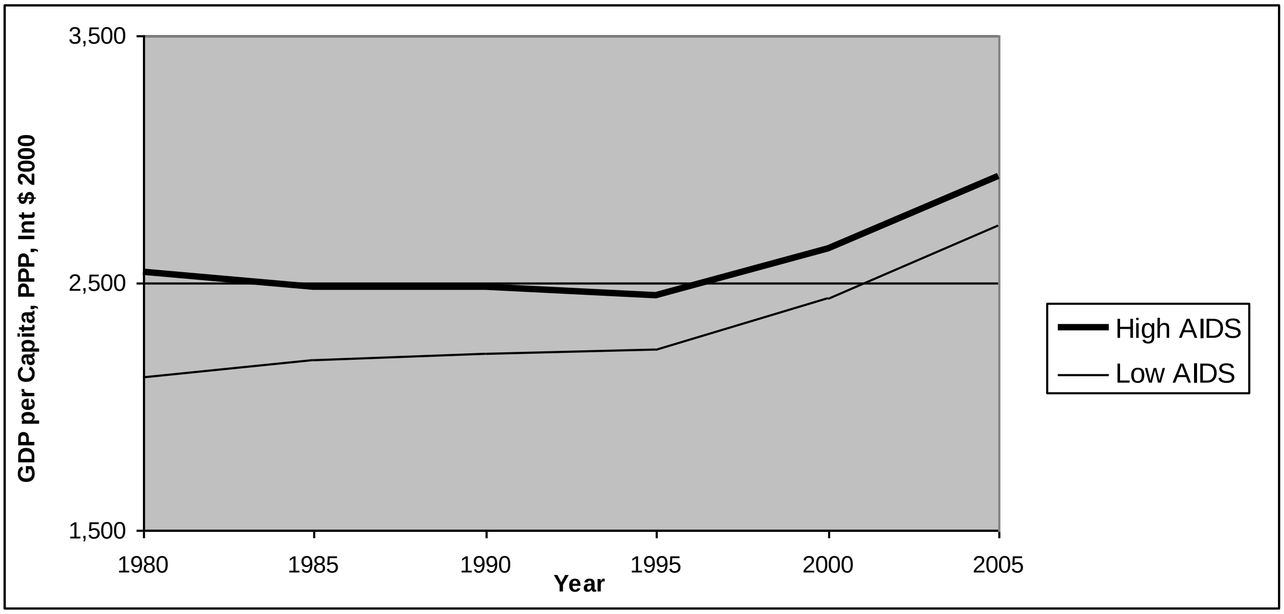


Figure 4b: GDP per capita 1980-2005, by Male Circumcision Rate

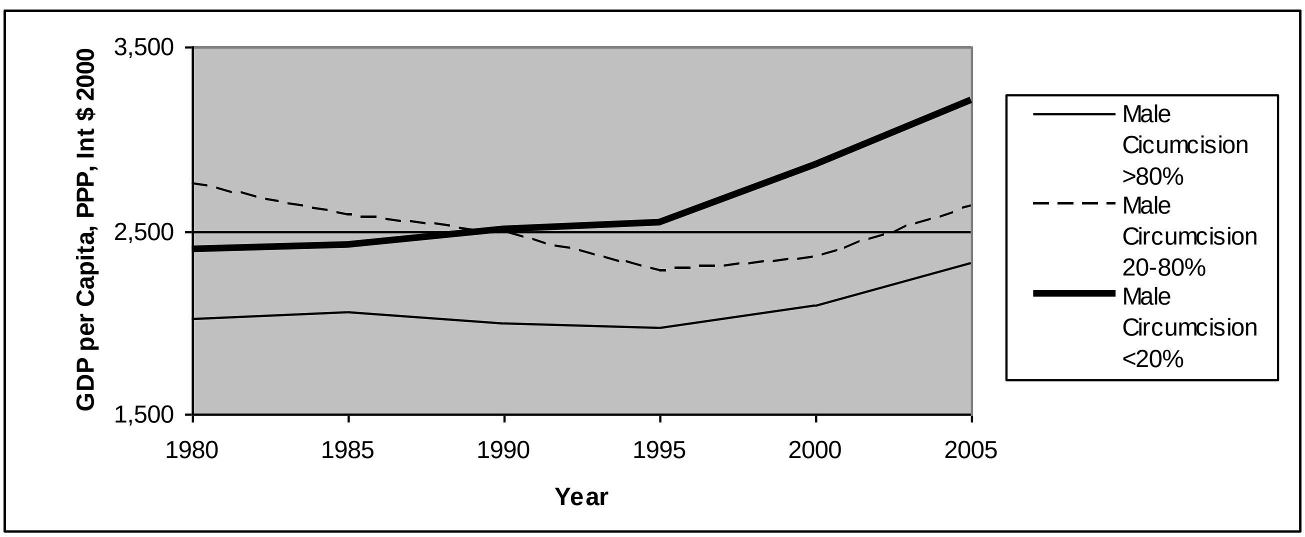
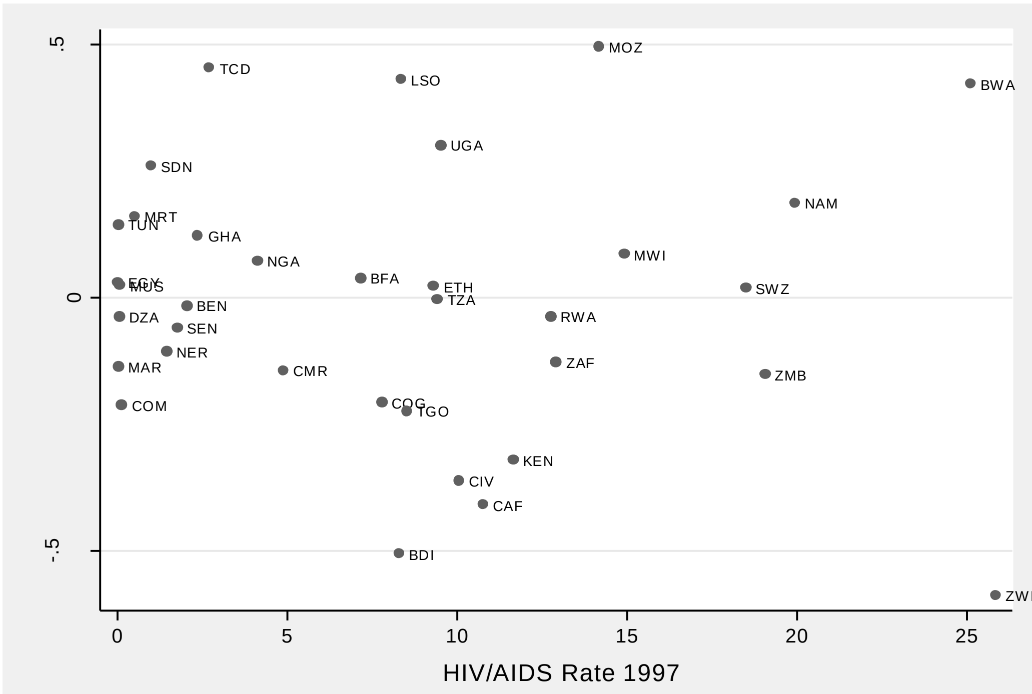
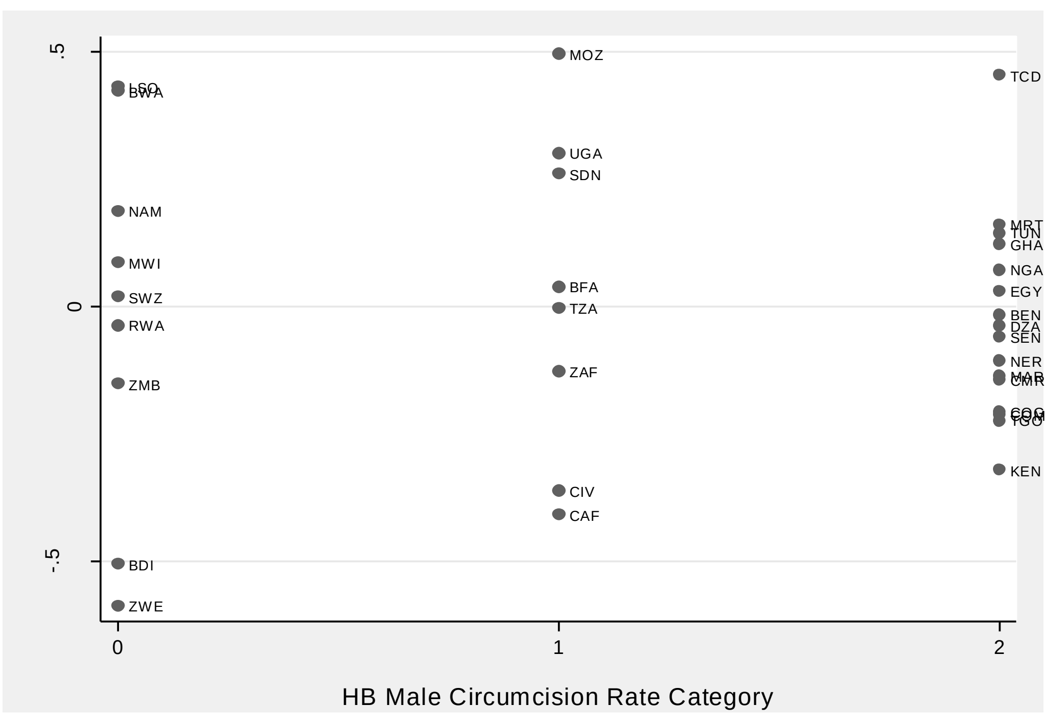


Figure 4c: Partial Correlation of GDP per Capita Growth 95-05 and HIV/AIDS Rate 1997



Note: Growth rates are filtered for the estimated effects of the following explanatory variables: ln(GDP per capita in 1990, PPP, Int. $2000); ln(Average Fertility, 1987-1992); Infant Mortality Rate, 1990; Adult Literacy Rate, 1990

Figure 4d: Partial Correlation of GDP per Capita Growth 95-05 and Male Circumcision



Note: Growth rates are filtered for the estimated effects of the following explanatory variables: ln(GDP per capita in 1990, PPP, Int. $2000); ln(Average Fertility, 1987-1992); Infant Mortality Rate, 1990; Adult Literacy Rate, 1990

Figure 5a: Savings (% of GDP) 1980-2005, by AIDS Rate

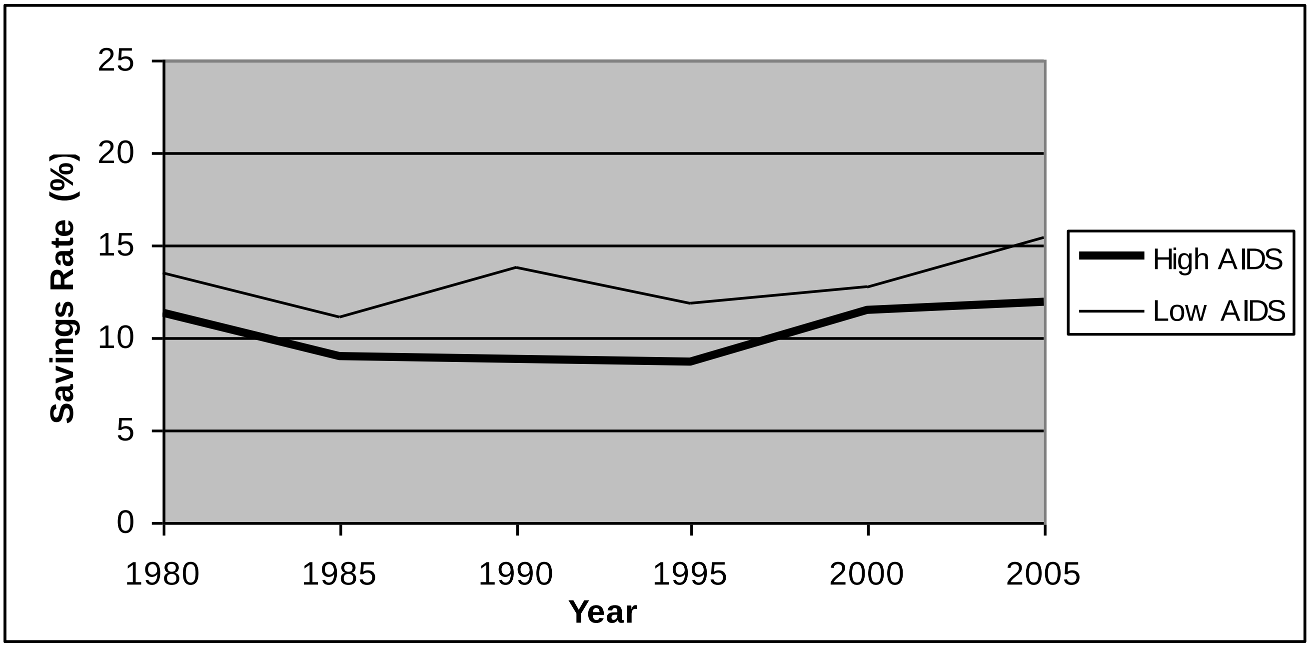


Figure 5b: Savings (% of GDP) 1980-2005, by Male Circumcision Rate

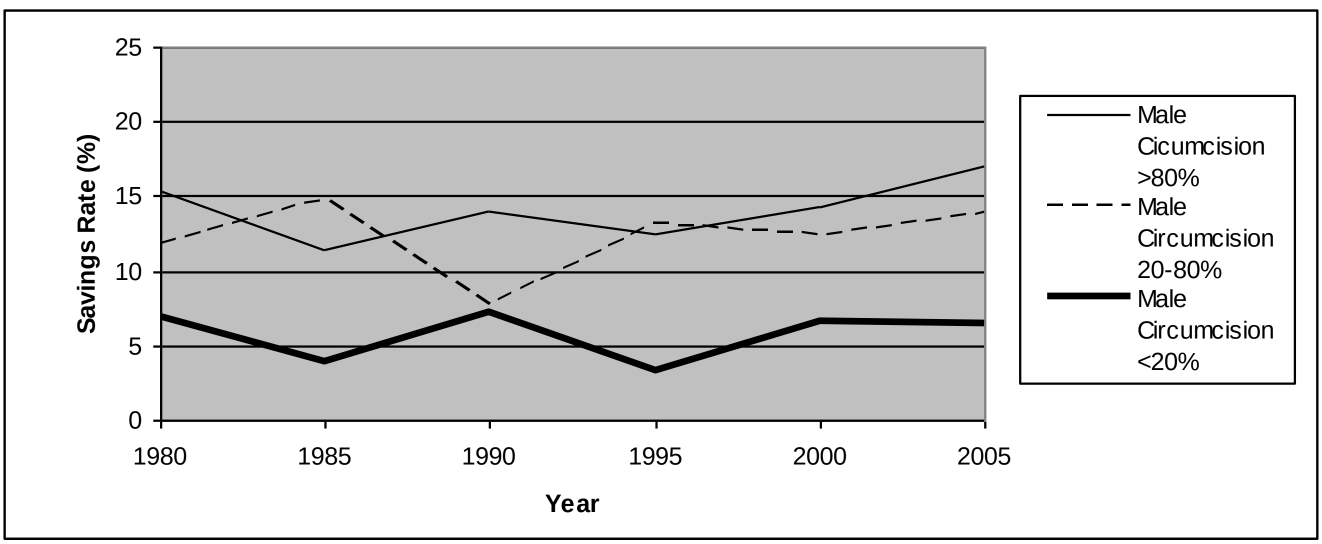


Figure 6a: Crude Birth Rate 1980-2005, by AIDS Rate

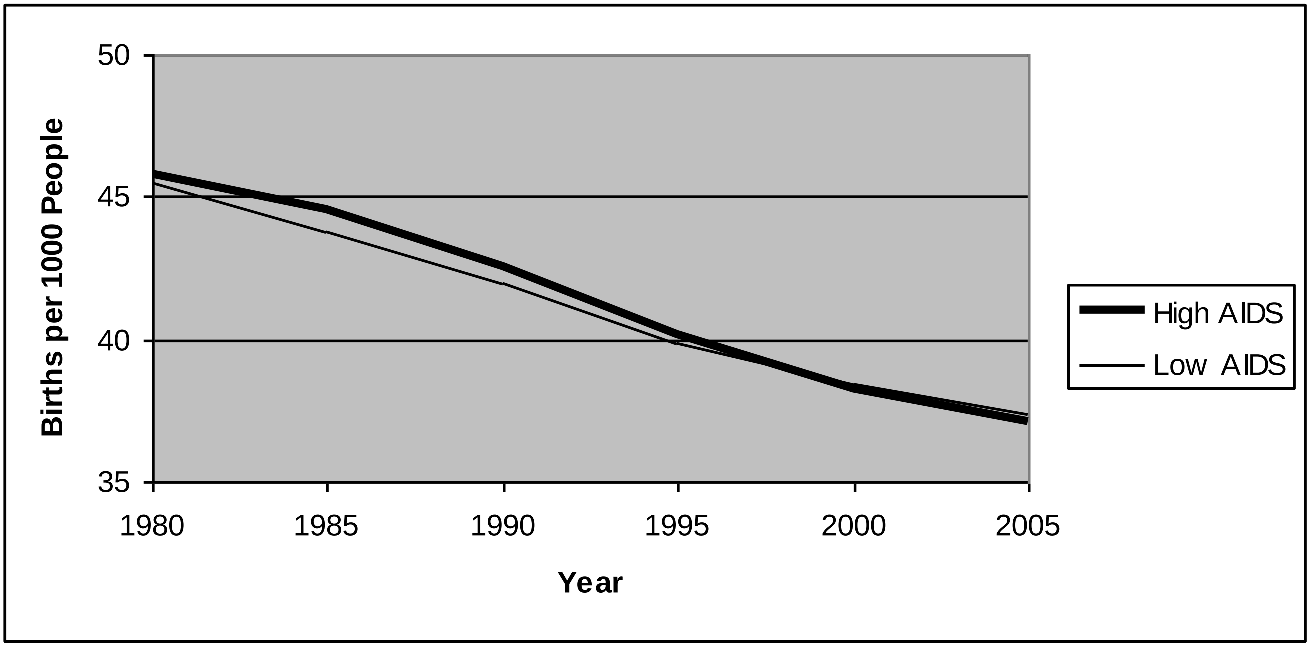


Figure 6b: Crude Birth Rate 1980-2005, by Male Circumcision Rate

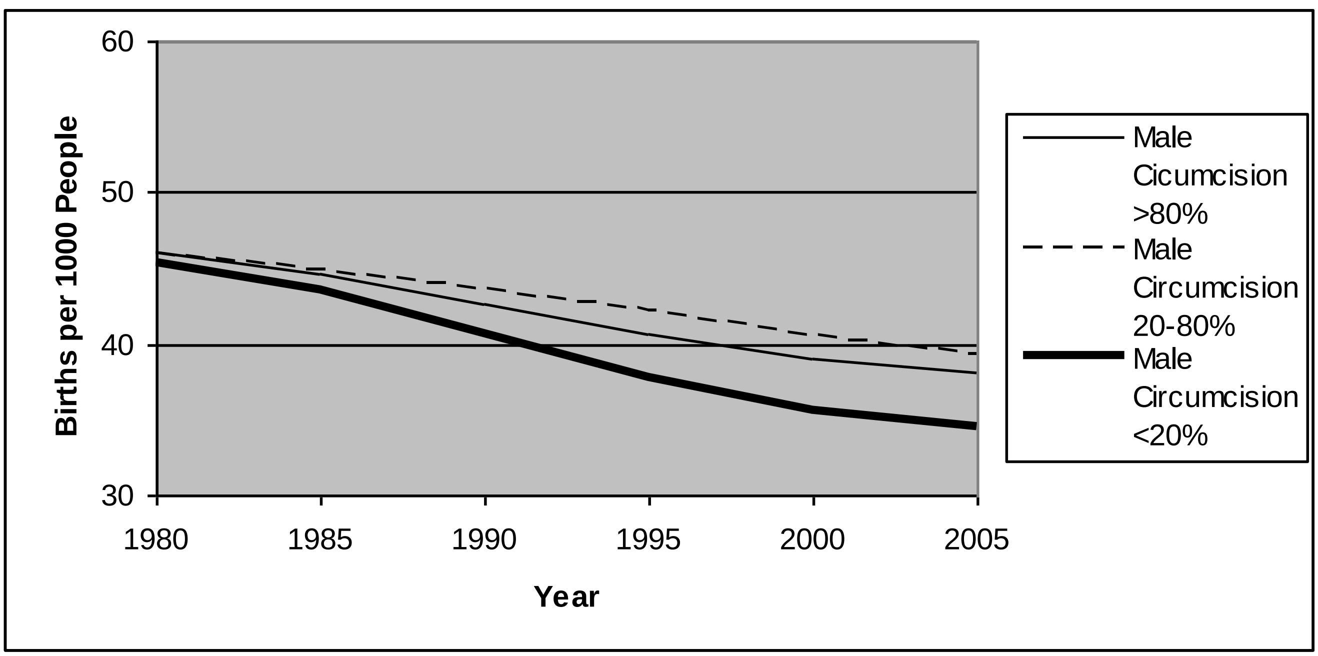


Figure 7a: Youth Literacy Rate 1980-2000, by AIDS Rate

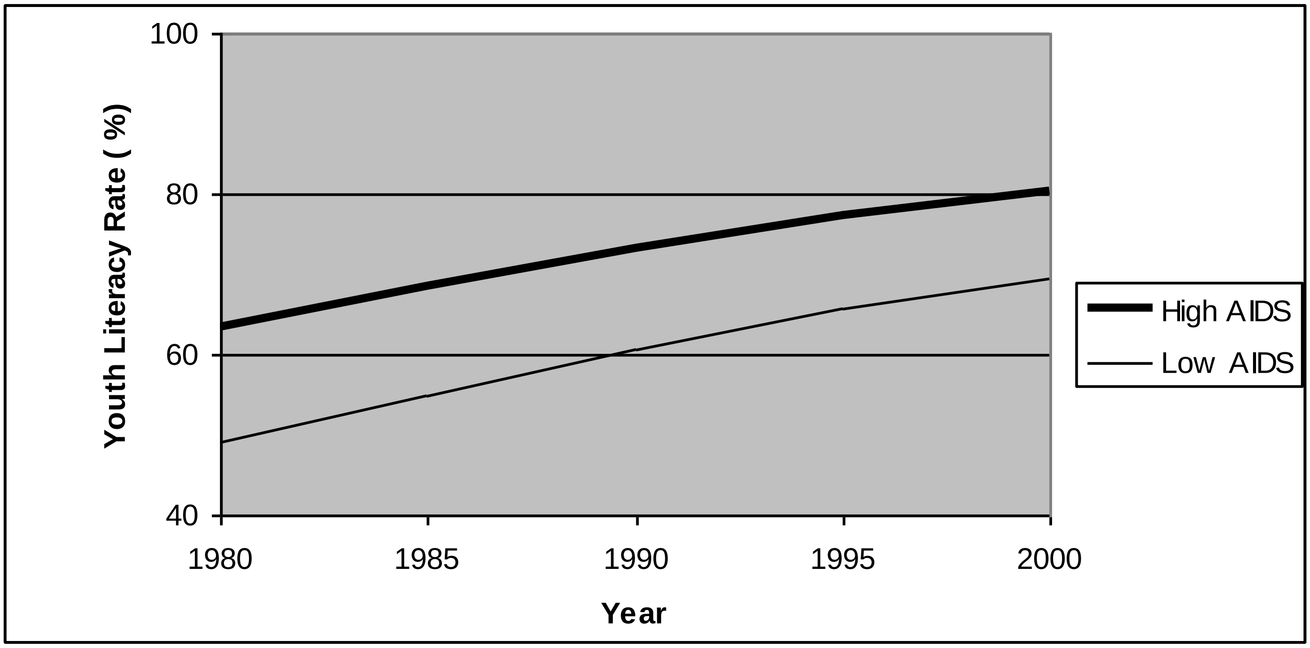


Figure 7b: Youth Literacy Rate 1980-2000, by Male Circumcision Rate

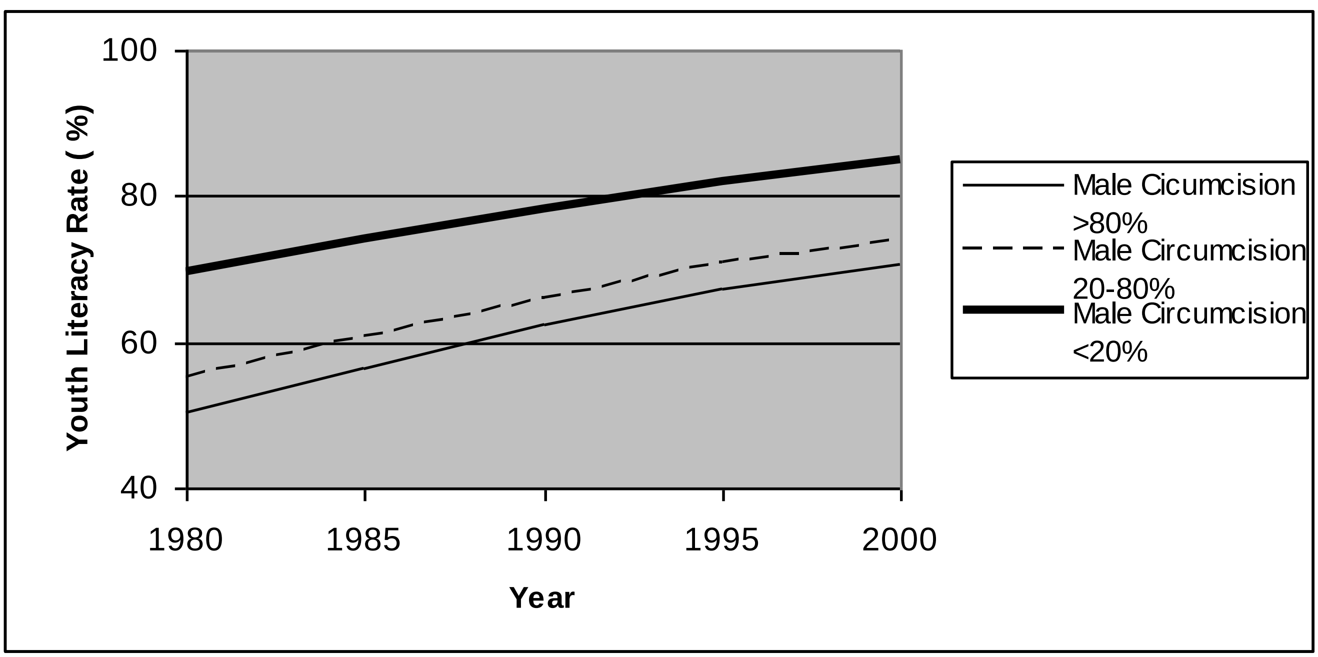


Figure 8a: Malnutrition Rate 1980-2000, by AIDS Rate

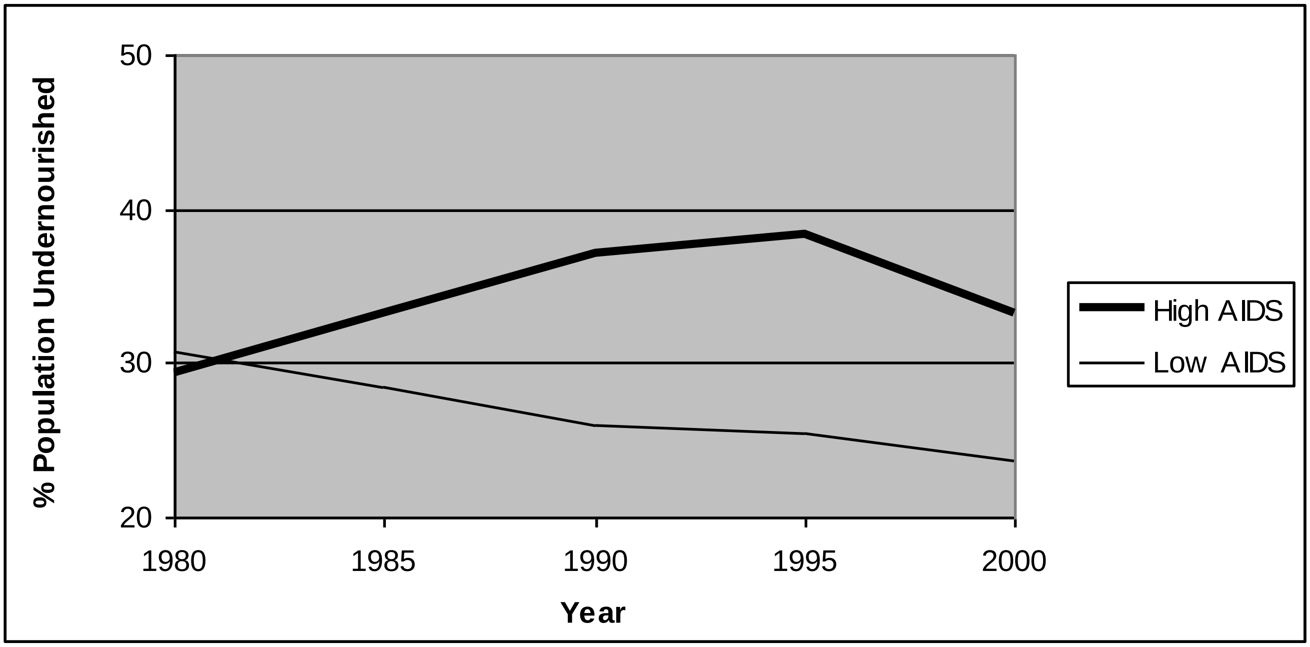


Figure 8b: Malnutrition Rate 1980-2000, by Male Circumcision Rate