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ABSTRACT

This paper presents empirical evidence on a specific mechanism through which demographic transition affects economic growth. The evidence provides support for models of demographic transition emphasizing the demand for children. Using a panel of African countries during 1985–2000, I show that the HIV/AIDS epidemic affects the total fertility rates positively and the school enrollment rates negatively. These patterns are consistent with theoretical models that argue the existence of a precautionary demand for children in the face of uncertainty about child survival. Parents who are faced with a high mortality environment for young adults choose to have more children and provide each of them with less education, leading to a reversal in the fertility transition and a reduction in the aggregate amount of human capital investment. The empirical estimates predict that parents in a country with a high level of HIV/AIDS prevalence, such as Congo, have 2 more children compared to a country with a low level of HIV/AIDS prevalence, such as Madagascar. A country such as Botswana that has witnessed a quadrupling in HIV/AIDS prevalence, has had 1.5 more births per woman and 30 percentage points lower primary school enrollment since 1985. The results imply lower economic growth and welfare for current and future African generations.

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1 Introduction

The scope of the worldwide AIDS epidemic is staggering. As of 2004 there were an estimated 40 million people living with HIV/AIDS with more then 90 percent of the infected people living in developing countries. In 2004 alone, there was 5 million new infections. Africa alone accounts for the two-thirds of the world total and almost all of the infected children.[1] In the 35 highly affected countries of Africa life expectancy at birth dropped 7 to 10 years on average in the last 10 years. As shown in figures 1a and 1b, in Botswana, Uganda, South Africa, Zambia and Zimbabwe, the five countries with the highest HIV/AIDS prevalence, life expectancies for females and males are now at their 1950 levels. In Botswana life expectancy for females has dropped from 62 years in 1985 to 38 years in 2000 and is projected to fall to 30 years in 2010. For males it has dropped from 58 years to 40 since 1985. Figures 2a and 2b show the spread of the epidemic during the last 15 years in these most affected countries.

Recently, there has been an increase in the number of research papers that investigate the impact of HIV/AIDS on economic growth. The results vary extensively. While most of the researchers find negative effects of the epidemic on economic growth, some find no effects and some even find positive effects.[2] The results of Lorentzen, McMillan, Wacziarg (2004) imply significant long-run costs of the AIDS epidemic on various dimensions. Bloom and Mahal (1997) run cross-country regressions of growth of GDP per capita on HIV/AIDS and find no effect, whereas Bonnel (2000) finds a negative effect within a similar framework. Over (1992), who also uses cross-country data, finds a reduction of 0.5 percent per year in per capita growth rates as a result of the epidemic. Papageorgiou and Stoytcheva (2004) find that an increase in AIDS incidence by 1 in 100,000 people is associated with a 0.004 percent reduction in income per worker. Werker, Ahuja, and Wendell (2006) instrument HIV/AIDS prevalence by national circumcision rates and show that there is no effect of the epidemic on growth of the African countries. Corrigan, Gloom, and Mendez (2005) show calibration results that imply large negative effects of the epidemic on growth. Using micro data from South Africa, Young (2005) argues that the HIV/AIDS epidemic increases the growth and welfare for the future generations of South Africa due to its negative impact on population growth.

[1]See tables 1 and 2.

[2]See UNAIDS Global report (2004) for a summary of micro and macro empirical evidence together with various simulation exercises of demographic models that show 0.5−1.5 percent reduction in yearly growth rates for various countries. See also Wehrwein (2000).

One reason for these different results might be the fact that there are numerous channels through which AIDS may affect economic development.[3] These channels might differ from country to country and over time and hence estimating the direct effect of AIDS on economic growth might be misleading. Families who are experiencing the disease and the death must cope with it, must care for the sick and hence must re-allocate all their savings. Private and public businesses lose workers and overall productivity decreases. School enrollments decline and the epidemic puts tremendous pressure on government budgets. On top of these domestic problems, foreign investors might refrain from investing in a country with high HIV/AIDS prevalence rates.[4]

If we want to make the right policy recommendations we have to investigate each channel separately. For example, many think that HIV/AIDS will substantially reduce the population growth rates. In their 2004 global report, UNAIDS argues that negative effects of the epidemic on production are counterbalanced by similar reductions in consumption and resource use due to lower population growth. As a result, they argue, the epidemic's impact on per-capita GDP is relatively small, even positive in some of the scenarios considered. Arguing along similar lines and by drawing on the parallels between AIDS and the "Black Death," Young (2005) shows that as a result of the significant decreases in population, AIDS will increase the welfare of the future generations in South Africa by increasing their per capita income. Young (2005) accepts the detrimental impact of the epidemic on the human capital accumulation, however, he argues that in South Africa infection lowers fertility through a reduction in the willingness to engage in unprotected sexual activity and by increasing the scarcity of labor. He shows that fertility effect dominates on net.[5]

The evidence shown by Young (2005) is at odds with the facts of the demographic transition. At the start of the demographic transition the mortality rates started to decline which was followed by a decline in the fertility rates. Eventually the decline in the fertility rates

[3] Acemoglu and Johnson (2005) investigate the direct effect of life expectancy on growth using pre-intervention distribution of mortality from various diseases and dates of global interventions as instruments. They do not include AIDS among the diseases they consider.

[4] See Over (1992) and Haacker (2002).

[5] Bell, Shantayanan, and Gersbach (2003), using similar data from South Africa argue that the long-term economic costs of AIDS could be devastating because of the cumulative weakening from generation to generation of human capital. See also Ferreira and Pessoa (2003), who document significant reductions in schooling. Young's (2005) findings are also strongly at odds with Lorentzen, McMillan, and Wacziarg's (2004) findings, who claim that South Africa is one of the outlier observations and leaving it out results in a more statistically significant coefficient for the effect of adult mortality on economic growth.

surpassed the decline in the mortality rates, causing an inverted U-shaped pattern for net fertility and hence population growth. The question is, then, as follows: Do we see the opposite of these patterns in Africa today? The answer is yes as I show that the HIV/AIDS epidemic has a positive impact on the fertility rates, which in turn dampens the negative effect of the epidemic on population growth and might even cause population growth to increase in the future.

I estimate the effect of HIV/AIDS prevalence on the total fertility rates and the school enrollment rates using panel data on 44 countries from Africa for the period 1985−2000.[6] AIDS represents an exogenous change in the health environment to which parents respond by changing their fertility behavior. The results are twofold. First, as a result of the epidemic the total fertility rate increases and the human capital investment decreases. The empirical estimates predict that parents in a country with a high level of HIV/AIDS prevalence, such as Congo, have 2 more children compared to a country with a low level of HIV/AIDS prevalence, such as Madagascar. A country such as Botswana, where the infection rates have more than quadrupled since 1985, has 1.5 more births and 30 percentage points lower primary school enrollment. Taken together these effects have a substantial negative effect on economic development. Second, the evidence provides support for models of fertility transition emphasizing the demand for children. The patterns observed in the data are consistent with theoretical models that argue the existence of a precautionary demand for children in the face of uncertainty about child survival. Parents that are faced with a high mortality environment for young adults choose to have more children and provide them with less education, leading to a reversal in the fertility transition and a reduction in the aggregate human capital investment.[7] This type of "insurance effect" has been shown in theoretical models but have not

[6]After this paper was substantially completed I became aware of a new working paper by Young (2005b), that undertakes a similar analysis using macro data from selected African countries and finds a negative effect of HIV on fertility. I hope that future work will sort out the differences.

[7]For theoretical models based on this mechanism, see Sah (1991) and Kalemli-Ozcan (2003). See also Ehrlich and Lui (1991) for an indirect mechanism that generates a similar result for fertility but not for human capital investment. Sah (1991) and Kalemli-Ozcan (2003) develop models based on precautionary demand for children in the presence of uncertain child survival and can generate a decline in net fertility (after an initial increase) together with a decline in total fertility as a result of a decline in mortality. See also Chakraborty (2004) and Soares (2004) for different ways of modeling the relation between mortality and fertility. There are also models in the spirit of Barro-Becker world where gross fertility might be positively related to mortality but net fertility is negatively related to mortality. Among these models are Doepke (2004) and Boldrin and Jones (2002). Thus the evidence provided in this paper can be viewed as supportive evidence for a broader class of models; See Lorentzen, McMillan, and Wacziarg (2004) for an excellent review of the literature on mortality and fertility.

been captured in previous empirical studies. Although there is a very strong positive relationship between child mortality and fertility at the aggregate level, because child mortality may be endogenous the macro estimates will be biased.[8] AIDS provides an exogenous source of variation. More importantly AIDS mortality takes place much later in life, which makes insurance against the AIDS related deaths early on extremely important.

The rest of the paper is structured as follows. Section 2 discusses background information on HIV/AIDS and micro evidence on the behavioral response. Section 3 examines the data on total fertility rates, enrollment rates and HIV/AIDS prevalence. Section 4 presents the empirical analysis. Section 5 concludes.

2 Background: HIV/AIDS Epidemic and the Behavioral Response

There are four characteristics of AIDS that make its economic impact far greater than the other diseases. First, it is always fatal in Africa. Second, AIDS in Africa is affecting prime-aged adults in their most productive years. Third, it is very widespread in urban areas and it is the leading cause of death in Africa today. Fourth, unlike other diseases in Africa, AIDS is affecting educated and upper class individuals. Thus a big part of the aggregate economic impact of AIDS depends on the behavioral responses of individuals to the demographic shocks caused by the epidemic.

The demographic impact of the epidemic depends on its effect on mortality and fertility. Demographers argue that—assuming no significant change in fertility—the higher death rates due to AIDS will eventually reduce the population growth rate to zero.[9] Thus, the response of fertility to AIDS is one of the important elements for determining the aggregate impact of the epidemic on economic development. According to the demographers, HIV infection will not shorten the lives of a large enough number of women to reduce national birth rates unless infection lowers the age-specific fertility rates. Demographic models assume that by the time

[8] Schultz (1997) shows a positive effect of child mortality on fertility using panel data from a set of developing countries. However, he argues that these type of estimates cannot claim causality due to the endogeneity of child mortality. Micro empirical studies focus on estimating the magnitude of the "replacement effect," which is replacing each death child ex-post instead of ex-ante insurance by having more children.

[9] This effect might change from country to country since it depends on the incubation period—the time from HIV infection to AIDS. Some studies suggest that this period is shorter in Africa. See Ainsworth and Over (1995).

most HIV infected women die, they would already have given birth to several children; thus, the total fertility rates at the national level will not be affected. This type of argument assumes there are no behavioral responses and the aggregate impact will only come from various clinical responses. It is very plausible to think that as a response to the epidemic, individuals decide to change their fertility behavior, which in turn will affect the aggregate fertility rate.[10]

Presumably, people who were entirely unaware of the epidemic would not change their behavior. On the other extreme, women, who are born with the infection or got infected before their child-bearing years and know about their positive status may want to decrease their fertility rather then giving birth to infected children. If a large enough number of women behaves this way then the effect of the epidemic on the total fertility rate will be negative. However, existing evidence tells us a different story about the behavioral responses. Figure 3 shows indicators of risk perception of women for selected African countries.[11] The percentage of sexually active women (15-19) that perceive not to be at risk at all of getting AIDS is rather high, with a mean of 48 percent among the countries shown. The percentage of 15-49 year old women who knows that HIV can be transmitted from mother to child, is also plotted for the same countries, with a mean of 58 percent. It does not seem to be the case that higher HIV countries necessarily have better knowledge.

There is also empirical evidence that HIV-positive women may not decrease their fertility for various reasons. One issue is lack of information. Oster (2005) argues that knowledge of one's HIV status appears to be very low in Africa, which suggests no behavior change in response to being HIV-positive. Setel (1995) argues that informed HIV positive people make up only a small part of all that are affected by the disease and they become informed very late. Thus, they will not live long enough to alter their fertility even if they want to. He cites various studies that test groups of women from individual countries that show that the ones who came back for a follow up after the HIV testing (the informed) only constitutes 30 percent of all the test subjects.[12] He further argues that people who voluntarily seek testing

[10]See Kremer (1996) for a model that produces multiple equilibria for the behavior change as a result of the epidemic.

[11]Data comes from various DHS and nationwide surveys over 1994-1999 and reported by the 2000 Global Report of UNAIDS.

[12]Sentinel surveillance programs (a form of surveillance relates to a particular group) monitoring HIV incidence in Africa are not designed to detect and notify at-risk individuals. They are conducted using anonymous and unlinked blood samples from hospital blood donors, pregnant women attending antenatal clinics, or STD clinic attenders. Thus, those with HIV who are tested will not receive a notification of their

and counseling are in the minority. Thornton (2006) designed a randomized experiment involving 2700 individuals in Malawi and finds that less than half of the participants attended clinics to learn their HIV status.[13] Malawi survey data shows that only 20 percent of the respondents have ever been tested and only half of those tested learned their results.

Biswalo and Lie (1995) claim that for those women who lack the power to negotiate fertility it is plausible that those who become infected with HIV may also be reluctant to reveal their positive status. They present evidence from interviews with a small sample of HIV-positive women in Tanzania that in spite of being pressed for more children, women did not reveal their status. Higgins et al. (1991) and Green (1994) review studies done for various African countries and find no evidence of HIV testing and counseling on the reproductive behavior of HIV positive or high risk individuals. Temmerman et al. (1990) find that in Nairobi a single session of counseling—which is common in most African countries—has no effect on the subsequent reproductive behavior of HIV-positive women. Allen et al. (1993) using cohort data from Kigali, Rwanda, find that in the first 2 years of follow-up after HIV testing, seronegative women were more likely to become pregnant than HIV-positive women. However, among HIV-positive women those with no children were more likely to become pregnant than those with children and married women are more likely to become pregnant than unmarried women. The desire to have children among HIV-positive women altogether was 45 percent. Thornton (2006) finds no impact of testing, long counseling sessions, education about safe sex on HIV-negatives sexual behavior and finds little impact on HIV-positives. The main conclusion of these papers is that fertility decisions of infected people will not depend on their awareness of their own positive status in general.

Uninfected people, or people who think they are not at risk, might behave differently. Although they are uninfected these people probably know that there is a high level of mortality in their surrounding population. Young (2005) argues that individual fertility rates will decrease for everybody since the willingness to engage in unprotected sexual activity will decline due to the HIV/AIDS epidemic. To the best of my knowledge there is no systematic evidence that shows the willingness to engage in sexual activity decreases as a result of the epidemic. The evidence is on the contrary. Sociologists have long arguing that in Africa married women don't have a lot of power over their husband's extra-marital sexual activity.

status.

[13]She also finds that if a small monetary incentive is provided then the share of the ones who want to learn their status increased by 50 percent.

Luke and Munshi (2004) find, in a high AIDS prevalence environment, married men are no different then single men in the number of non-marital partners. One would expect the number of non-marital partners to fall more for the married men if unprotected sexual activity is an issue or if wives could influence husband's extra-marital sexual activity. The data on sexual behavior are available from DHS, however these data are far from being perfect. These data from the surveys are self-reported measures and they are subject to downward biases. This bias is likely to be more serious in the case of Africa. They are only available since the epidemic got underway and hence a comparison between pre-epidemic and post-epidemic sexual behavior is impossible. Nevertheless, some studies investigated a single location over time to observe changes in sexual behavior. The results suggest very little or no behavioral change at all.[14] Oster (2005), using the DHS data on sexual behavior from ten African countries where the surveys run more than once, investigates the change in sexual behavior over time. She finds little or no behavior change over time. Combining these data with the HIV rates, she shows that there has been a very small decrease in sexual activity with increase in the HIV rates: 1 percent increase in the HIV rate is associated with a 0.2 percent decrease in the share of single women having premarital sex.

One plausible scenario for the uninfected parents might be to respond to the higher mortality environment by having more children to guarantee a certain number of survivors. This response of fertility to expected deaths, where parents bear more children than their optimal number of survivors is based on uncertainty about child survival. This uncertainty leads parents to produce more children, a condition that causes an increase in fertility larger than the average increase in mortality and hence increases the expected number of surviving children. Parents can also undertake a "replacement strategy," where parents replace deceased children.[15] However in the case of the HIV/AIDS, where AIDS related deaths come later in life, it will be biologically impossible to replace those dead children.[16] Figure 4 shows data from Botswana, where HIV/AIDS prevalence peaks around age 25−30, implying AIDS mortality to take place much later in life.[17] Figures 5a shows the mortality profile for adults and

[14] See Mwaluko et al. (2003), Williams et al. (2003), and Bloom et al. (2000).

[15] Doepke (2005) shows that the insurance effect will disappear when replacement is allowed. However, micro studies estimates the replacement effect to be less than 1. See Schultz (1997).

[16] I am assuming that parents presume their children will be infected via sexual activity, which probably will not start before early teen years.

[17] The data come from 2001 Botswana, HIV sero-prevalence (the proportion of persons who have serologic evidence of HIV infection) sentinel survey among pregnant women and men with sexually transmitted diseases.

children as a function of time since infection. These estimates come from UNAIDS, Reference Group, 2002. In the absence of antiretroviral therapy, the median survival time for adults is 9 years. The estimates also imply that all infected children die by age 12. Figure 5b shows estimates from Feeney (2001) for Zimbabawe. The probability of a 15 year old dying before age 50 shows a sharp increase since late 1980s, implying extreme high mortality for young and middle-aged adults due to the epidemic during this time period.[18] The main point of these figures is that AIDS related mortality is very high for young and middle aged adults, which makes the insurance mechanism extremely important.[19] If a large number of women establish a precautionary demand for children then the total fertility rate will increase in the aggregate, causing a "reversal" in the fertility transition that has been underway since 1980. Surely enough, by having more children, parents move along a quality-quantity trade-off and invest less in their education, an action that reduces the aggregate amount of human capital.[20] The aggregate implications of these effects are higher population growth and lower economic growth.

[18]This probability is defined as q_{15}^{35} in demographic terminology. Records from vital registration, reports from households and reports from surviving siblings all show an upward trend. Feeney (2001) argues the discrepancy between registered deaths and sibling reports comes from the fact that the former is adjusted for underreporting and the latter is not. The higher probabilities implied by the household reports might reflect the rapidly rising mortality that is captured in those surveys which are undertaken in 1997 relative to others that are done earlier.

[19]Note that HIV/AIDS also causes adult mortality to increase, fecundity to decrease, sex to be more costly and transmission from mother to child to be more likely. All of these will cause a decrease in the demand for children. As argued above the evidence is not supportive of the latter two effects causing a decrease for the demand for children. As to be shown later the empirical exercise will try to control for the first two effects.

[20]The other potential reasons that can be independent of the fertility decision but still lead to a reduction in human capital investment are as follows: 1) Higher mortality implies a lower rate of return to education. Kalemli-Ozcan, Ryder, and Weil (2000) show that 1 percent reduction in mortality leads to 1 percent increase in schooling. Meltzer (1992) argues that AIDS raises mortality of young adults, which is going to have the biggest effect on the rate of return on educational investment. He claims for a 30 percent HIV positive population like Botswana, there would be a 6 percent reduction in the rate of return to education relative to no HIV/AIDS. Bleakley (2003) finds a significant negative effect of malaria and hookworm eradication on human capital accumulation in the American South (see also Bleakley and Lange (2005) who shows a substantial positive effect on fertility); 2) The HIV/AIDS epidemic affects the supply of education by compressing government and households budgets. See Cohen (2002) for an extensive analysis; 3) The epidemic will affect the firm-specific human capital. Engel (2002) shows that 1 percentage point raise in AIDS related mortality reduces the probability of the average 20-year-old worker being trained by 0.7 percentage points.

3 Data

Figures 6a-b show a declining trend for the total fertility rates for the African countries during 1985−2000, using data from World Bank, World Development Indicators (2003). However these trends are much weaker in countries with high levels of HIV/AIDS prevalence. The three countries that are shown in figure 6a, namely, Central African Republic, Namibia, and Uganda have HIV prevalence rates among pregnant women that are higher than 20 percent and AIDS incidence that are higher than 30 per 100,000 (see figure 2). Among these countries Uganda has a flat fertility rate since 1992. The second set of countries that are shown in figure 6b, Benin, Comoros, Gambia and Madagascar, have fertility rates that are declining with a steeper slope. All of these countries have HIV prevalence rates among pregnant women that are less than 2 percent and AIDS incidence per 100,000 that are lower than 5. As seen from the figures these seven countries had the similar levels of fertility at the beginning of the sample.

The picture becomes even more dramatic if I use data from the demographic health surveys, DHS, www.measuredhs.com, as shown in figures 6c-d. Most micro economists and demographers would argue that DHS is a more reliable source for the total fertility rates than the data from World Bank.[21] Each country's survey year falls in the category shown on the x-axis.[22] Figure 6c shows that for the countries with high levels of HIV/AIDS prevalence, the total fertility rate is either flat since 1992 or increasing since 1997 with a clear uptick as in the case for Kenya.[23] What is more interesting is the fact that there is also an uptick for the countries with medium levels of HIV/AIDS prevalence, as shown in figure 6d.[24] The countries with low levels of HIV/AIDS prevalence has declining fertility rates as shown in

[21] In principle the World Bank data are based on DHS data, however World Bank data involve some extrapolations between the survey years.

[22] Survey years are: Cote D'Ivoire (1994, 1999); Kenya (1989, 1993, 1998, 2003); Uganda (1988, 1995, 2001); Mali (1987, 1996, 2001); Mozambique (1997, 2003); Niger (1992, 1998); Nigeria (1990, 1999).

[23] For Cote D'Ivoire the average AIDS incidence per 100,000 during 1985–2000 is 28; average HIV prevalence among pregnant women during 1985–2000 is 5.6 percent. For Kenya the average AIDS incidence per 100,000 during 1985–2000 is 26; average HIV prevalence among pregnant women during 1985–2000 is 10.3 percent. For Uganda the average AIDS incidence per 100,000 during 1985–2000 is 20; average HIV prevalence among pregnant women during 1985–2000 is 14.9 percent.

[24] For Mali the average AIDS incidence per 100,000 during 1985–2000 is 3.7; average HIV prevalence among pregnant women during 1985–2000 is 2.2 percent. For Mozambique the average AIDS incidence per 100,000 during 1985–2000 is 9.4; average HIV prevalence among pregnant women during 1985–2000 is 4.4 percent. For Niger the average AIDS incidence per 100,000 during 1985–2000 is 3.4; average HIV prevalence among pregnant women during 1985–2000 is 1.4 percent. For Nigeria the average AIDS incidence per 100,000 during 1985–2000 is 2.2; average HIV prevalence among pregnant women during 1985–2000 is 2.6 percent.

figure 6e. It seems that the survey data from DHS indicate the start of a reversal in the fertility transition.

Figures 7b and 7d show that enrollment rates increase throughout the sample period in the low HIV/AIDS countries on average, using data from World Bank World Development Indicators (2003). However, for the high HIV/AIDS prevalence countries enrollment rates decrease or stay constant as shown in figures 7a and 7c.

The total fertility rate is the sum of age-specific fertility rates (number of children that a woman would have if she lived through all of her child-bearing years and experienced the current age-specific fertility rates at each age); i.e., it is an approximation for the average lifetime fertility of women. School enrollment rates are useful measures of participation in education, but they have serious limitations. According to World Bank, school administrations may overstate the rates for financial incentives. Also, the length of primary education differs across countries. Overage and underage enrollments frequently occur or children's age at enrollment can be misstated. Repetitions of grades are very common in developing countries, leading to a significant number of overage children enrolled in each grade and hence raising the enrollment ratio. If the ratio is over 100, that indicates the discrepancies between the estimates of school age population and the reported enrollment data due to all of the above reasons. As a result, gross enrollment ratios provide an indication of the capacity of each level of the education system and a high ratio usually, but not always, indicates a successful education system.[25]

The data on AIDS come from UNAIDS/WHO, Epidemiological Fact Sheets (2003). These are the number of reported AIDS cases for each country in every year. Data from individual AIDS cases is aggregated to the national level. I multiply the number of reported incidents by 100,000 and divide by the country's population in each year, to obtain incidence per 100,000 per country per year. According to UNAIDS, AIDS incidence reports come from surveillance systems of varying quality. Reporting rates vary substantially from country to country and low reporting rates are common in developing countries due to weaknesses in the health care and epidemiological systems. AIDS case reporting provides information on transmission patterns and levels of infection approximately 5-10 years in the past, limiting its usefulness for monitoring recent HIV infections. Despite these caveats, AIDS case reporting

[25]Note that although the net enrollment ratio excludes over-age students, it does not solve the problem completely since some children fall outside the official school age because of early or late entry rather than repetition.

is useful in estimating the burden of HIV-related morbidity, which is the focus of this paper.

The data on HIV prevalence rates among pregnant women are from US Census Bureau, HIV Surveillance Database (2003). UNAIDS/WHO also provides similar data. This database collects all studies and estimates of HIV/AIDS prevalence since the early 1980s. It provides information on prevalence, population and other factors and it also provides regional estimates. The main indicator for the epidemic within this database is the percent HIV-1 incidence among pregnant women for each country. In principle, it is available on an annual basis, though the data are missing for some years for most countries. I prefer to use the AIDS data for the general population in most of the analysis since the representativeness of the HIV rates for pregnant women for the general population is debatable. Also since HIV is transmitted from mothers to infants, it is more likely that fertility and HIV among pregnant women might be simultaneously determined. As argued in Timberg (2006), HIV rates are overestimated since they are based on the assumption that the extent of the infection among pregnant women who attended prenatal clinics provided a rough proxy for the rate among all working-age adults in a country. In spite of these caveats, I still present results at the country level and evidence at the regional level using the HIV data since this database is used by many researchers. One has to keep in mind that, both the AIDS and the HIV data suffer from serious measurement error, which will create an attenuation bias regardless of the outcome variable.

4 Empirical Analysis

Table 3 shows the mean, maximum, minimum, and standard deviation (across the 44 countries over 1985−2000) of the total fertility rate, total gross primary school enrollment rate, and the independent variables. Fertility rates vary from 2.2 children to 7.6 children. Total primary school enrollment rate shows large variation with the enrollment rate being 5 times higher in the country with the highest enrollment rates than in the country with the lowest enrollment rates. For AIDS incidence, the most affected country has an incidence per 100,000 that is 15000 times higher than that of the least affected country. GDP per capita moves between 101.8 and 6246.4 dollars. The remaining variables also show a great deal of variation. In table 4, I display the correlation matrix between the regressors. The correlations are in general not so high that it precludes obtaining estimates of the separate impact of the regressors. The highest correlations are between female secondary school enrollment and

GDP per capita (0.86), between urbanization and GDP per capita (0.55), and between infant mortality and GDP per capita (−0.59). The negative correlation between AIDS and infant mortality should be interpreted with caution since these correlations are based on averaged data. Contemporaneous or average correlations might be misleading since they mask the time lag. For example, the correlation between HIV in 1985 and AIDS in 2000 is 50 percent, whereas the contemporaneous correlation between the two is much lower. One needs to look at the correlation between past HIV infections and current levels of infant/adult mortality. Indeed the correlation between HIV/AIDS in 1985 and infant/child mortality in 2000 is 30 percent.

4.1 Cross-Country Regressions: Fertility and AIDS

Theoretical models of the demand for fertility predict four empirical regularities: 1) increased education of women raises the cost of childbearing and reduces fertility; 2) reduced child mortality, assuming the demand for surviving children is price inelastic, is associated with a decline in fertility;[26] 3) increased national income per capita increases demand for children if they are normal goods; 4) the net cost of child bearing is greater for parents in urban than in agricultural settings. Thus, I use proxies to control for these variables in a regression of total fertility rate on AIDS incidence. These determinants shown to be significant in the other empirical studies.

Table 5 reports Ordinary Least Squares (OLS) regressions of total fertility rate on AIDS incidence. The linear regressions are for the equation,

$$TFR_i = \alpha + \beta \log(AIDS_i) + \mathbf{X}_i' \gamma + \epsilon_i, \quad (1)$$

where TFR_i is the total fertility rate, $\log(AIDS_i)$ is the log of AIDS incidence per 100,000, $\mathbf{X}_i$ is a vector of other covariates, and ϵ_i is a random error term. The coefficient of interest is β, the effect of AIDS on fertility.

Table 5 uses the average values of dependent and independent variables over 1985−2000 and show that AIDS incidence is positively significant at 1 percent to 5 percent level depending on the specification.[27] AIDS incidence and GDP per capita are used in logs to smooth

[26] Notice that inelastic demand ceases to be a necessary condition once you introduce uncertainty about child survival into the model. See Kalemli-Ozcan (2003).

[27] I have 7 years of data for TFR, namely, 1985, 1987, 1990, 1992, 1995, 1997, 2000. I matched the AIDS

the effect of outliers.[28] Secondary schooling for females is negative significant at 10 percent level and primary schooling is insignificant, and GDP per capita is positive significant only when used with primary schooling due to the high correlation between GDP per capita and secondary schooling. Another important variable is infant/child (age 5) mortality, which is positive and significant at 1 percent level. As shown in column (2), using HIV prevalence among pregnant women instead of AIDS incidence does not alter these results. All of the other controls, such as population structure, male schooling, urbanization, and adult mortality, come in as insignificant. AIDS, infant mortality, and secondary schooling can explain 75 percent of the cross-country variation in total fertility rates.

To interpret the coefficient, I perform the following thought experiment: going from a country with a low level of AIDS incidence (Madagascar) to a country with a high level of AIDS incidence (Congo) predicts an increase of 1.7 to 1.9 children.[29] If we use the mean increase over time in AIDS of 120 times from 1985 to 2000 then a coefficient of 0.18 (0.20) implies an increase of 0.9 (1) births. For a country like Botswana where AIDS increased 3000 times from 1985 to 2000, a coefficient of 0.18 (0.20) implies an increase of 1.4 (1.5) births. Given the attenuation bias caused by the measurement error in AIDS incidence these quantitative impacts are very large by any standard.

To test my hypothesis further, I use data on perceptions about the epidemic instead of the actual prevalence rates.[30] Table 6 reports the results. Parents who heard of HIV/AIDS or more importantly who know someone who died of AIDS are the ones who should react most by changing their fertility behavior. As shown in columns (1)-(5) this is indeed the case. The data on percent female between 15-49 who heard of HIV/AIDS and percent female who know someone personally who has the virus that causes AIDS or has died of AIDS are both from DHS. They are averaged according to the available survey years. In spite of the limited number of countries there is a strong positive association between the perceptions about the epidemic and the fertility behavior.[31] The variable "know someone who died of

data to these years before averaging. In the next section where I run panel regressions also these matched data will be used.

[28]Using the log of the AIDS incidence also has the advantage of making the estimated coefficient immune to the scale effect due to underreporting.

[29]The coefficient 0.18 predicts 1.7 extra children and the coefficient 0.20 predicts 1.9 extra children.

[30]Francis (2006) shows that having a relative with AIDS changed the sexual behavior, desire and the self-reported identity of homosexual man in the U.S.

[31]I have also tried interacting the perception variables with the actual prevalence rates. However due to the high correlation between the HIV/AIDS prevalence rates and the perception variables and also due to

AIDS" can alone explain 20 percent of the cross-country variation in the fertility behavior.[32] For columns (2)-(5), I use the other control variables one at a time due the fact that there are only 12 countries. The estimated coefficient of 0.02 implies that going from a country of 17 percent of people who know someone who died of AIDS, such as South Africa to a country of 90 percent of people who know someone who died of AIDS such as Uganda predicts an increase of 1.5 children.

So far, I have not talked about the potential endogeneity problem. Measuring the impact of HIV/AIDS epidemic on any outcome variable will be problematic given the omitted variable bias due to unobservable factors such as culture, prudence of the parents, and governments' response to the epidemic. These and similar factors can determine AIDS and fertility simultaneously. As shown in the next section, by employing a country fixed effects specification, I am able to control for the unobservable factors that are time-invariant such as religion, climate and culture.[33] The time-varying variable that is more likely to create endogeneity problems is whether or not people are more careful and take less risks as a result of the epidemic. This will lead to lower fertility and a lower incidence of AIDS. As argued in the previous section, the evidence from micro studies are such that there is no change in risky sexual behavior as a result of the epidemic.[34]

Another concern is reverse causality. Given that the dependent variable here is fertility and not income I worry about this less. Nevertheless, table 7 reports results from regressions of total fertility rate in 2000 on the 1985 values of the explanatory variables. AIDS in 1985 is similar to an exogenous experiment. In 1985 all countries were different in their fertility rates. Then AIDS hit and affected them differently. Differences in population age structure and educational attainment might have affected the initial spread of the epidemic, and hence I control for these. Table 7 shows that AIDS incidence in 1985 and infant/child

the fact that I have limited number of countries the results of those interaction regressions are weaker. The correlation between AIDS incidence (HIV prevalence) and the variable "heard of AIDS" is 63 (55) percent; the correlation between AIDS incidence (HIV prevalence) and the variable "know someone who died of AIDS" is 65 (61) percent.

[32]This is the partial R^2 since the R^2 from a regression with GDP per capita alone is 0.62.

[33]Note that even without the fixed effects framework I am not worried about endogeneity via frequency of sex, which will lead to higher fertility and AIDS. People decide on how many children they want. Even in historical Europe parents managed to control their fertility if they want to.

[34]Even we assume there is a decrease in risky sexual behavior and people start using more condoms (or abstaining) because of AIDS then fertility will decrease as a by-product. If this is the case I should have found a negative relation between fertility and AIDS. Thus the positive result that I am finding between fertility and AIDS constitutes a lower limit.

mortality in 1985 are important determinants of total fertility rate in 2000.[35] AIDS incidence is positively significant at 10 percent level, whereas infant mortality is positively significant at 1 percent level. Again, using HIV prevalence among pregnant women in 1985 does not alter the result, rather strengthens it. HIV prevalence in 1985 is positive and significant at 1 percent level. The other right hand side variables, such as population structure, male schooling, urbanization, and adult mortality, come in as insignificant. The last column of this table also investigates the role of contraception. The contraception data are available only for 27 countries in 2000. The main result does not change, i.e., AIDS incidence is still positive and significant. Contraception use is negative and significant at 10 percent level.[36] The results should be interpreted with caution, though. Some researchers have argued that contraception should be treated as endogenous since more than half of the effect of family planning on fertility operates through its impact on child mortality, which then leads to lower fertility.[37] Other studies found that family planning programs explain only 10 percent-40 percent of the decline in developing countries and the rest of the decline is explained by the changes in desired fertility, i.e., the number of children families want to have.[38]

The quantitative impact is still economically significant. Going from a country with a low level of AIDS incidence (Madagascar) to a country with a high level of AIDS incidence (Congo) predicts an increase of 1.2 children. For a country like Botswana where AIDS increased 3000 times from 1985 to 2000, a coefficient of 0.11 implies an increase of 1 birth. These effects are quite significant given the exogenous nature of AIDS in 1985 and the fact that the estimates are lower bounds given the attenuation bias.

Section 4.5 will perform instrumental variables regressions to investigate the endogeneity issue further.

[35] I obtain similar results when I use average fertility rate over 1985–2000 on the left hand side instead of the one in 2000.

[36] In a bivariate regression, AIDS and contraceptive use have the following coefficients (standard errors): 0.11 (0.04) and -0.05 (0.001).

[37] See Schultz (1997).

[38] See Weil (2003) and Pritchett (1994), who shows that the relation between actual fertility and desired fertility among a cross-section of developing countries are very close and thus there is little scope for reducing fertility in many countries through better provision of contraceptives.

4.2 Panel Regressions: Fertility and AIDS

The total fertility rates were falling in almost all of the African countries before the HIV/AIDS epidemic.[39] Any of the reasons mentioned in the previous section might be responsible for this decline. Depending on the specific country, one reason might have played a bigger role compared to the others and/or there might be long lags before any of these reasons start affecting fertility. For example, a rise in women's relative wages in 1980 might cause fertility to decline 20 years later. Thus, the initial pattern of the fertility decline may not be similar among these countries. Demographers emphasize that a fertility transition begins at the point where fertility falls 10 percent below its peak. Once this happens the pattern of the decline is similar in timing and magnitude in different countries.

To capture this phenomenon, I run a panel regression with country fixed effects and a time trend. Table 8 reports Ordinary Least Squares (OLS) and Weighted Least Squares (WLS) panel regressions of total fertility rate on AIDS incidence. The linear regressions are for the equation,

$$TFR_{it} = \mu_i + \lambda TIME_t + \omega \log(AIDS_{it}) + \mathbf{X}'_{it}\theta + \varepsilon_{it}, \tag{2}$$

where TFR_{it} is the total fertility rate, μ_i is the country fixed effect, $TIME_t$ is the time trend, $\log(AIDS_{it})$ is the log of AIDS incidence per 100,000, $\mathbf{X}_{it}$ is a vector of other covariates, and ε_i is a random error term. The coefficient of interest is ω, the effect of AIDS on fertility. The country fixed effects are essential to control for the time-invariant unobservable factors. I also run a regression both with country fixed and time fixed effects as shown below.

Results are given in table 8. The time trend comes in with a significant negative coefficient and it captures the declining trend of fertility in the absence of AIDS. Thus, while other factors contributed to the decline in fertility, AIDS has the opposite effect. AIDS incidence is positive and highly significant in all of the specifications. One thing to notice is that the specifications that are estimated without the country fixed effects (columns (1) and (5)) posit larger coefficients. This is because the regressions without country fixed effects exploit both the *within* and *between* variations whereas the country fixed effects regressions exploit only the *within* variation. In addition, panel regressions, in general, suffer more from attenuation bias caused by measurement error than cross-section regressions, where the bias might be dampened via averaging. Figure 8 plots the partial correlation plot based on column (3). The

[39] Cohen (1998) shows that a widespread decline in fertility was underway across Africa in the late 1980s.

slope of the fitted line is 0.03 and it is evident from the figure that the positive effect of AIDS on the total fertility rate is not driven by outliers. Using HIV prevalence among pregnant women yields similar results for the specifications without the country fixed effects. But the results turn out to be negative and insignificant in the country fixed effects specifications. This means at the cross-country level data on AIDS and HIV are highly correlated and they both have predicative power for the fertility behavior. However only the variable AIDS can predict the fertility rates when we look at the *within* country variation.

The coefficient to the time trend implies a decline of 0.09 births per year on average. Cumulated over 1985 to 2000 this coefficient implies a total decline of 1.4 births. For the countries in my sample the increase in AIDS incidence varies from a doubling to an increase of 9000 times. In a country like Botswana, AIDS incidence increased 3000 times since 1985, hence a coefficient of 0.03 implies an increase of 0.3 births. If we use the mean increase of 120 times then a coefficient of 0.03 implies an increase of 0.2 births since 1985.[40] A coefficient of 0.10 implies, as estimated in the specification without the country fixed effects, an increase of 0.6 births for the mean increase in AIDS and 0.8 births for a country that experienced an increase in the epidemic similar to Botswana.

The impact of AIDS on infant/child mortality becomes insignificant in the country fixed effects framework.[41] Female schooling and GDP per capita are both highly significant with the expected signs. The economic impact of the other variables are in line with the existing empirical literature. The coefficient on GDP per capita of -0.23 implies that a country that doubles its GDP per capita is going to have 0.11 less births on average. Again the change in GDP per capita from 1985 to 2000 varies between no change to a quadrupling in this sample of African countries. If we use the average change of 1.1 times, a coefficient of -0.23 implies 0.02 less births on average. The change in the female primary and secondary schooling from 1985 to 2000 varies between 65 percentage points to -25 percentage points, the mean being 7 percentage points. Thus the coefficient of -0.004 implies 0.01 fewer births as a result of the mean increase in female schooling during the sample period. As a result, based on column (7), the estimates multiplied by the changes from 1985 to 2000 in the conditioning variables lead to a predicted decline in fertility of 1.3. Fertility actually fell by 1.1 in this sample of

[40]These results are comparable to Bleakley and Lange (2005), who finds that a decline in the hookworm infection rate of 50 percent between 1910 and 1920 in the American South leads to a decline in the total fertility rate of 0.1.

[41]This is a typical result out of the fixed effects estimation; See Schultz (1997).

countries between 1985 and 2000. Overall AIDS incidence slowed down the decline in fertility during the sample period and together with the other variables it explains 78 percent of the variation in fertility rates. These results imply a potential reversal of the fertility transition in the coming decades.

Table 9 reports robustness results. Column (1) uses a full set of time dummies together with country fixed effects instead of a linear time trend yielding similar results. The response of the total fertility rate to the time trend may be non-linear and hence I use a quadratic and a cubic trend. The results are similar. Column (2) shows the quadratic trend, which comes in negative but insignificant. There also may be a non-linear relationship between AIDS and the time trend thus I interact the two, which also comes in as insignificant. The rest of the columns add different explanatory variables or use different samples. Column (3) uses countries with GDP per capita levels that are below the sample mean. Female schooling and GDP per capita becomes insignificant in this sample. Experimenting with samples above the mean and below/above the median level GDP per capita gives similar results. AIDS is also robust to the addition of other control variables, such as, urbanization, population age structure and adult mortality, all of which might have affected the initial spread of the epidemic but come in as insignificant. Male schooling is significant with the expected sign. Column (8) uses all the available data and column (9) omits South Africa, which might be atypical.[42] Results are similar.

4.3 Comparison to Young's (2005) Results

Using micro level data from South Africa, Young (2005) shows a negative effect of HIV prevalence on fertility. My country level data are consistent with his findings. Figures 9 and 10 show macro times series data from South Africa. It is clear from figure 9 that the total fertility rate is falling in spite of the increase in the HIV/AIDS epidemic. Primary and secondary school enrollment rates are rising before 1990. Figure 10 plots the total fertility rate against AIDS incidence (top x-axis) and HIV prevalence among pregnant women (bottom x-axis) over time for South Africa. It seems that there is a weak negative relation between HIV/AIDS and the total fertility rate.

There can be various reasons why I find a positive relation between HIV/AIDS in a cross-section regression and a panel regression of African countries, whereas Young (2005) finds a

[42] Due to the abolition of apartheid there are some discrete changes in the South Africa variables.

negative relation within South Africa.

Is South Africa representative? The effect of HIV for South Africa may not apply to the rest of the Sub-Saharan Africa. In fact, as shown in figure 11 different countries have different patterns for the relationship between TFR and the epidemic. The demographics of HIV/AIDS might vary from country to country and time path of the epidemic also might vary from country to country. My analysis uses data for 44 Sub-Saharan African countries and might lead to more representative results.

Cohort-Specific Trends: Young's (2005) identification comes from variation in HIV exposure by age and cohort. He controls for secular effects of age and cohort using linear (and sometimes polynomial) trends in birth year, age and time, all of which will control for a smooth trend. In a country like South Africa one can imagine the existence of more complicated trends due to the abolition of apartheid, which is a discrete change. This type of cohort-specific trends may not be captured by Young's methods.

Spillovers between Cohorts: One important issue might be the effect of one cohort on another. Women of a given cohort have social interactions with people outside their cohort as well, such as with parents and siblings. For example, a young woman may have witnessed siblings' death from AIDS which might affect her own fertility choices.

Omitted Variables: Education affects fertility only through wages in Young's (2005) model. If there is a direct negative effect of education on fertility then Young's (2005) estimates will be biased downwards.[43] Another omitted variable which might be important is urbanization. Before the abolition of apartheid only male migrants were allowed to go to urban areas. Since 1988, mobility has been free. So urbanization was not smooth over the last 30 years and it is plausible that this type of discrete change will affect cohort-specific trends (See Posel, 2003).[44] Still another omitted variable might be preferences. People with irresponsible life styles might be more likely to have AIDS and less likely to have children. Again this will result in a negative bias caused by unobserved individual preferences. Overall, to the extent that macro data can control for these omitted variables, the estimate in this paper will be a lower bound for the effect of AIDS on total fertility rate. Given that I found a positive effect it is more plausible that AIDS will cause an increase in the total fertility rate on average in

[43]The correlation between education and AIDS is positive as shown in table 4 and the partial correlation between female education and fertility is negative as shown in table 5.

[44]The correlation between urbanization and AIDS is positive as shown in the table 4 and the partial correlation between urbanization and fertility is negative as shown in table 5.

Africa.

4.4 Panel Regressions: Human Capital Investment and AIDS

What is the effect of the HIV/AIDS epidemic on human capital investment? The answer to this question is as important as knowing the effect of the epidemic on the fertility behavior in order to investigate the total impact of HIV/AIDS on economic development. There are many channels that the effect of AIDS on human capital investment will operate. First and foremost, parents' fertility and human capital investment decisions are linked. Having more children as a result of AIDS implies parents move along a quality-quantity trade-off and invest less in their education. This will in turn reduce the aggregate amount of human capital on average. Second, a high mortality environment can have a direct effect on educational investment in addition to the indirect effect that is related to the fertility decision. The reason for this is simply that higher mortality implies a lower rate of return to education. Both of these channels will cause a decrease in the demand for education. The HIV/AIDS epidemic also affects the supply for education by compressing government and households budgets. As a result we should expect to find a negative effect of HIV/AIDS epidemic on the educational investment.

As shown in figures 7a-d, human capital investment had an increasing trend before AIDS. Thus, I run a panel regression with country fixed effects and a time trend, controlling for the other potential determinants of human capital investment.[45] I also run a regression with both country and time fixed effects instead of a linear trend as shown below.

Table 10 reports Ordinary Least Squares (OLS) and Weighted Least Squares (WLS) regressions of gross primary school enrollment rates on AIDS incidence. The linear regressions are for the equation,

$$ENROLLMENT_{it} = \kappa_i + \tau TIME_t + \varphi \log(AIDS_{it}) + \mathbf{X}'_{it}\zeta + \eta_{it}, \tag{3}$$

where $ENROLLMENT_{it}$ is the gross primary school enrollment rate, μ_i is the country fixed effect, $TIME_t$ is a time trend, $\log(AIDS_{it})$ is the log of AIDS incidence per 100,000, $\mathbf{X}_{it}$ is a vector of other covariates, and η_{it} is a random error term. The coefficient of interest is φ,

[45] AIDS turns out to be insignificant in the cross-sectional regressions of human capital investment, whereas GDP per capita is highly positively significant. The insignificance of AIDS in the cross-section can be due to small number of countries and limited variation in the human capital investment variables.

the effect of AIDS on educational investment.

Results are given in table 10. The time trend is always positively significant and it captures the rising trend of the primary school enrollment rates in the absence of AIDS. However, AIDS had an opposite effect. AIDS per capita is highly negatively significant in all of the specifications with similar coefficients. Using HIV prevalence instead of AID incidence does not change the results. Figure 12 plots the partial correlation plot that corresponds to column (5). The slope of the fitted line is -3.93. It is evident that the significant negative relation between AIDS incidence and enrollment rates is not driven by outliers.

According to the estimated time trend, each country has an increase of 2.2 percentage points in the enrollment rates in every year, implying an almost 36 percentage points increase over the sample. For a country where AIDS doubles, on the other hand, the enrollment rates are going to decline 3 percentage points.[46] Using the average increase of AIDS incidence of 120 times over the sample period in Africa, a coefficient of -3.93 implies a 18 percentage points decrease in human capital investment. For a country like Botswana, that experienced an increase in AIDS of 3000 times, the estimated coefficient implies a decrease in enrollment of 30 percentage points. On the cross-sectional dimension going from a country with a low level of AIDS incidence (Madagascar) to a country with a high level of AIDS incidence (Congo) predicts an decline in the enrollment rates of 38 percentage points.

The impact of the other variables are again in line with the existing empirical literature. A country that doubles its GDP per capita is going to have 18 percentage points more enrollment in the primary school. Using the mean increase of 1.1 times in GDP per capita we have an increase of 2.5 percentage points in the enrollment rates. A decline in infant mortality from 150 to 50 thousand live births is associated with an increase in the enrollment rates of 92 percentage points. However the average decline in infant mortality is 10 more live births implying a 9.2 percentage points increase in the enrollment rates. Adding these together, column (5) implies an increase of 15.7 percentage points in primary school enrollment rates over the sample period on average. The actual change is 16 percentage points. As argued above, there can be many channels behind this negative effect of AIDS on educational investment. One explanation, the one entertained here, is the quality-quantity trade-off. It is also possible that children become orphans, schools close down since the teachers die, and there

[46] This result is comparable to Bleakley (2003) who finds that an infection rate of hookworm of 50 percent as opposed to 0 percent leads to decline in the school enrollment rate of 5 percentage points.

is lower lifetime return to human capital investment due to lower life expectancy. Probably all of them operated together. The answer to the question of which one is more important is beyond the scope of this study.

Table 11 performs the same type of sensitivity analysis as in table 9. Including a full set of time dummies instead of a linear time trend does not change the results. Quadratic trend, urbanization, adult mortality and population age structure come in as insignificant. Infant mortality also becomes insignificant when I use the secondary school enrollment rate as a dependent variable. Indeed the regression in column (6), where secondary school is the dependent variable has rather low R^2 and the significance of AIDS decreases, together with the other variables.

4.5 IV Regressions

As discussed in detail in section 4.1 endogeneity can be an issue given the potential country-specific omitted variables and reverse causality. So far, I show that the results are robust to a country fixed effects specification and also using initial values (1985) of the independent variables on the right hand side. Nevertheless, this section presents the results from instrumental variables regressions for robustness. One caveat is that the sample size is drastically reduced due to the availability of the data for the instruments.

Table 12 reports the results from various 2SLS specifications. Column (1) instruments average AIDS incidence over 1985–2000 with the circumcision rate—the percent of male between ages 15–59 who are circumcised— in the cross-country fertility regression.[47] The data is from Werker et al. (2006). They use the same instrument for HIV/AIDS in a cross-country growth regression.[48] Note that we have 40 countries instead of our base sample of 41 since there is no circumcision data for Mauritius. Hence we need to compare the IV regression that is reported in column (1) to the corresponding OLS regression with 40 countries, which delivers a coefficient (standard error) of 0.12 (0.06) on log of average AIDS

[47] Using HIV instead of AIDS yields similar results.

[48] Werker et al. (2006) assemble national circumcision rates for African nations using data from various sources and by matching ethnographic practices at the tribal level with the demographic breakdowns of countries by tribe. For their first stage regression, they regress percent of adults living with HIV/AIDS in 1997 on the national circumcision rates and controls. They report a coefficient (standard error) of –15.52 (2.51) and an R^2 of 0.57. They interpret the coefficient as follows: going from a totally uncircumcised country to a totaly circumcised country predicts a decrease in the infection rate of HIV/AIDS by over 15 percentage points. See Werker et al. (2006) for details.

incidence. The coefficient on column (1) is positive and significant although the significance level is little lower. Notice that the coefficient is higher indicating the fact that the IV regression corrects for the measurement error which leads to attenuation bias in the OLS regression.[49] To interpret the coefficient of 0.13, I perform the same thought experiment: going from a country with a low level of AIDS incidence (Madagascar) to a country with a high level of AIDS incidence (Congo) predicts an increase of 1.3 children. This is little lower than the effect estimated from the OLS regression that uses average AIDS incidence but higher than the ones that are estimated from the OLS regression that uses the initial (1985) values of AIDS incidence and HIV prevalence. The reason is that the attenuation bias is stronger with a single year of data.

Column (2) uses 2 instruments, "STD" and "premarital." "STD" is the percent of female between ages 15–49 who has a sexually transmitted disease and not treated. This variable is averaged over 1995–2005 depending on the survey year. "Premarital" is the percent of female between ages 15–29 who has premarital sex. This variable is averaged over 1985–2005. Both of these data are from DHS. Oster (2005) shows that sexually transmitted infections are the main reason why African nations have much higher infection rates compared to the U.S. Hence I use STD rate as an instrument together with premarital sex rate that supposed to capture sexual habits. However these data are only available for 17 countries and hence I did not want to put too much emphasis on these results.

The time series dimension of the instruments are extremely limited due the fact that these variables come from DHS surveys and both questions were not asked at the surveys that are undertaken in the earlier years.[50] Nevertheless we can group the premarital sex variable for 1985, 1995, 2005 given the survey years around these years. Column (3) shows 2SLS results for 21 countries and 3 years in a panel regression framework, where I have the premarital sex variable. The coefficient on log AIDS incidence is positive and significant although the significance level is little lower compared to the OLS panel regressions. One should interpret the results with caution though since now I have 63 observations instead of 228. In fact the corresponding OLS panel regression with 63 observations shows that only the time trend variable is significant. This might be due to low number of observations and/or

[49]The corresponding first stage regression delivers a coefficient of –0.60 (0.17) for the circumcision rate and an R^2 of 0.31. All other controls come in as insignificant in the first stage regression.

[50]Circumcision rates are not available on a time series dimension.

the attenuation bias.[51] Using HIV prevalence delivers insignificant results as in the OLS panel regressions. Finally the last column presents the 2SLS results for the human capital investment in a panel regression framework.[52] In general the results are similar to the ones reported from the OLS panel regressions but the coefficient is higher in the 2SLS. However once more one should interpret the results with caution since now I have 63 observations instead of 228. In fact the corresponding OLS panel regression with 63 observations shows that only the time trend variable is significant as in the case for the fertility regressions.

4.6 Regional Evidence

This section provides additional supporting evidence for the positive effect of the epidemic on fertility using regional data on fertility and HIV from the African countries where the data are available. I have data on 41 regions from 8 countries.[53] These are the regions with overlapping data on the total fertility rate and HIV prevalence rate. Regional total fertility rates are from demographic health surveys, DHS, www.measuredhs.com. Regional HIV prevalence rates among pregnant women come from US Census Bureau, HIV Surveillance Database (2003). I regress the regional total fertility rates over 1998–2004 on the logarithm of regional HIV prevalence rates among pregnant women over 1985–1990, with and without country dummies.[54] Each country's survey year falls between 1998–2004. If there is more than 1 survey year during this period, than the data on the total fertility rates are averaged. HIV prevalence rates are available on an annual basis for some countries, but not all. These rates are averaged over 1985–1990 or used as a single year during that period depending on availability. DHS surveys for the 8 countries are available as follows: Ethiopia (2000), Ghana (1988, 1993, 1998, 2003), Lesotho (2004), Malawi (1992, 2000), Nigeria (1990, 1999, 2003), South Africa (1998), Tanzania (1992, 1996, 1999), Zimbabwe (1988, 1994, 1999).

Table 13 shows the results. Columns (2) and (4) are estimated by weighted OLS. In order to limit the influence of small regions, the data used in these columns are weighted by the logarithm of regional population from DHS, averaged over the survey years. All specifications

[51]The corresponding first stage regression delivers a coefficient of 1.91 (0.50) for the premarital sex variable and an R^2 of 0.76. All other controls come in as insignificant except the time trend in the first stage regression.

[52]The corresponding first stage regression is similar to the one reported for the 2SLS fertility regressions, i.e., a coefficient of 1.91 (0.50) for the premarital sex variable and an R^2 of 0.76. All other controls come in as insignificant except the time trend in the first stage regression.

[53]See the data appendix for the regions.

[54]Log transformation is used to smooth out the effect of outliers.

show a positive significant effect (at 1 percent level) of HIV prevalence on fertility. When country dummies are not included I obtain a larger coefficient, 0.40, compared to 0.28, which is obtained from the regression with country dummies.[55]

The quantitative impact is large and significant and similar to the country regressions. Going from the region with lowest level of HIV (Western Cape Province of South Africa) to the highest level of HIV (Manicaland region of Zimbabwe), implies 1.7 to 2.5 more births. These effects are very dramatic, especially given the fact that column (4) which implies 1.7 more births control the country effects and the fact that all the coefficients are biased downwards due to the measurement error. Overall regional results provide additional supporting evidence for the positive effect of the epidemic on fertility.[56]

5 Conclusion

This paper presents empirical evidence on a specific mechanism through which the demographic transition affects economic growth. The evidence provides support for models of fertility transition emphasizing the demand for children. Using a panel of African countries from 1985 to 2000, I show that the HIV/AIDS prevalence affects the total fertility rates positively and the school enrollment rates negatively. These patterns are consistent with theoretical models that argue that a precautionary demand for children exists in the face of low probabilities of child survival. Parents, who are faced with a high mortality environment for young adults, choose to have more children and provide each of them with less education, leading to a reversal in the fertility transition and a reduction in the aggregate amount of human capital investment.

Overall the impact of the HIV/AIDS epidemic on fertility and educational investment is statistically and economically significant and robust. The empirical estimates predict that parents in a country with a high level of HIV/AIDS prevalence such as Congo have 2 more children compared to a country with a low level of HIV/AIDS prevalence such as Madagascar. A country such as Botswana that has witnessed a quadrupling in HIV/AIDS prevalence, has had 1.5 more births and 30 percentage points lower primary school enrollment since 1985.

[55]Note that the results shown in columns (3) and (4) include only the dummies that come in as significant. If I include all the 7 country dummies then I get a coefficient of 0.28 with a t-stat of 1.9.

[56]Additional supporting evidence that shows a positive relation between the forecast error, which is the difference between the actual TFR in 2000 and the projected TFR for 2000, and the HIV/AIDS prevalence is also available at Kalemli-Ozcan (2005).

The results imply that in the coming decades AIDS can cause a reversal in the fertility transition and a substantial decrease in human capital investment even after accounting for other effects that works for the decline in fertility and increase in educational investment. As a result the epidemic exerts a tremendous negative effect on economic development.

Data Appendix

Countries: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo Democratic Republic, Congo Republic, Cote D'Ivoire, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

- AIDS: The AIDS data come from UNAIDS/WHO, Epidemiological Fact Sheets (2003). These are the number of reported AIDS cases for each country in every year. It is available for 44 African countries for 1985−2000. The data on AIDS come from UNAIDS/WHO, Epidemiological Fact Sheets (2003). These are the number of reported AIDS cases for each country in every year. Data from individual AIDS cases is aggregated at the national level. I multiply these number of reported incidents by 100,000 and divide by the country's population in each year, converting them to incidence per 100,000 per country per year. WHO-UNAIDS definition of AIDS (Acquired Immunodeficiency Syndrome) is that AIDS is the most severe manifestation of infection with the HIV (human immunodeficiency virus). The Centers for Disease Control and Prevention (CDC) lists numerous opportunistic infections and neoplasms (cancers) that, in the presence of HIV infection, constitute an AIDS diagnosis. There are also instances of presumptive diagnoses when a person's HIV status is unknown or not sought. This was especially true before 1985 when there was no HIV-antibody test. In 1993, CDC expanded the criteria for an AIDS diagnosis to include CD4+ T-cell count at or below 200 cells per microlitre in the presence of HIV infection. In persons (aged 5 and older) with normally functioning immune systems, CD4+ T-cell counts usually range from 500 to 1500 cells per microlitre. Persons living with AIDS often have infections of the lungs, brain, eyes and other organs, and frequently suffer debilitating weight loss, diarrhoea, and a type of cancer called Kaposi's sarcoma.

- Circumcision: This is the percent of male between ages 15–59 who are circumcised from Werker et al. (2006).

- HIV: HIV data come from US Census Bureau, HIV Surveillance Database (2003). This is the percent HIV-1 incidence among pregnant women for each country and year. HIV is the retrovirus isolated and recognized as the etiologic (i.e. causing or contributing to the cause of a disease) agent of AIDS. HIV-1 is classified as a lentivirus in a subgroup of retroviruses. Most viruses and all bacteria, plants, and animals have genetic codes made up of DNA, which uses RNA to build specific proteins. The genetic material of a retrovirus such as HIV is the RNA itself. HIV inserts its own RNA into the host cell's DNA, preventing the host cell from carrying out its natural functions and turning it into an HIV factory. HIV-2 is a virus closely related to HIV-1 that has also been found to cause AIDS. It was first isolated in West Africa. Although HIV-1 and HIV-2 are similar in their viral structure, modes of transmission, and resulting opportunistic infections, they have differed in their geographical patterns of infection.

- Enrollment rates: School enrollment rates are also from WB (2003). Primary school enrollment is available for 42 countries and 6 years (1985, 1990, 1992, 1995, 1997, 2000). Secondary school enrollment is limited.
- Heard of AIDS: The data on percent female between 15-49 who heard of HIV/AIDS are from DHS, averaged according to the available survey years.
- GDP per capita: GDP per capita (PPP) is from WB (2003) and is available for 44 countries and 7 years (1985, 1987, 1990, 1992, 1995, 1997, 2000).
- Infant mortality (Age 5 mortality, adult mortality): Infant mortality (age 5 mortality, adult mortality) is the rate per 1000 births and is from WB (2003). It is available for 44 countries and 7 years (1985, 1987, 1990, 1992, 1995, 1997, 2000).
- Know someone who died of AIDS: The data on percent female who know someone personally who has the virus that causes AIDS or has died of AIDS are from DHS, averaged according to the survey years.
- Population: Total population is also from World Bank and available for 44 countries and for 1960-2000.
- Premarital Sex: It is the percent of female between ages 15–29 who has premarital sex averaged over 1985–2005, from DHS.
- STD: It is the percent of female between ages 15–49 who has a sexually transmitted disease and not treated averaged over 1995–2005, from DHS. Specifically it is the per-

centage of women reporting an STI or symptoms of an STI 12 months preceding the survey, who did not receive any advice or treatment. Symptoms of an STI are an abnormal genital discharge, a genital sore or a genital ulcer.

- Total fertility rate: Total fertility rate comes from World Development Indicators, WB (2003) and is available for 44 countries and 7 years (1985, 1987, 1990, 1992, 1995, 1997, 2000). Total fertility rate projections for 2000 is from UN, Population Projections (1985).

- Urbanization: Urbanization is the percent of urban population in total population from WB (2003) and is available for 44 countries and for 1960-2000.

Regions:

Ethiopia: Addis Ababa, Dire Dawa, Gambella, Harari.
Ghana: Accra, Northern region, Upper East region, Upper West region.
Lesotho: Maseru, Leribe district, Mafeteng district, Quthing district, Mokhotlong.
Malawi: Lilongwe, Blantyre, Mangochi, Mulanje, Mzimba, Thyolo.
Nigeria: North East zone, North West zone, South East zone, South West zone.
South Africa: Eastern Cape Province, Free State Province, Gauteng Province, Mpumalanga Province, Northern Cape Province, Northern Province, North-West Province, Western Cape Province.
Tanzania: Dar es Salaam, Rukwa region, Arusha region, Zanzibar area.
Zimbabwe: Harare, Bulawayo, Manicaland, Masvingo, Mashonaland West Province, Matabeleland South.

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Table 1: Global HIV/AIDS Statistics, end of 2004

	Adults and children living with HIV/AIDS	Adult and children newly infected with HIV	Adult prevalence rate (%)	Adult and child deaths due to AIDS
Sub-Saharan Africa	25 million	3.0 million	7.5	2.2 million
North Africa and Middle East	480 000	75 000	0.2	24 000
South and South-East Asia	6.5 million	850 000	0.6	460 000
East Asia	900 000	200 000	0.1	44 000
Latin America	1.6 million	200 000	0.6	84 000
Caribbean	430 000	52 000	2.3	35 000
Eastern Europe and Central Asia	1.3 million	360 000	0.6	49 000
Western Europe	580 000	20 000	0.3	6 000
North America	1.0 million	44 000	0.6	16 000
Oceania	32 000	5 000	0.2	700
TOTAL	37.8 million	4.8 million	1.1	2.9 million

Notes: Data are from UNAIDS/WHO. Adult prevalence rate is the proportion of adults (15-49 years of age) living with HIV/AIDS based on 2004 population.

Table 2: Global HIV/AIDS Statistics for Children, end of 2004

	Children living with HIV/AIDS	Children newly infected with HIV	Child prevalence rate (%)	Child deaths due to AIDS
Sub-Saharan Africa	1.9 million	550 000	0.1	440 000
North Africa and Middle East	21 000	8 400	0.0003	5 000
South and South-East Asia	160 000	47 000	0.003	34 000
East Asia	7 700	3 300	0.0002	2 000
Latin America	25 000	6 400	0.0003	5 600
Caribbean	22 000	6 000	0.001	5 200
Eastern Europe and Central Asia	8 100	1 500	0.001	900
Western Europe	6 200	100	0.0001	<100
North America	11 000	100	0.0002	<100
Oceania	600	300	0.0001	<200
TOTAL	2.1 million	630 000	0.001	490 000

Notes: Data are from UNAIDS/WHO. Children refers to children younger than 15 years of age.

Table 3: **Descriptive Statistics**

	Mean	Std.dev.	Max	Min
Average Total Fertility Rate, 1985–2000	5.8	1.1	7.6	2.2
Average Primary School Enrollment, 1985–2000 (%)	160.1	56.8	281.6	58.8
Average Secondary School Enrollment, 1985–2000 (%)	49.5	36.9	169.5	10.0
Average AIDS Incidence, 1985–2000 (per 100, 000)	25.6	47.4	298.0	0.02
Average HIV Prevalence, 1985–2000 (%)	6.9	6.3	25.7	0.09
Average GDP per capita, 1985–2000 (PPP 1995 $s)	860.8	1317.4	6246.4	101.8
Average Urban Population, 1985–2000 (%)	31.5	14.2	70.9	5.5
Average Infant Mortality, 1985–2000 (per 1000)	103.2	37.3	184.0	15.2
Average Primary School for Female, 1985–2000 (%)	73.4	31.6	140.7	22.1
Average Secondary School for Female, 1985–2000 (%)	21.6	20.1	90.8	3.2

Notes: All variables are averaged over 1985−2000. Data is available for 44 countries and 7 years. Total Fertility Rate is the sum of age-specific fertility rates (number of children that a woman would have if she lived through all of her child-bearing years and experienced the current age-specific fertility rates at each age). Enrollment Rates are the gross primary and secondary school enrollment rates. (Schooling variables for female are also gross enrollment rates). AIDS Incidence is the number of reported AIDS cases per 100, 000. HIV Prevalence is the percent HIV-1 incidence among pregnant women. GDP per capita is the Gross Domestic Product (PPP 1995 $) divided by population. Urban Population is the percent of urban population in total population. Infant mortality is the infant mortality rate per 1000 births.

Table 4: **Correlation Matrix**

	Log AIDS Incidence	Log GDP per capita	Urban Population	Infant Mortality	Female Primary School	Female Secondary School
Log AIDS Incidence	1.0000					
Log GDP per capita	0.1398	1.0000				
Urban Population	0.2621	0.5590	1.0000			
Infant Mortality	-0.2502	-0.5980	-0.3067	1.0000		
Female Primary School	0.4196	0.6445	0.3467	-0.6607	1.0000	
Female Secondary School	0.3490	0.8615	0.4908	-0.7180	0.7833	1.0000

Notes: All variables are averaged over 1985−2000. See table 3 for the definitions of the variables.

Table 5: Fertility in a Cross-Section of Countries

Dependent variable is Average Total Fertility Rate, 1985–2000

	Base Sample (1)	Base Sample (2)	Base Sample (3)	Base Sample (4)	Base Sample (5)	Base Sample (6)	Base Sample (7)	Base Sample (8)
Log Average AIDS Incidence,	0.18	–	0.20	0.18	0.18	0.18	0.18	0.20
1985–2000	(0.06)	–	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Log HIV Prevalence,	–	0.18	–	–	–	–	–	–
1985–2000	–	(0.07)	–	–	–	–	–	–
Average Secondary School	–0.02	–0.02	–	–0.02	–0.02	–0.02	–0.02	–0.02
for Female, 1985–2000	(0.01)	(0.01)	–	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Average Primary School	–	–	–0.01	–	–	–	–	–
for Female, 1985–2000	–	–	(0.01)	–	–	–	–	–
Log Average GDP per capita,	–0.17	–0.07	–0.34	–0.16	–0.14	–0.18	–0.10	–0.18
1985–2000	(0.13)	(0.14)	(0.12)	(0.13)	(0.14)	(0.18)	(0.10)	(0.17)
Average Infant Mortality,	0.01	0.01	0.02	–	0.01	0.01	0.01	0.01
1985–2000	(0.003)	(0.003)	(0.004)	–	(0.002)	(0.002)	(0.002)	(0.002)
Average Mortality Under	–	–	–	0.01	–	–	–	–
Age 5, 1985–2000	–	–	–	(0.002)	–	–	–	–
Average Urban Population,	–	–	–	–	–0.01	–	–	–
1985–2000	–	–	–	–	(0.03)	–	–	–
Average Secondary School	–	–	–	–	–	0.01	–	–
for Male, 1985–2000	–	–	–	–	–	(0.02)	–	–
Average Population age 65	– –	–	–	–	–	–	–0.27	–
and above, 1985–2000	–	–	–	–	–	–	(0.16)	–
Average Adult Mortality,	–	–	–	–	–	–	–	–0.01
1985–2000	–	–	–	–	–	–	–	(0.02)
R^2	0.77	0.75	0.75	0.76	0.76	0.77	0.77	0.79
N	41	41	41	41	41	41	41	41

Notes: Heteroscedasticity consistent (White correction) standard errors are in parentheses. All regressions include a constant and are estimated by OLS. Base sample is 41 countries out of 44 countries. Omitted countries are Equatorial Guinea, Seychelles (due to missing observations in schooling variables) and Madagascar (outlier). See table 3 for the detailed explanation of the variables.

Table 6: Fertility in a Cross-Section of Countries: Perceptions

Dependent variable is Average Total Fertility Rate, 1985–2000

	(1)	(2)	(3)	(4)	(5)
Heard of HIV/AIDS,	0.02	–	–	–	–
1988–2000	(0.007)	–	–	–	–
Know someone died of AIDS,	–	0.02	0.02	0.02	0.02
1993–2000	–	(0.01)	(0.004)	(0.007)	(0.004)
Average Secondary School	–0.02	–	–	–	–
for Female, 1985–2000	(0.008)	–	–	–	–
Log Average GDP per capita,	–0.04	–	–0.70	–	–0.45
1985–2000	(0.17)	–	(0.13)	–	(0.17)
Average Infant Mortality,	0.01	–	–	0.03	0.01
1985–2000	(0.004)	–	–	(0.005)	(0.005)
R^2	0.75	0.26	0.82	0.78	0.88
N	30	12	12	12	12

Notes: Heteroscedasticity consistent (White correction) standard errors are in parentheses. All regressions include a constant and are estimated by OLS. The data on percent female between 15-49 who heard of HIV/AIDS and percent female who know someone personally who has the virus that causes AIDS or has died of AIDS are both from DHS. They are averaged according to the available survey years. See table 3 for the detailed explanation of the variables.

Table 7: Fertility in a Cross-Section of Countries: AIDS in 1985

Dependent variable is Total Fertility Rate in 2000

	Base Sample (1)	Base Sample (2)	Base Sample (3)	Base Sample (4)	Base Sample (5)	Base Sample (6)	Base Sample (7)	Base Sample (8)	Available Sample (9)
Log AIDS Incidence	0.10	–	0.10	0.11	0.10	0.11	0.11	0.11	0.11
in 1985	(0.05)	–	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)
Log HIV Prevalence	–	0.18	–	–	–	–	–	–	–
in 1985	–	(0.06)	–	–	–	–	–	–	–
Secondary School	–0.002	–0.004	–	–0.01	–0.01	–0.01	–0.01	–0.01	–0.01
for Female in 1985	(0.01)	(0.01)	–	(0.05)	(0.05)	(0.05)	(0.17)	(0.18)	(0.10)
Primary School	–	–	0.01	–	–	–	–	–	–
for Female in 1985	–	–	(0.05)	–	–	–	–	–	–
Log GDP per capita	–0.23	–0.10	–0.27	–0.21	–0.19	–0.23	–0.20	–0.23	–0.23
in 1985	(0.14)	(0.14)	(0.11)	(0.21)	(0.l20)	(0.20)	(0.19)	(0.22)	(0.22)
Infant Mortality	0.02	0.02	0.02	–	0.02	0.02	0.02	0.01	0.01
in 1985	(0.004)	(0.004)	(0.004)	–	(0.004)	(0.004)	(0.004)	(0.002)	(0.002)
Mortality	–	–	–	0.01	–	–	–	–	–
Age 5 in 1985	–	–	–	(0.004)	–	–	–	–	–
Urban Population	–	–	–	–	–0.01	–	–	–	–
in 1985	–	–	–	–	(0.02)	–	–	–	–
Secondary School	–	–	–	–	–	0.01	–	–	–
for Male in 1985	–	–	–	–	–	(0.01)	–	–	–
Population age 65	– –	–	–	–	–	–	–0.10	–	–
and above in 1985	–	–	–	–	–	–	(0.13)	–	–
Adult Mortality	–	–	–	–	–	–	–	–0.01	–
in 1985	–	–	–	–	–	–	–	(0.02)	
Contraceptive Use	–	–	–	–	–	–	–	–	–0.03
in 2000	–	–	–	–	–	–	–	–	(0.013)
R^2	0.68	0.71	0.68	0.69	0.67	0.68	0.70	0.69	0.81
N	41	41	41	41	41	41	41	41	27

Notes: Heteroscedasticity consistent (White correction) standard errors are in parentheses. All regressions include a constant and are estimated by OLS. The last column adds contraceptive use, which is only available for 27 countries in 2000. See table 3 for the detailed explanation of the variables.

Table 8: Fertility in a Panel of Countries

Dependent variable is Total Fertility Rate

	Base Sample (1)	Base Sample (2)	Base Sample (3)	Base Sample (4)	Base Sample (5)	Base Sample (6)	Base Sample (7)	Base Sample (8)	Base Sample (9)	Base Sample (10)
	OLS	OLS	OLS	OLS	WLS	WLS	WLS	WLS	WLS	WLS
Country Fixed Effects	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Time Trend	–0.09	–0.07	–0.10	–0.08	–0.10	–0.08	–0.09	–0.08	–0.09	–0.09
	(0.01)	(0.01)	(0.01)	(0.01)	(0.005)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Log AIDS	0.07	–	0.03	–	0.07	–	0.02	–	0.02	0.02
Incidence	(0.02)	–	(0.01)	–	(0.01)	–	(0.006)	–	(0.006)	(0.006)
Log HIV	–	0.08	–	–0.03	–	0.06	–	–0.02	–	–
Prevalence	–	(0.02)	–	(0.03)	–	(0.01)	–	(0.02)	–	–
Secondary School	–0.02	–0.02	–0.001	–0.001	–0.02	–0.02	–0.004	–0.003	–	–0.004
for Female	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.001)	(0.001)	–	(0.001)
Primary School	–	–	–	–	–	–	–	–	–0.003	–
for Female	–	–	–	–	–	–	–	–	(0.001)	–
Log GDP	–0.15	–0.09	–0.21	–0.18	–0.16	–0.16	–0.23	–0.21	–0.22	–0.22
per capita	(0.05)	(0.05)	(0.07)	(0.06)	(0.03)	(0.03)	(0.05)	(0.04)	(0.05)	(0.05)
Infant Mortality	0.01	0.01	0.001	0.002	0.01	0.01	0.001	0.001	0.001	–
	(0.001)	(0.001)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001	(0.001))	(0.01)	–
Mortality Under	–	–	–	–	–	–	–	–	–	0.001
Age 5	–	–	–	–	–	–	–	–	–	(0.01)
R^2	0.73	0.74	0.79	0.78	0.73	0.73	0.78	0.79	0.78	0.78
N	228	228	228	228	228	228	228	228	228	228

Notes: Heteroscedasticity consistent (White correction) standard errors are in parentheses. The regressions have a constant term if they do not have country fixed effects. The WLS, "Weighted LS," is a 2-step estimation where all observations are weighted in the second step with the inverse of the estimated standard deviations from the first step. Specifications are estimated with 38 countries and 6 years (Missing observations in the schooling variables are Equatorial Guinea, Seychelles and the year 1987; outliers are CongoRep, Kenya, Madagascar, Mauritius). See table 3 for the detailed explanation of the variables.

Table 9: Fertility in a Panel of Countries: Robustness

Dependent variable is Total Fertility Rate

	Base Sample (1)	Base Sample (2)	No Rich (3)	Base Sample (4)	Base Sample (5)	Base Sample (6)	Base Sample (7)	Whole Africa (8)	No South Africa (9)
	WLS	WLS	WLS	WLS	WLS	WLS	WLS	WLS	WLS
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	No	No	No	No	No	No	No	No
Time Trend	–	–0.09	–0.09	–0.09	–0.09	–0.09	–0.09	–0.09	–0.09
	–	(0.002)	(0.002)	(0.004)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)
Time Trend^2	–	–0.001	–	–	–	–	–	–	–
	–	(0.001)	–	–	–	–	–	–	–
Log AIDS Incidence	0.01	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02
	(0.004)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)
Secondary School for Female	–0.004	–0.004	–0.002	–0.004	–0.02	–0.005	–0.003	–	–
	(0.002)	(0.001)	(0.003)	(0.002)	(0.005)	(0.001)	(0.002)	–	–
Log GDP per capita	–0.20	–0.21	–0.08	–0.21	–0.26	–0.22	–0.23	–0.16	–0.16
	(0.04)	(0.04)	(0.007)	(0.04)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)
Urban Population	–	–	–	0.008	–	–	–	–	–
	–	–	–	(0.01)	–	–	–	–	–
Secondary School for Male	–	–	–	–	0.02	–	–	–	–
	–	–	–	–	(0.01)	–	–	–	–
Population age 65 and above	–	–	–	–	–	–0.008	–	–	–
	–	–	–	–	–	(0.04)	–	–	–
Adult Mortality	–	–	–	–	–	–	–0.001	–	–
	–	–	–	–	–	–	(0.001)	–	–
R^2	0.30	0.78	0.78	0.78	0.76	0.79	0.78	0.78	0.78
N	228	228	198	228	228	228	228	280	273

Notes: Heteroscedasticity consistent (White correction) standard errors are in parentheses. Specification in column (3) is estimated with 33 countries that have GDP per capita levels below the sample average and 6 years. Specification in column (8) is estimated with all the available data (minus outliers): 40 countries and 7 years. Specification in column (9) is estimated without South Africa: 39 countries and 7 years. See table 3 for the detailed explanation of the variables.

Table 10: Human Capital Investment in a Panel of Countries

Dependent variable is Gross Primary School Enrollment

	Base Sample (1)	Base Sample (2)	Base Sample (3)	Base Sample (4)	Base Sample (5)
	OLS	OLS	WLS	WLS	WLS
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes
Time Trend	2.50	1.17	2.18	0.96	2.18
	(0.56)	(0.47)	(0.26)	(0.22)	(0.24)
Log AIDS Incidence	–5.04	–	–4.25	–	–3.93
	(1.16)	–	(0.63)	–	(0.58)
Log HIV Prevalence	–	–3.83	–	–2.11	–
	–	(2.09)	–	(1.04)	–
Log GDP per capita	24.64	20.52	26.79	19.64	25.90
	(8.00)	(8.54)	(5.56)	(5.16)	(5.36)
Infant Mortality	–1.19	–1.09	–0.92	–0.71	–
	(0.25)	(0.25)	(0.13)	(0.10)	–
Mortality Under	–	–	–	–	–0.48
Age 5	–	–	–	–	(0.06)
R^2	0.32	0.26	0.32	0.28	0.50
N	228	228	228	228	228

Notes: Heteroscedasticity consistent (White correction) standard errors are in parentheses. See table 3 for the detailed explanation of the variables.

Table 11: Human Capital Investment in a Panel of Countries: Robustness

Dependent variable is Gross Primary or Secondary School Enrollment

	Base Sample (1)	Base Sample (2)	Base Sample (3)	Base Sample (4)	Base Sample (5)	Base Sample (6)	No Rich (7)
	WLS	WLS	WLS	WLS	WLS	WLS	WLS
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	No	No	No	No	No	No
Dependent Var.	Primary	Primary	Primary	Primary	Primary	Secondary	Primary
Time Trend	–	2.21	2.30	2.18	2.30	0.74	2.46
	–	(0.26)	(0.38)	(0.30)	(0.27)	(0.17)	(0.30)
Time Trend^2	–	0.04	–	–	–	–	–
	–	(0.02)	–	–	–	–	–
Log AIDS Incidence	–2.25	–4.22	–4.64	–4.44	–4.47	–0.80	–2.43
	(1.05)	(0.61)	(0.64)	(0.67)	(0.61)	(0.40)	(0.61)
Log GDP per capita	19.55	26.99	28.74	26.99	28.24	5.89	20.37
	(5.10)	(5.36)	(5.82)	(5.92)	(5.86)	(2.65)	(6.28)
Infant Mortality	–1.10	–0.93	–0.95	–0.98	–0.87	–0.11	–0.03
	(0.09)	(0.10)	(0.15)	(0.12)	(0.14)	(0.11)	(0.24)
Urban Population	–	–	0.16	–	–	–	–
	–	–	(0.36)	–	–	–	–
Population age 65 and above	–	–	–	–11.95	–	–	–
	–	–	–	(3.67)	–	–	–
Adult Mortality	–	–	–	–	–0.01	–	–
	–	–	–	–	(0.01)	–	–
R^2	0.50	0.60	0.59	0.59	0.60	0.25	0.59
N	228	228	228	228	228	192	198

Notes: Notes: Heteroscedasticity consistent (White correction) standard errors are in parentheses. Specification in column (6) is estimated with 32 countries and 6 years. The outliers for this column that are omitted from the base sample are Botswana, Ghana, Namibia, South Africa, Swaziland, Zimbabwe. Specification in column (7) is estimated with 33 countries that have GDP per capita levels below the sample average and 6 years. See table 3 for the detailed explanation of the variables.

Table 12: Instrumental Variable Regressions

Dependent variable:	Average Fertility Rate 1985–2000	Average Fertiltiy Rate 1985–2000	Fertility Rate	Gross Primary School Enrollment
	(1)	(2)	(3)	(4)
Time Trend	–	–	–0.14	9.01
	–	–	(0.03)	(2.91)
Log Average AIDS Incidence,	0.13	0.60	–	–
1985–2000	(0.08)	(0.31)	–	–
Log AIDS Incidence	–	–	0.09	–10.25
	–	–	(0.05)	(5.93)
Average Secondary School	–0.02	–0.03	–	–
for Female, 1985–2000	(0.01)	(0.02)	–	–
Secondary School	–	–	–0.001	–
for Female	–	–	(0.001)	–
Log Average GDP per capita,	–0.12	–0.04	–	–
1985–2000	(0.12)	(0.3)	–	–
Log GDP per capita	–	–	0.24	20.74
	–	–	(0.26)	(4.67)
Average Infant Mortality,	0.01	0.02	–	–
1985–2000	(0.003)	(0.006)	–	–
Infant Mortality	–	–	–0.01	–1.25
	–	–	(0.01)	(0.56)
R^2	0.70	0.34	0.82	0.10
Countries	40	17	21	21
Time	1	1	3	3
N	40	17	63	63
Instrument	circumcision	STD, premarital	premarital	premarital

Notes: Heteroscedasticity consistent (White correction) standard errors are in parentheses. Columns (1) and (2) are cross country regressions with a constant, columns (3) and (4) are panel regressions with a country fixed effect. All columns are estimated by 2SLS. "Circumcision" is the percent of male between ages 15–59 who are circumcised from Werker et al. (2006). "STD" is the percent of female between ages 15–49 who has a sexually transmitted disease and not treated, averaged over 1995–2005 depending on the survey year. "Premarital" is the percent of female between ages 15–29 who has premarital sex, averaged over 1985–2005. Both of these data are from DHS. See table 3 for the detailed explanation of the variables.

Table 13: Fertility in a Cross-Section of Regions

Dependent variable is Total Fertility Rate in 1998–2004

	Pooled OLS (1)	Pooled OLS (Weighted) (2)	Pooled OLS (3)	Pooled OLS (Weighted) (4)
Log HIV Prevalence, 1985–1990	0.40	0.43	0.28	0.27
	(0.11)	(0.11)	(0.08)	(0.08)
Country Dummies	No	No	Yes	Yes
R^2	0.17	0.26	0.57	0.69
N	41	41	41	41

Notes: Heteroscedasticity consistent (White correction) standard errors are in parentheses. All regressions include a constant and are estimated by OLS. These are pooled regressions with 41 regions from 8 countries. These are the regions with overlapping data on the total fertility rate and HIV prevalence rate. Regional total fertility rate is from demographic health surveys (mean: 4.3, std dev.: 1.5. max: 7.4, min: 1.9). HIV prevalence rates are in percent and come from US Census Bureau, HIV Surveillance Database (2003). This is the percent HIV-1 incidence among pregnant women for each region (mean: 7.9, std dev.: 9.1, max: 46.0, min: 0.1). Each country's survey year falls between 1998–2004 for the TFR. If there is more than 1 survey year during this period than the data are averaged. HIV prevalence rates are available on an annual basis for some countries but not all. These rates are averaged over 1985–1990 or used as a single year during that period depending on the availability. Columns (2) and (4) are estimated by weighted OLS, using weighted data where the weights are the logarithm of regional population from DHS, averaged over the survey years. DHS surveys for the 8 countries are available as follows: Ethiopia (2000), Ghana (1988, 1993, 1998, 2003), Lesotho (2004), Malawi (1992, 2000), Nigeria (1990, 1999, 2003), South Africa (1998), Tanzania (1992, 1996, 1999), Zimbabwe (1988, 1994, 1999).

Figure 1a: Changes in Female Life Expectancy in Selected African Countries with high HIV/AIDS Prevalence, 1950-2000

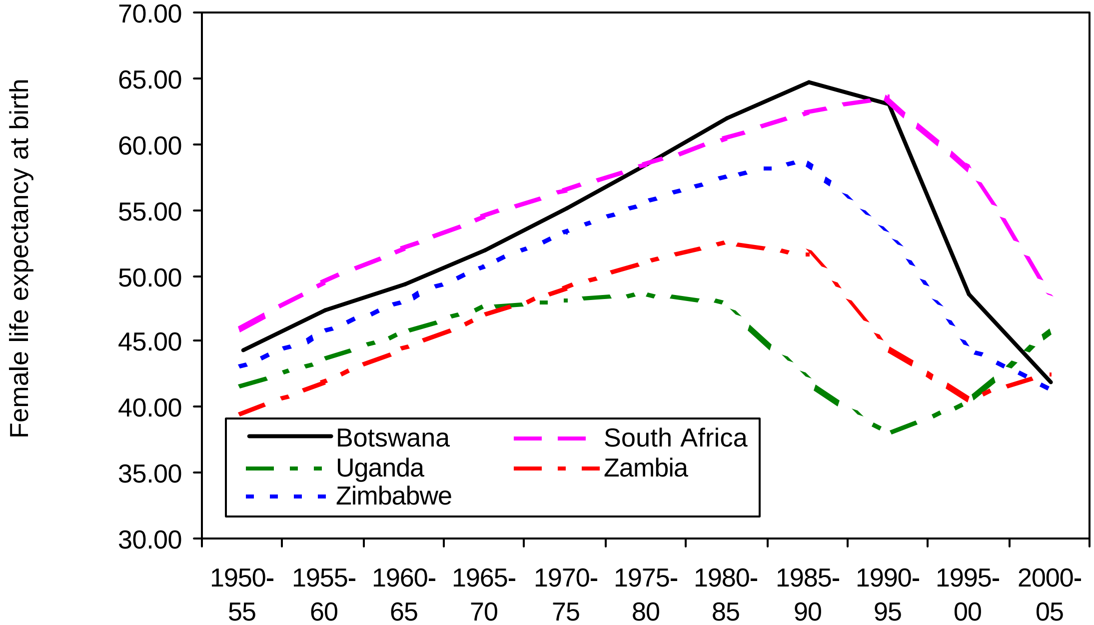
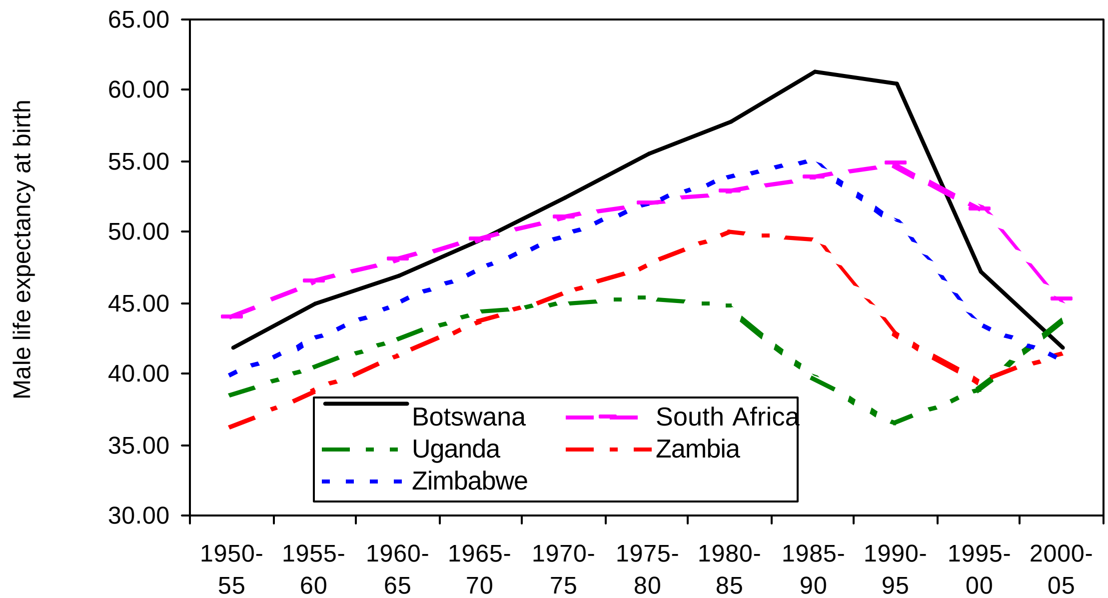


Figure 1b: Changes in Male Life Expectancy in Selected African Countries with high HIV/AIDS Prevalence, 1950-2000



Data: UN, World Population Prospects, 2003.

Figure 2a: AIDS Incidence in Selected African Countries, 1985-2000

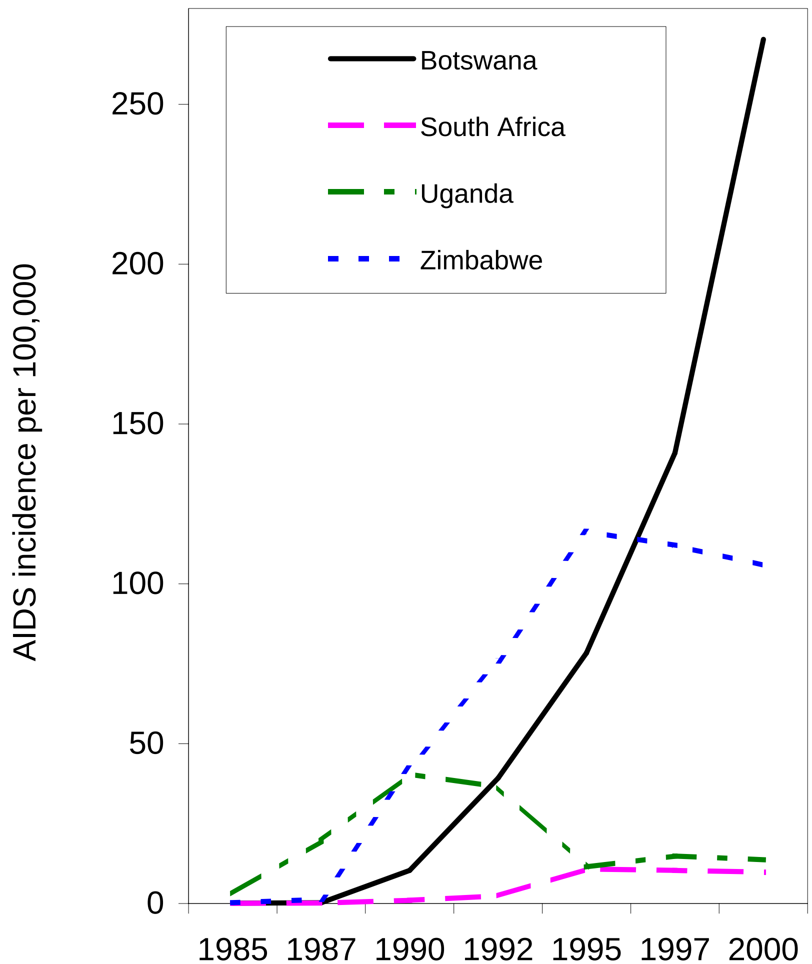
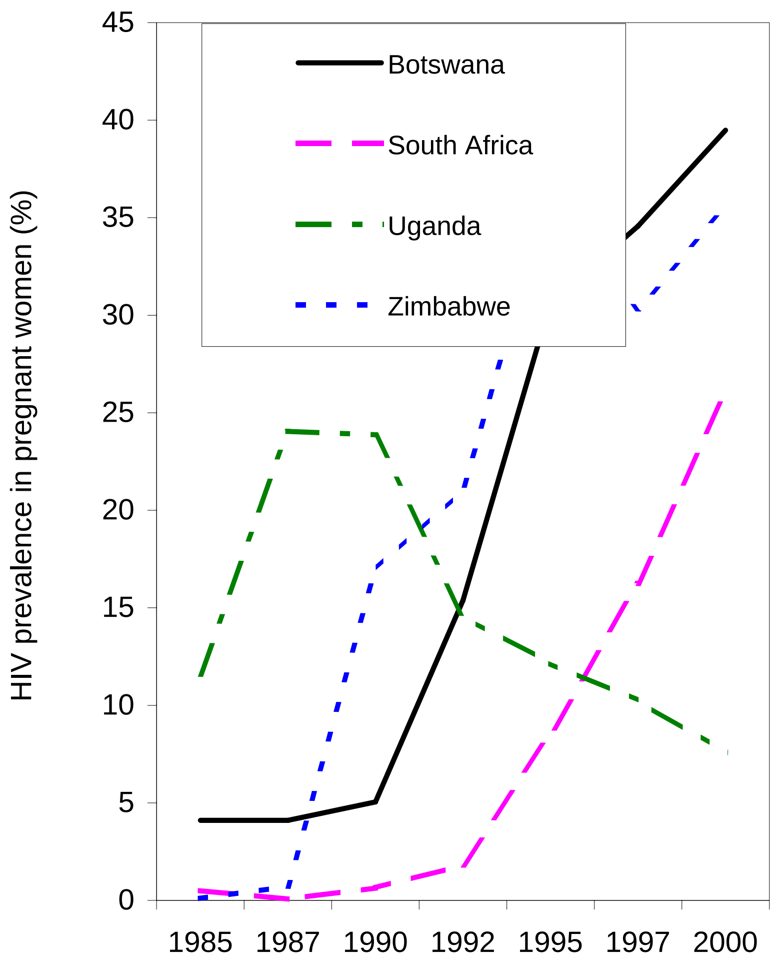
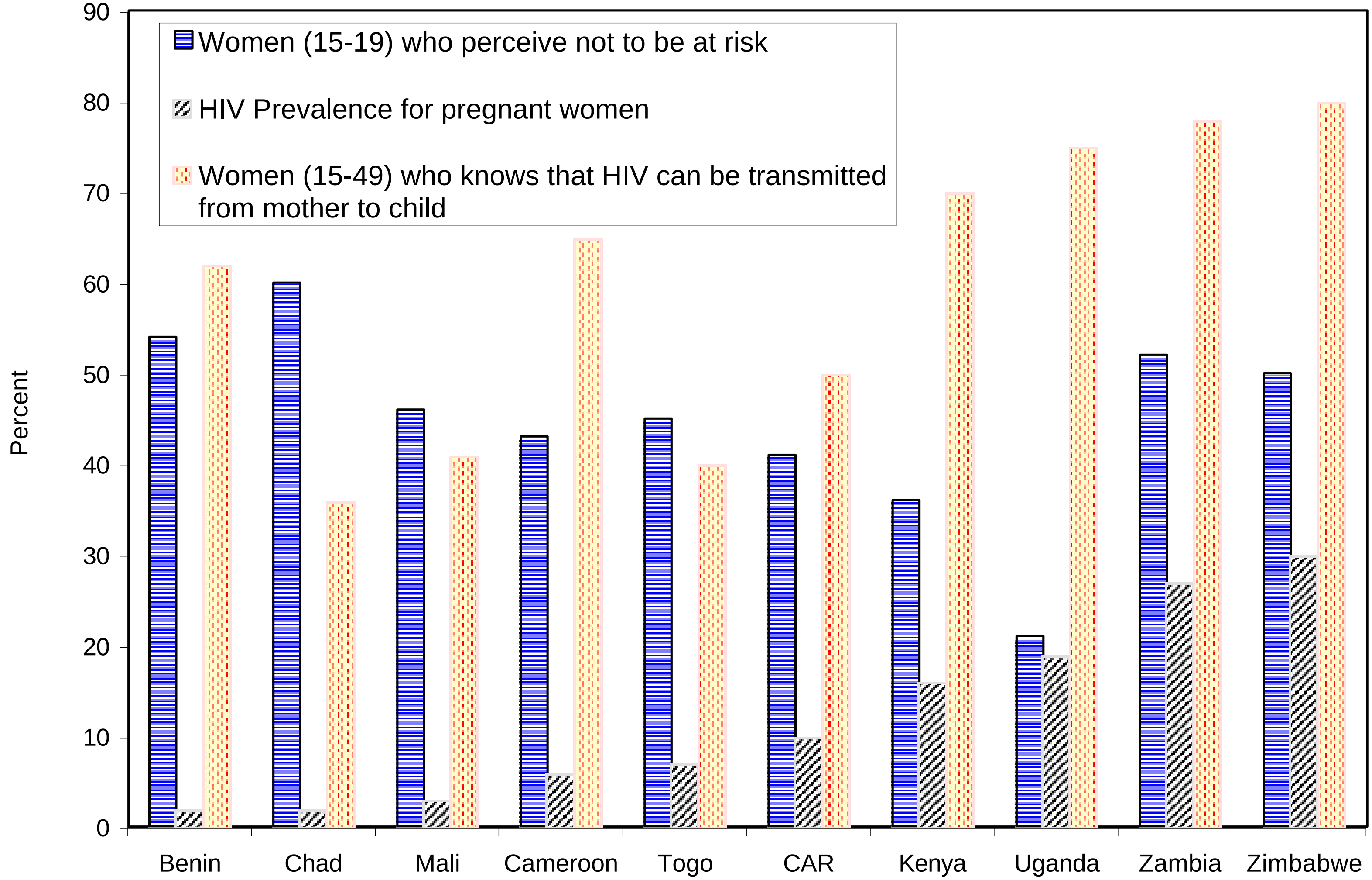


Figure 2b: HIV Prevalence in Selected African Countries, 1985-2000



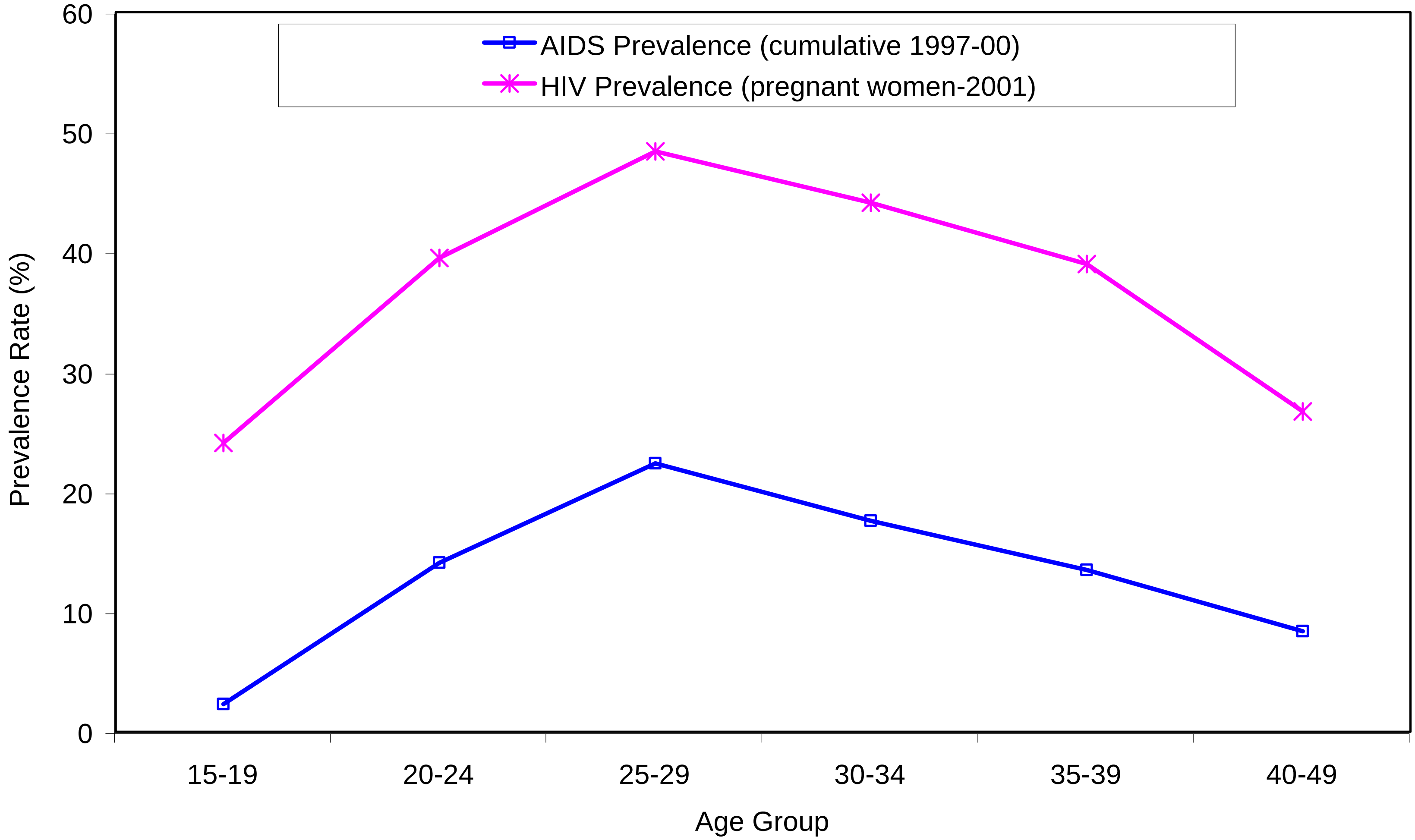
Data: UNAIDS, Epidemiological Fact Sheets, 2003; U.S. Census Bureau, HIV Surveillance Database, 2003.

Figure 3: Risk Perception, DHS Surveys, Selected African Countries, 1994-99



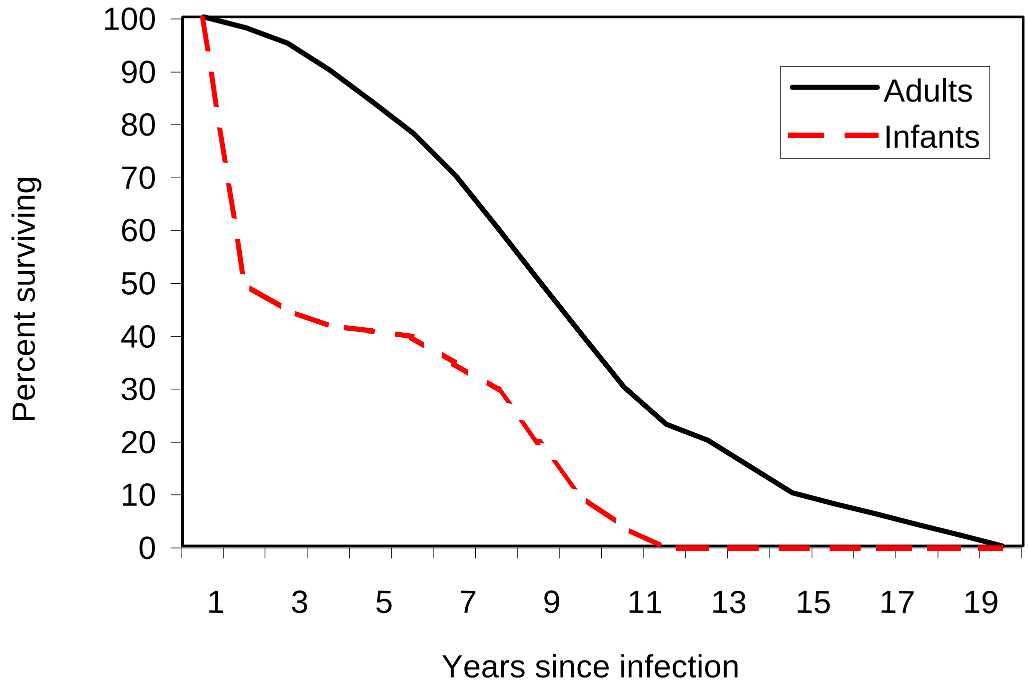
Data: UNAIDS, 2000.

Figure 4: HIV/AIDS Prevalence by Age in Botswana



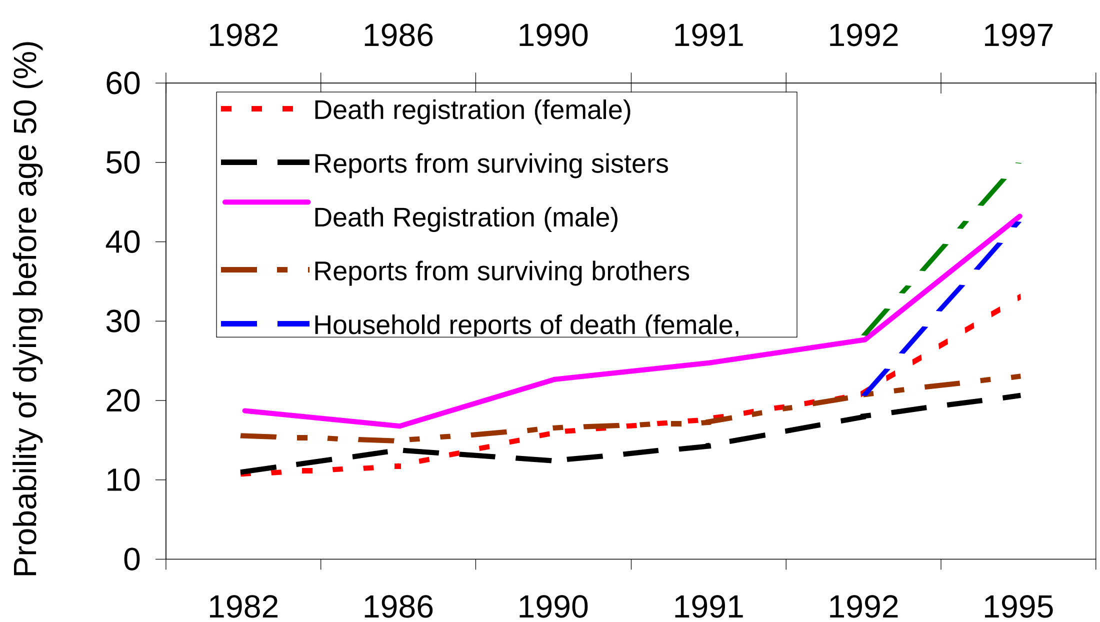
Data: Botswana 2001 HIV Sero-Prevalence Sentinel Survey among Pregnant Women.

Figure 5a: Survival Rates in Low/Mid Income Countries



Data: UNAIDS Reference Group, 2002.

Figure 5b: Probability of a Zimbabwean child aged 15 dying before age 50, 1980-1997, various surveys



Data: Feeney, 2001.

Figure 6a: Total Fertility Rate in Selected African Countries with high HIV/AIDS Prevelance, 1985-2000

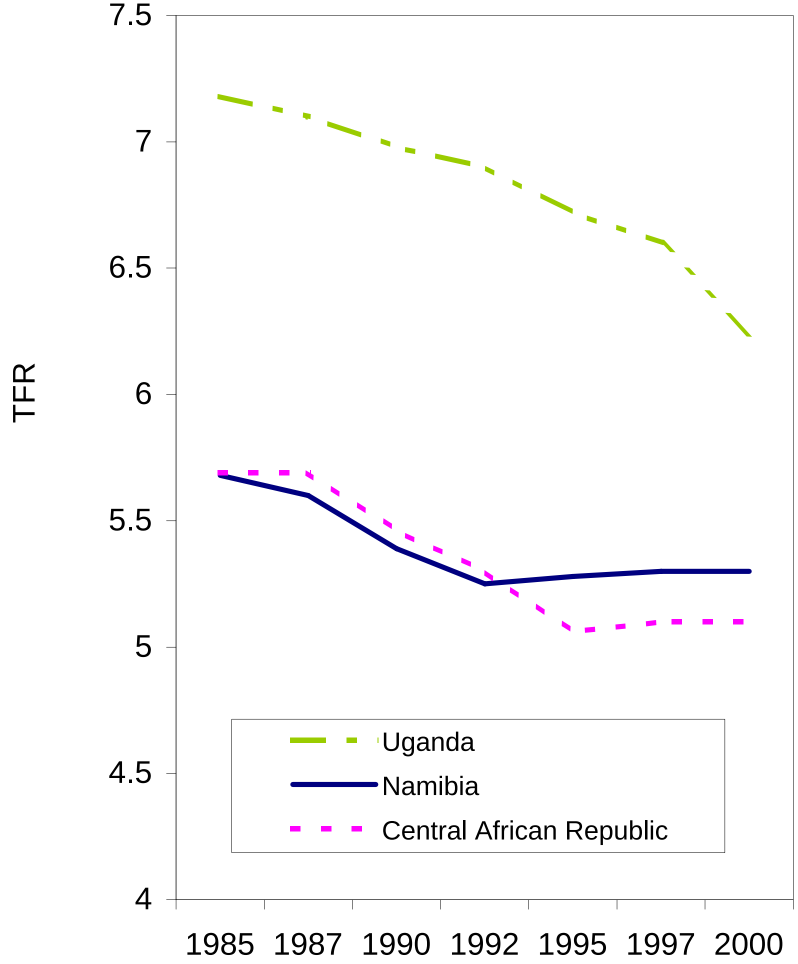
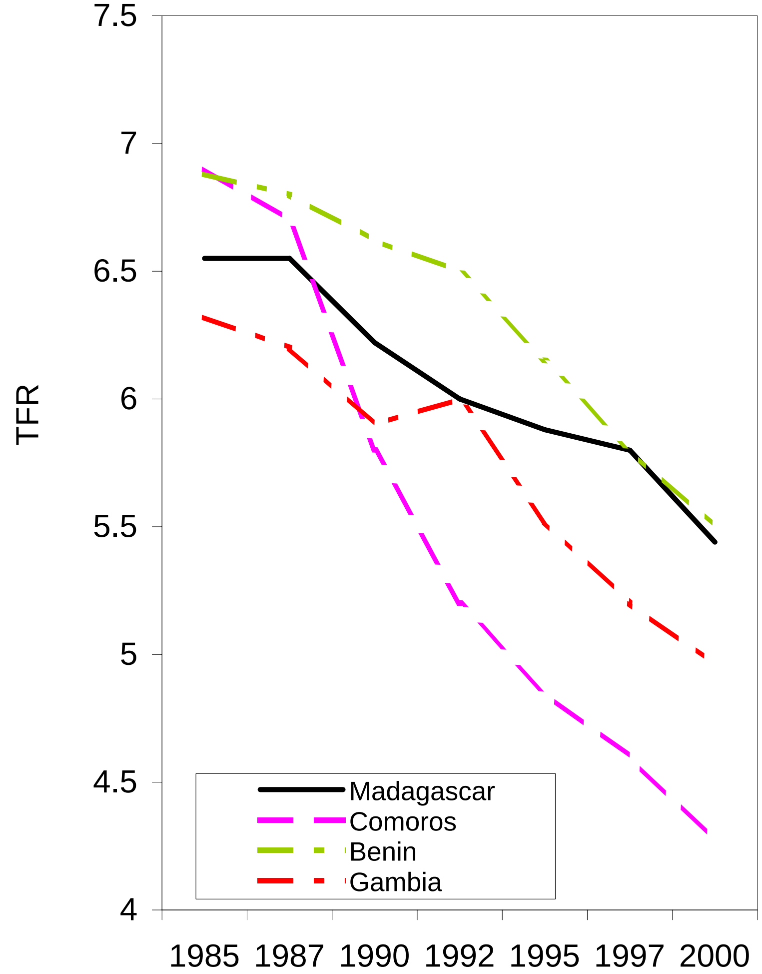


Figure 6b: Total Fertility Rate in Selected African Countries with low HIV/AIDS Prevelance, 1985-2000



Data: World Bank, World Development Indicators, 2003.

Figure 6c: Total Fertility Rate in Selected African Countries with high HIV/AIDS Prevalence, 1983-2004

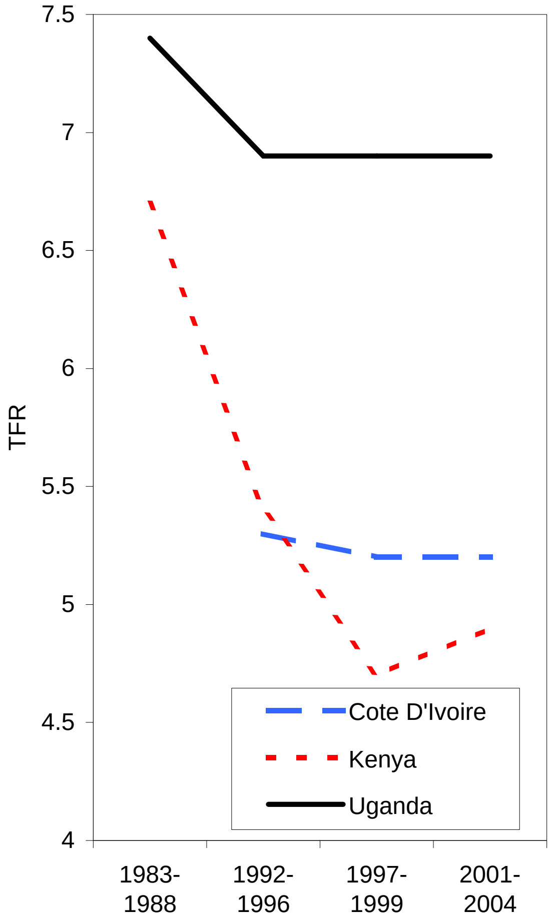


Figure 6d: Total Fertility Rate in Selected African Countries with medium HIV/AIDS Prevalence, 1983-2004

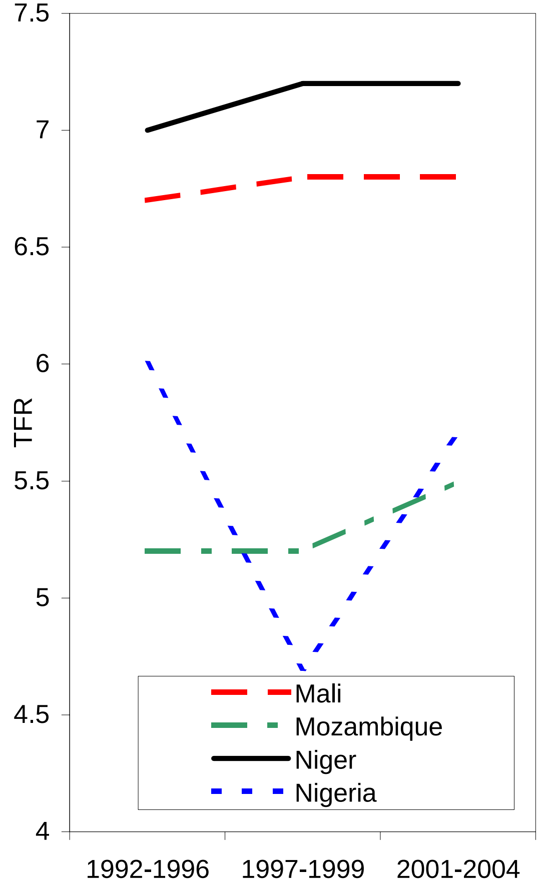
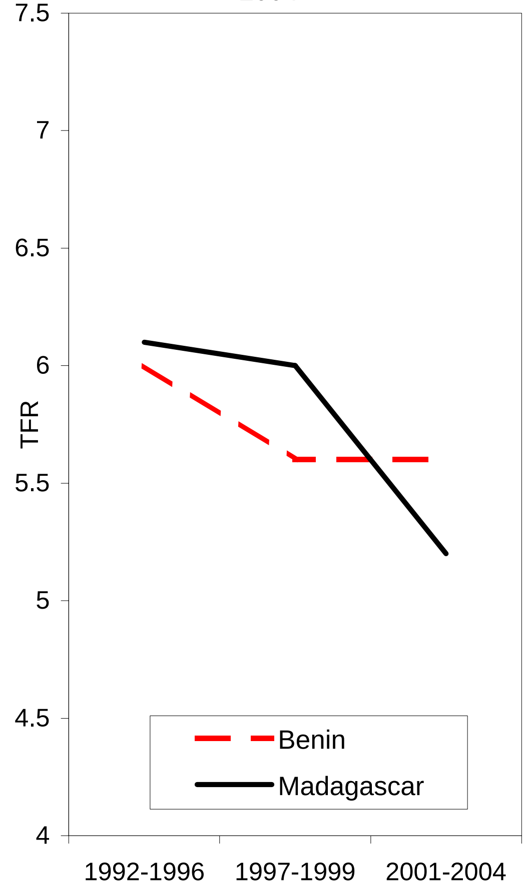


Figure 6e: Total Fertility Rate in Selected African Countries with low HIV/AIDS Prevalence, 1983-2004



Data: DHS data, www.measuredhs.com, MEASURE DHS, Macro International Inc. Each country's survey year falls in the category shown on the x-axis. Specifically Cote D'Ivoire (1994, 1999); Kenya (1989, 1993, 1998, 2003); Uganda (1988, 1995, 2001); Mali (1987, 1996, 2001); Mozambique (1997, 2003); Niger (1992, 1998); Nigeria (1990, 1999), Benin (1996, 2001); Madagascar (1992, 1997, 2004).

Figure 7a: Total Gross Primary School Enrollment in Selected African Countries with high HIV/AIDS Prevelance, 1985-2000

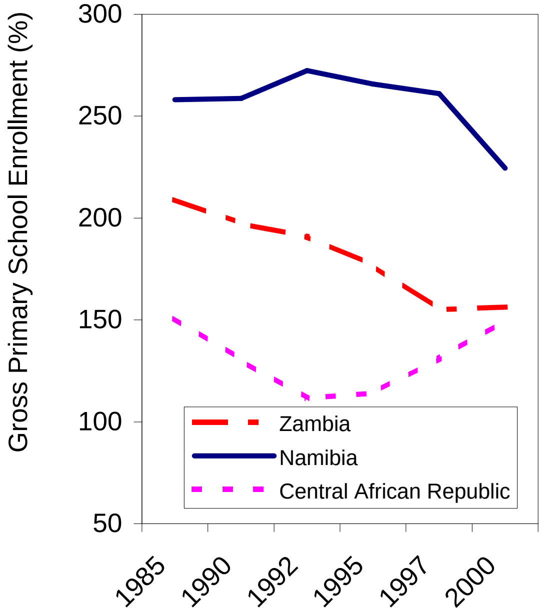


Figure 7b: Total Gross Primary School Enrollment in Selected African Countries with low HIV/AIDS Prevelance, 1985-2000

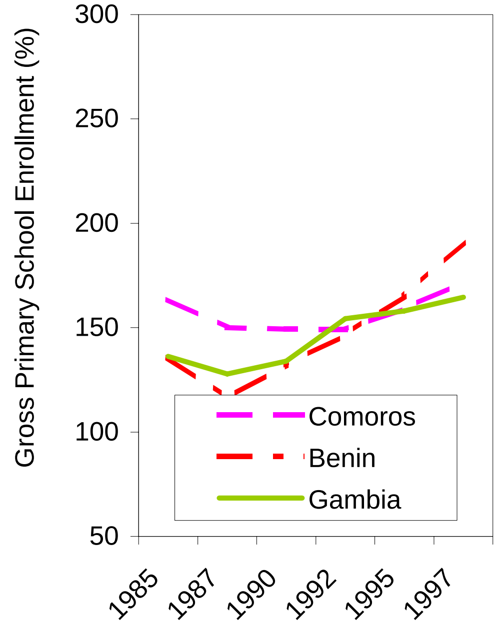


Figure 7c: Total Gross Secondary School Enrollment in Selected African Countries with high HIV/AIDS Prevelance, 1985-2000

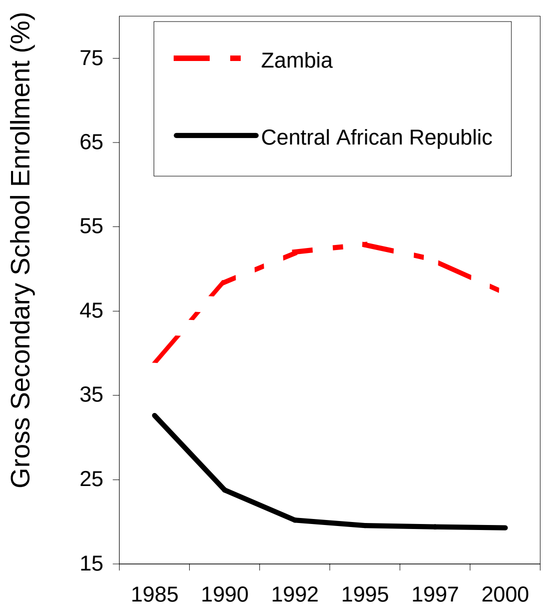
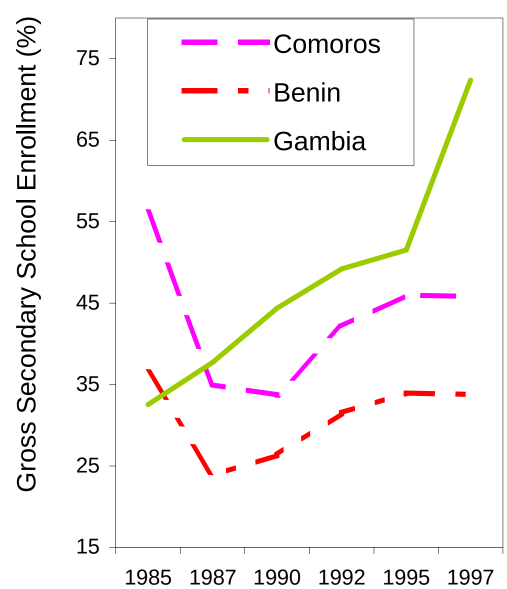
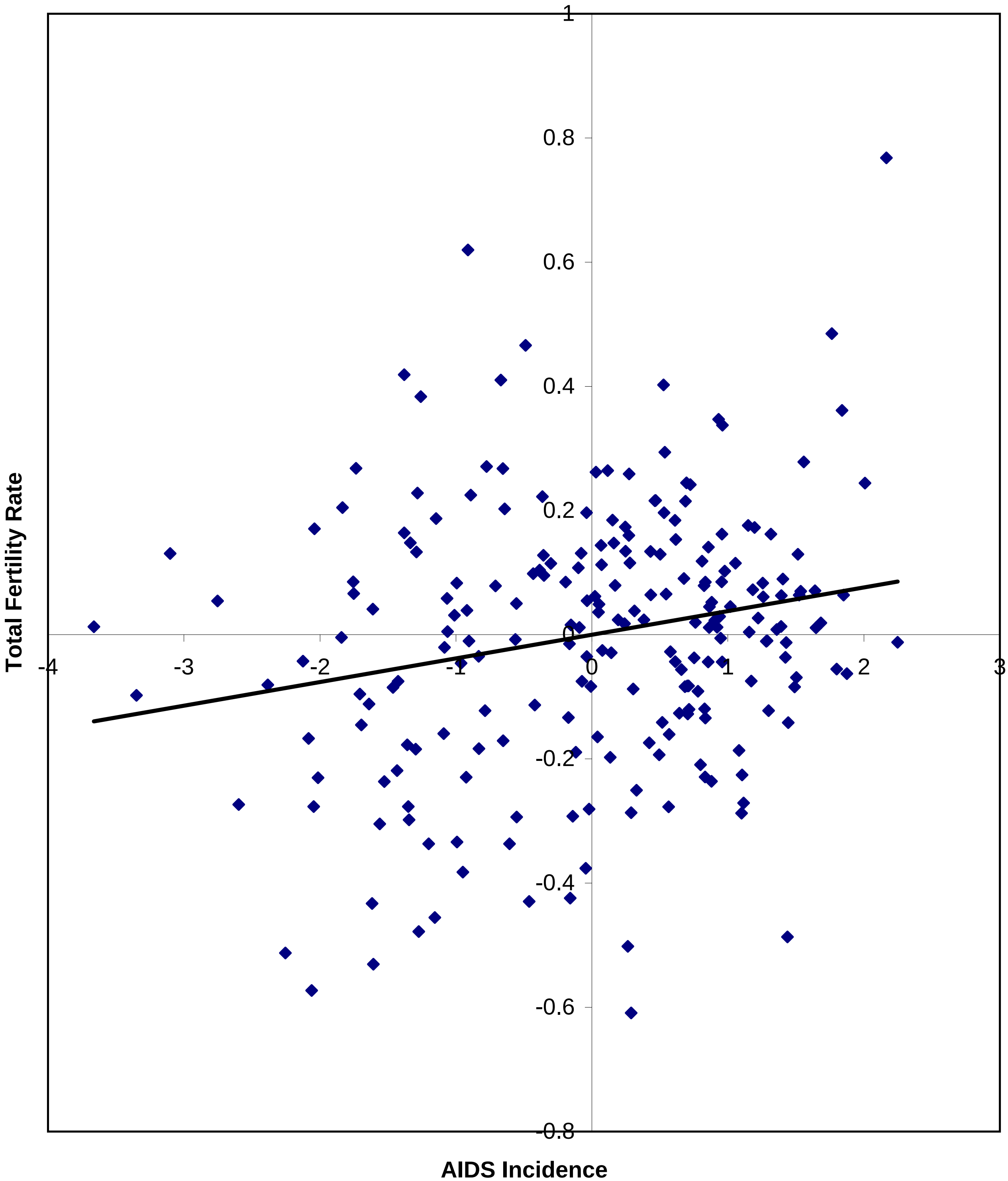


Figure 7d: Total Gross Secondary School Enrollment in Selected African Countries with low HIV/AIDS Prevelance, 1985-2000



Data: World Bank, World Development Indicators, 2003.

Figure 8: Regression of Total Fertility Rate on AIDS Incidence controlling for other regressors



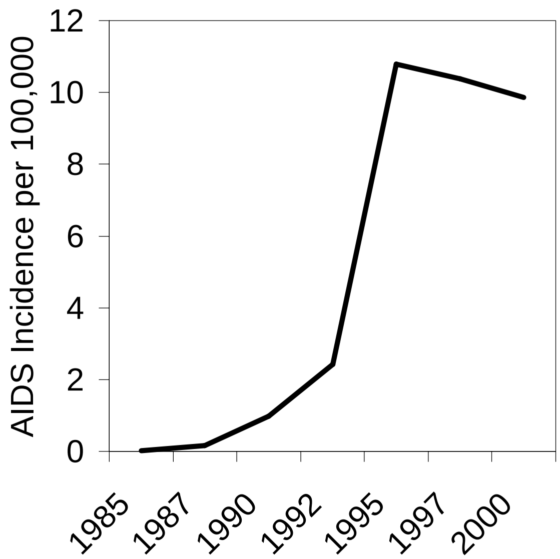


Figure 9a: AIDS Incidence in South Africa, 1985-2000

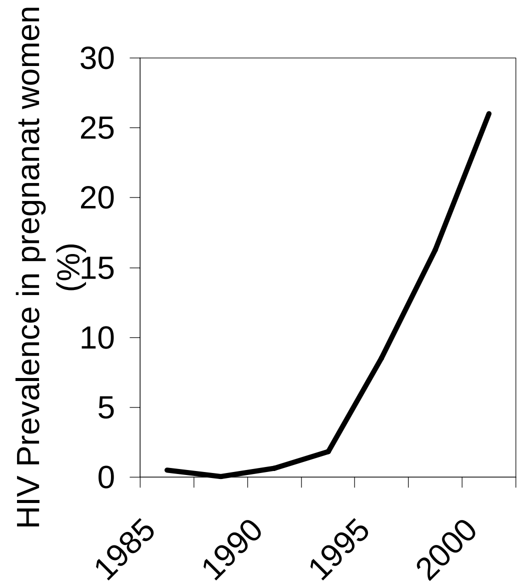


Figure 9b: HIV Prevalence in South Africa, 1985-2000

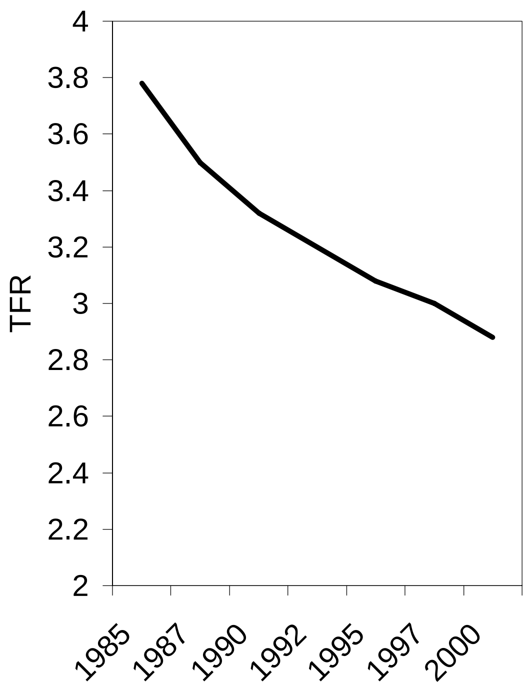


Figure 9c: Total Fertility Rate in South Africa, 1985-2000

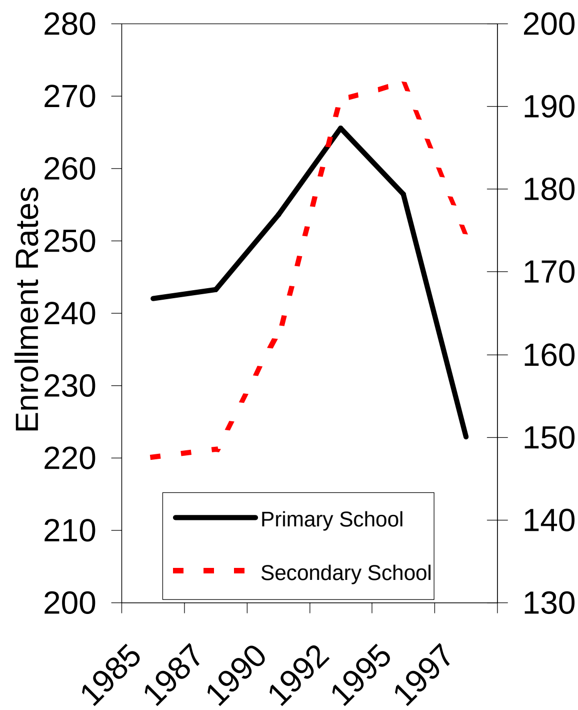


Figure 9d: Total Gross School Enrollment in South Africa, 1985-2000

Figure 10: Total Fertility Rate versus HIV/AIDS Prevalence in South Africa

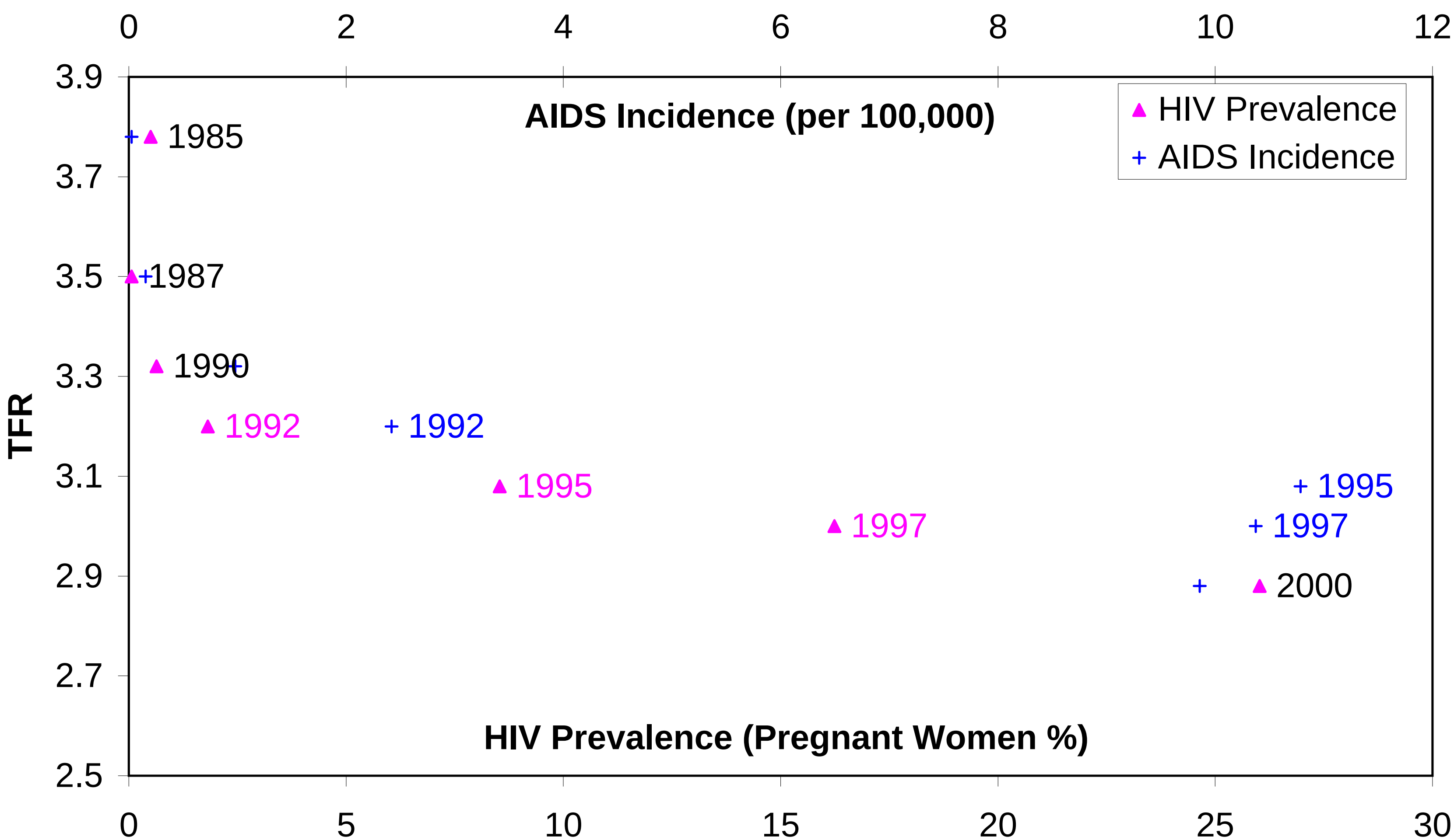


Figure 11a: Total Fertility Rate versus HIV/AIDS Prevalence in Bostwana

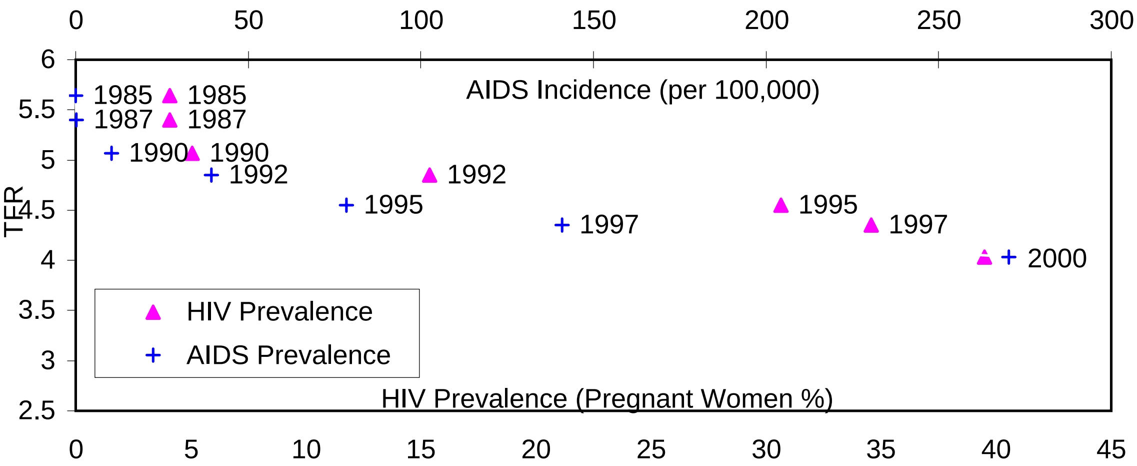


Figure 11b: Total Fertility Rate versus HIV/AIDS Prevalence in Benin

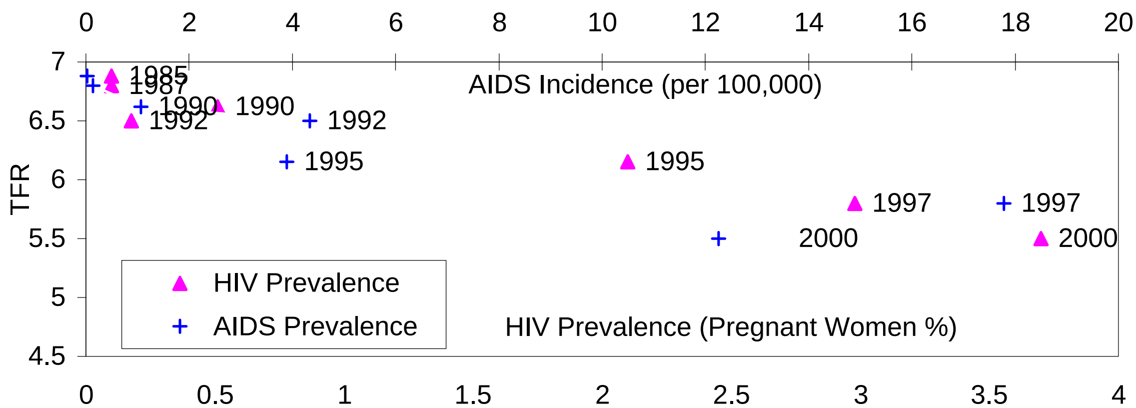


Figure 11c: Total Fertility Rate versus HIV/AIDS Prevalence in Burkina Faso

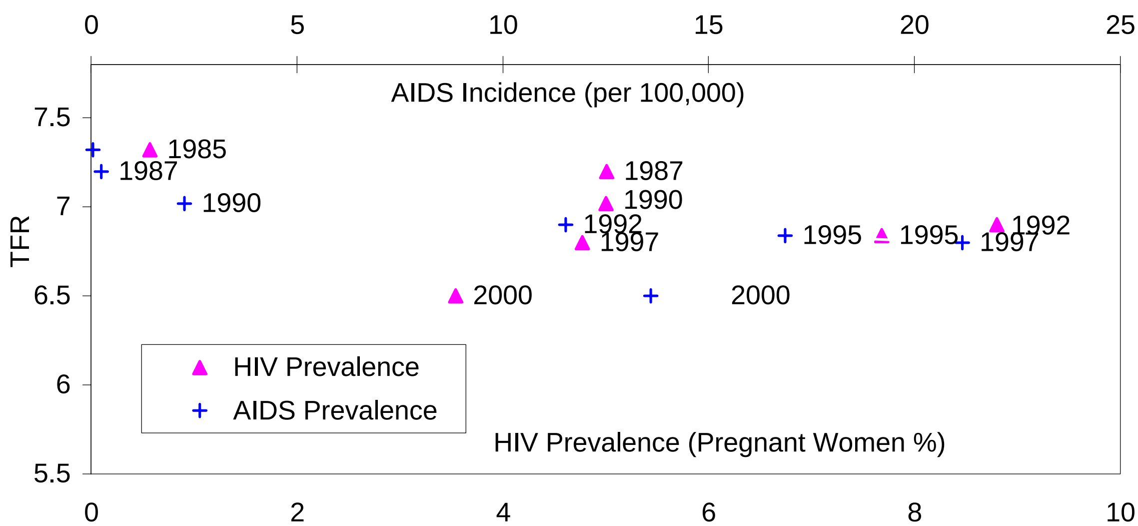


Figure 11d: Total Fertility Rate versus HIV/AIDS Prevalence in Gabon

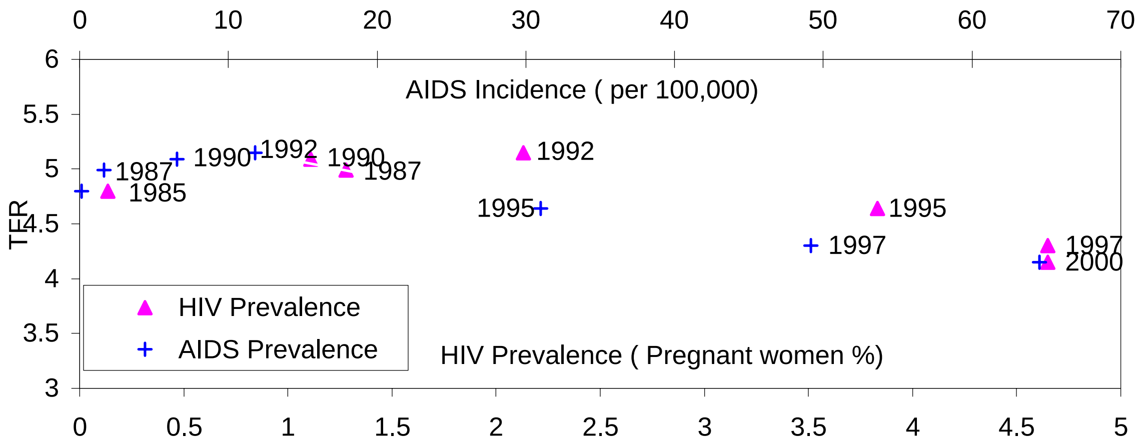


Figure 11e: Total Fertility Rate versus HIV/AIDS Prevalence in Namibia

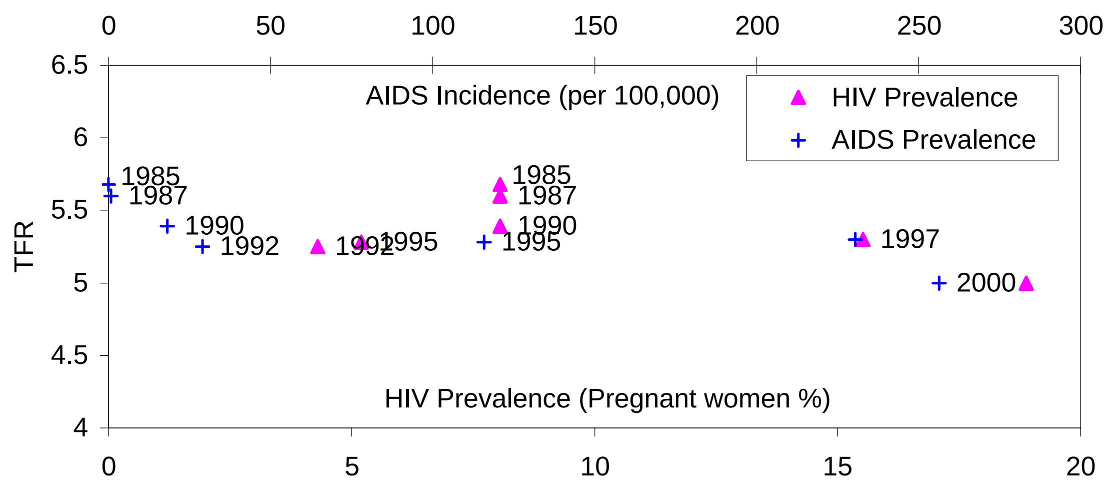


Figure 11f: Total Fertility Rate versus HIV/AIDS Prevalence in Zimbabwe

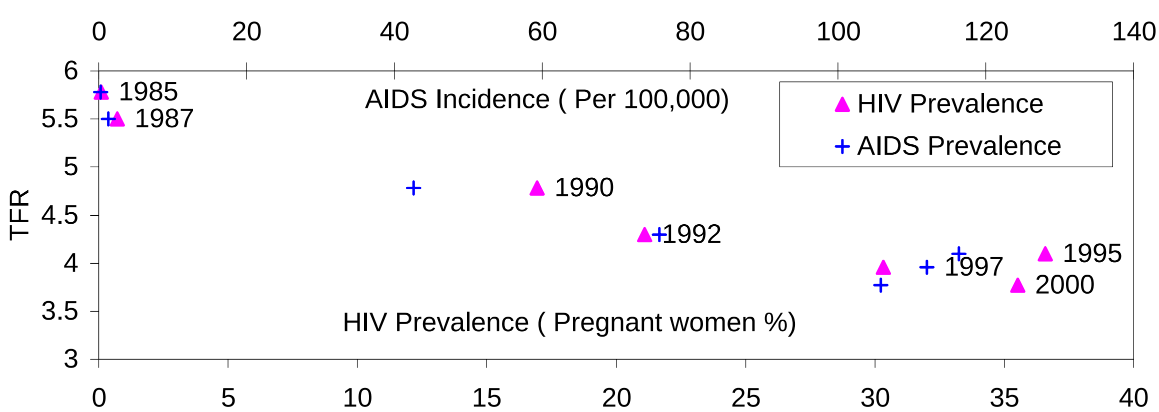


Figure 11g: Total Fertility Rate versus HIV/AIDS Prevalence in Central A

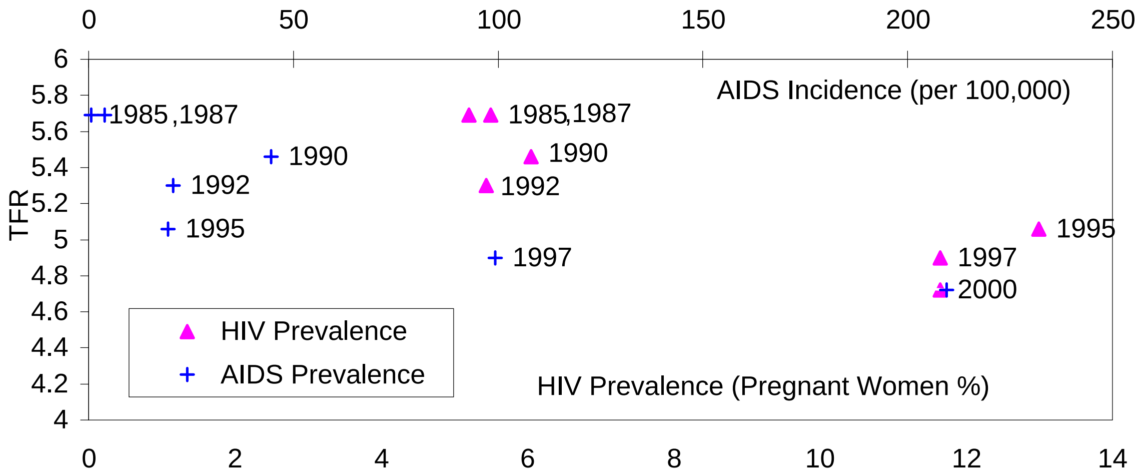


Figure 11h: Total Fertility Rate versus HIV/AIDS Prevalence in Rwanda

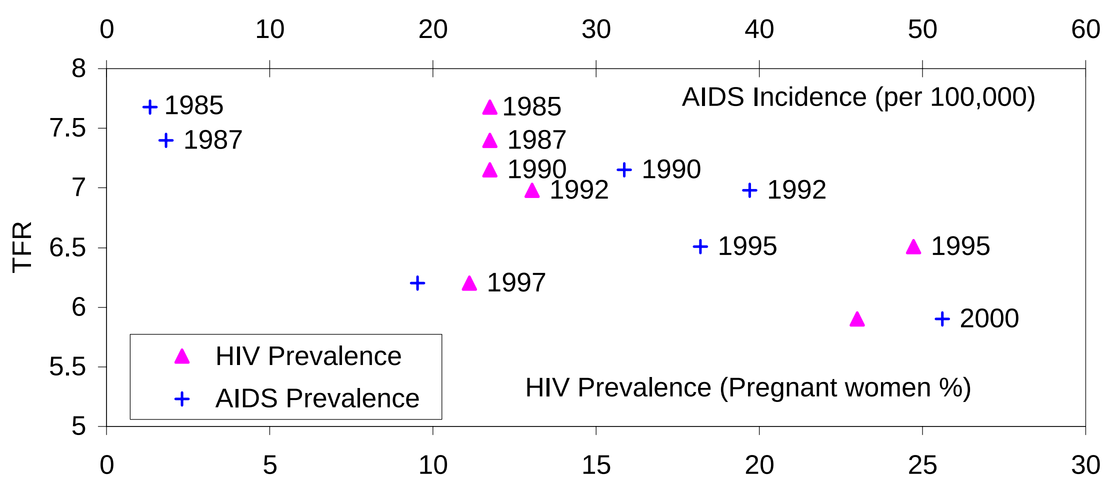


Figure 11j: Total Fertility Rate versus HIV/AIDS Prevalence in Madagascar

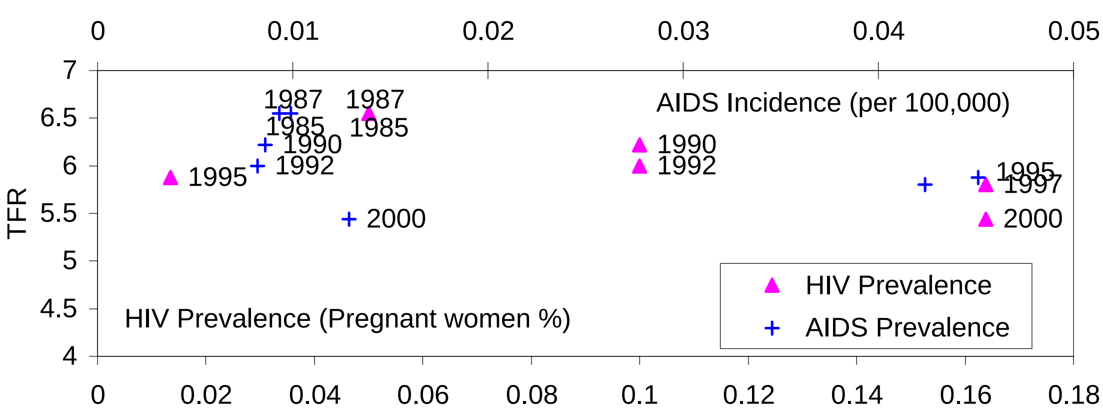


Figure 12: Regression of Human Capital Investment on AIDS Incidence after controlling for other regressors