HIV and Fertility: Long-term Evidence from Sub-Saharan Africa

Günther Fink
Harvard School of Public Health

Sebastian Linnemayr[1]
Harvard School of Public Health

Preliminary version - Please do not cite

This version: September 2008

Abstract

The emergence of HIV/AIDS constitutes the single largest negative health shock to the international health system over the last fifty years. Reducing life expectancy by up to 20 years in some countries, the arrival of HIV/AIDS has resulted in a sharp disruption of the global upward trend in life expectancy, and thus provides a natural study ground for the interactions between health and socioeconomic behavior. In this paper, we focus on one particular dimension of such an interaction: the effect of HIV as a health shock on family size choice. Combining historical micro data from the World Fertility Surveys (WFS) with the most recent rounds of the Demography and Health Surveys (DHS) in a pseudo-panel we find little relation between the onset of HIV and the average changes in fertility on the regional level. These results at the regional level, however, mask important heterogeneity in fertility responses at the individual level that are human-capital-specific: while women with primary school or less increase their fertility in the presence of HIV, the opposite is true for women with secondary or higher education. The arrival of HIV thus further underlines the importance of human capital investment for demographic change on the aggregate level, as well as the role of female education as a determinant of fertility from an individual perspective.

[1] Corresponding author: Center for Population and Development Studies, 9 Bow Street, Cambridge, MA 02138. E-mail: slinnema@hsph.harvard.edu.
The authors are grateful to David Canning, Jocelyn Finlay, Michael Moore, Younghwan Song and the participants of the Population Economics Program (PEP) Lunch Seminar Series for the comments and suggestions.

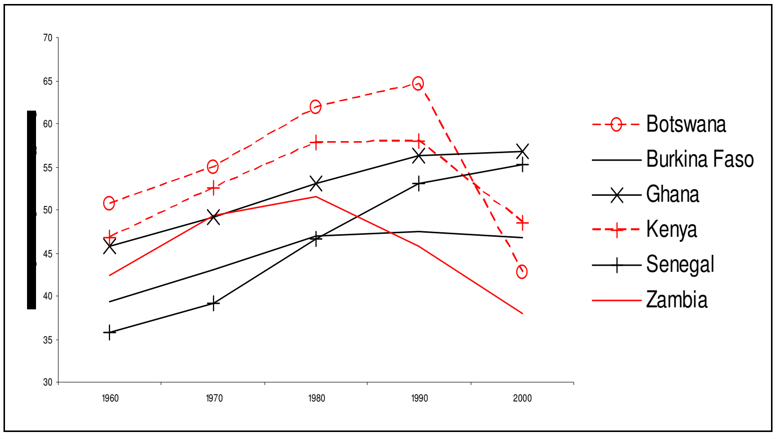
1. Introduction

With its first cases only diagnosed 25 years ago[2], HIV/AIDS has risen to become one of the most salient issues in international health over the last two decades. In 2007, 40 million people were estimated to be HIV-positive worldwide, and an estimated 12 million people have lost their lives to the disease. (UNAIDS, 2008). With its geographical origin in the heart of Sub-Saharan Africa[3], the HIV virus has had devastating effects to population health in many surrounding countries. Countries like Botswana, Kenya and Zambia have experienced reductions in life expectancy of more than 10 years during the 1990s and have seen previous improvements in child mortality vanish within a short period of time (Figures 1a and 1b).

From an analytical perspective, the arrival of HIV/AIDS is not only interesting because it constitutes a striking exception to the global upward trend in health and life expectancy, but also because the relative burden of the disease varies widely within and across countries. While there is still a lot of debate about the relative importance of individual factors for the diffusion of HIV, key determinants frequently cited include geographical distance to the origin of the virus, regional prevalence of circumcision, and differential sexual behavior (Halperin and Bailey, 1999; De Walque, 2006; Werker et al., 2006; Oster, 2008). The correlation between these factors and economic development is not obvious, and has led to strikingly different patterns in health for countries rather similar in terms of their income levels. As Figures 1a and 1b show, low HIV prevalence countries like Burkina Faso and Ghana have continued to see improvements in life expectancy and infant mortality throughout the 90s, while the same health statistics look rather grim for Botswana and Zambia throughout the 1990s. Given these markedly differential trends within and across countries, the arrival of HIV/AIDS constitutes a very interesting natural experiment to investigate the effects of health on socio-economic behavior.

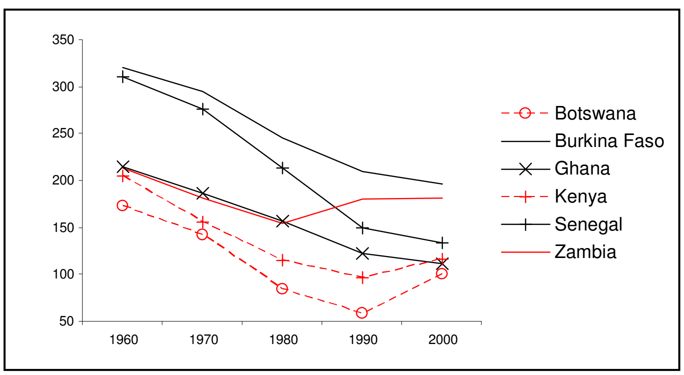
[2] HIV was first recognized and officially listed in the early 1980s (CDC, 1983).
[3] The virus appears to originate from the Democratic Republic of the Congo (Oster, 2008).

Figure 1a: Life expectancy



Source: World Development Indicators 2007 (World Bank, 2007)

Figure 1b: Under-5 mortality rate (deaths per 1.000 live births)



Source: World Development Indicators 2007 (World Bank, 2007)

In this paper, we look at one specific aspect of the interplay between health and demographic outcomes: the change in family size triggered by changes in health. While there is an extensive literature highlighting the negative correlation between health (as measured by child and adult mortality) and fertility in the cross-section of countries and regions[4] (Schultz, 1997), evidence regarding a direct fertility response to changing health at the micro-level is scarce.

[4] The correlation between life expectancy and fertility across countries was -0.81 in 2005 (World Bank, 2007).

In this study, we combine recent data from the Demography and Health Surveys (DHS) with previous waves of the World Fertility Surveys (WFS) to investigate the effects of negative health shocks in the form of HIV/AIDS on reproductive behavior. By linking the original WFS data to the later DHS waves, we are able to compare populations before and after the arrival of the epidemic. In the pseudo-panel compiled, we can identify the effects of health in a standard difference-in-difference framework, controlling for all region-specific factors that are constant over time.

Even though we find a low aggregate correlation between changes in HIV and fertility at the regional level, we find large and highly significant effects of HIV on family size at the individual level once we condition on education. While populations with no education or merely primary education increase their fertility in response to HIV, the opposite is true for populations with secondary or higher education, who reduce their fertility in the presence of HIV. The interaction between education and HIV appears robust to the inclusion of a large set of controls as well as within the various sub-samples of our data and leaves ample room for interpretation. Glick and Sahn (2007) and de Walque (2007) argue that HIV information is more likely to be absorbed by highly educated population groups, since they are more likely to be able to read relevant material, but also more likely to understand the risks associated with the epidemic. An alternative way to interpret our results is to view the heterogeneous response across educational groups as evidence for differential planning horizons or discount rates. Oster (2007) argues that members of higher socio-economic classes are more likely to adjust their risk behavior in the face of HIV due to the larger consumption loss implied by shorter life spans. Along the same lines, one could argue that the highly educated - who generally tend to invest more in child quality than in child quantity (Becker, 1960; Becker, 1981) - face a larger risk of losing a significant share of the investment in their children and thus are more responsive to HIV/AIDS than less educated populations.

The empirical results in this paper contribute to, and partly reconcile, an emerging literature on the effects of HIV on reproductive behavior. While Young's seminal work on the socioeconomic effects of the HIV epidemic finds a negative correlation between

HIV prevalence and fertility (Young, 2005), two recent studies by Kalemli-Oczan and coauthors argue that the fertility response to HIV is zero or positive as predicted by traditional hoarding models (Kalemli-Ozcan, 2006; Juhn et al., 2008). The existing studies rely either on country level variation over time or cross-sectional variation at a given point of time. The approach chosen in this paper allows us to explore both variation within countries and across time, and is to our knowledge the first paper to investigate the interactions between health and human capital and their implications for long-term fertility change in a Sub-Saharan African setting.

The analysis presented in this paper also contributes to an extensive literature on the socioeconomic effects of health in general, and HIV/AIDS in particular. Early economic studies such as Cuddington (1993) have argued for a relatively mitigated, or even positive, impact of the epidemic on economic growth, as a population that is declining at a faster rate than the output can share more output per capita than before the epidemic.[5] HIV can, however, have other, more indirect and longer-term effects on demographics. If the increases in mortality caused by HIV would trigger large behavioral changes in fertility, the positive population effects highlighted by Cuddington might not materialize. This effect on fertility is of particular importance for sub-Saharan Africa, the region least advanced in its demographic transition from high mortality/high fertility to a low mortality/low fertility steady state. Several papers have stated the case for significant economic growth effects of entering the transition given the right institutional framework (see, for example Bloom and Canning (2008)). Schooling is one of the key factors highlighted in this literature, a result which appears to be strengthened further by the evidence presented in this paper.

The rest of the paper is organized as follows: we introduce a basic theoretical framework in Section 2 of the paper, and then present the data in Section 3. After briefly

[5] A second, mechanical effect is biological: HIV-positive women tend to be less fertile than non-infected ones. The magnitude of this effect is of the order of a decrease in the probability of conceiving a child during the past year of around 25% (Gray et al., 1998).

discussing regional trends in HIV and fertility in section 4, we present our main empirical results in Section 5, and end the paper with a short summary and discussion in Section 6.

2. A Simple Framework of HIV and Fertility

A large set of biological, behavioral and evolutionary models have been used to analyze the linkage between health and mortality environment and reproductive behavior. From an economic perspective, most theoretical models of fertility build on the early works by Becker (1960; 1965) and Becker and Lewis (1973). In these models, the decision making household or woman makes a lifetime decision over the quality and quantity of children given a set of prices and wages. In the simplest form of the model, incomes and prices are given, and higher incomes are associated with increased spending on children. More resources allocated to children do, however, not necessarily imply larger family sizes. If the income elasticity of child quality is sufficiently large, higher incomes will lead to a smaller number of children and higher expenditure on child quality (Becker, 1960). A similar quality-quantity tradeoff emerges in a framework where the decision maker's human capital has positive income effects, but also raises the relative cost of child rearing which requires time spent out of the labor force (Becker, 1965; Willis, 1973).

HIV affects the fertility outcomes determined in a life time optimization framework through several channels: first, HIV has a direct and negative effect on fecundity, and thus imposes additional constraints on family planning. Second, HIV increases child mortality, making child bearing more risky and costly from the parent's perspective. Last, and potentially most importantly, HIV strongly affects the degree of lifetime uncertainty faced by young adults. This uncertainty entails the uncertainty of treatment possibilities for individuals knowing that they are infected, as well as uncertainties regarding the decision maker's current and future health status. These effects can also interact, for example if children of HIV-positive parents themselves are at a higher risk of contracting HIV; in such a case, there is an intergenerational link between the parent's HIV status and that of his child.

From an empirical perspective, the direct medical effects in terms of reduced fecundity are likely to be minor. Even with an estimated reduction in the unconditional pregnancy rates around 25 percent among infected women (Gray et al., 1998), the total effect on fertility rates is relatively minor in our sample, since the fraction of infected women is rather small and even those women infected women likely still can get pregnant.

Higher child mortality affects parental choices by making child bearing more risky. In a stochastic setting, where parents are sufficiently risk-averse, a higher risk of child death will make parents desire more births[6] (Schultz, 1997). This result, however, does not necessarily hold if the degree of risk aversion is small, or HIV more broadly affects the costs associated with child bearing. Mahy (1999) argues that HIV does not only impose an additional burden to women by forcing them to undergo blood tests at antenatal clinics in many cases, but also by exposing their own HIV status to their communities in the case of child death. If the stigma associated with HIV is large enough, the optimal number of children may decrease rather than increase even with very high degrees of risk-aversion.

The effect of parents' lifetime uncertainty on fertility is likely negative; higher lifetime uncertainty generally implies higher discount rates, and, in general, a shift towards short-term consumption. More importantly, in highly risky environments, altruistic parents have to account for the possibility of not being able to support their offspring during their childhood; the risk of exposing children to orphanhood constitutes an additional cost of child bearing, lowering the optimal number of children. This effect will be particularly pronounced for parents with a high propensity to invest in the quality of their children; the longer parents want children to stay in school, the higher a cost the life-time uncertainty imposed by HIV constitutes.

[6] Parents may anticipate child death and therefore plan to give birth to more children ex-ante (hoarding), but may also want to replace children lost ex-post.

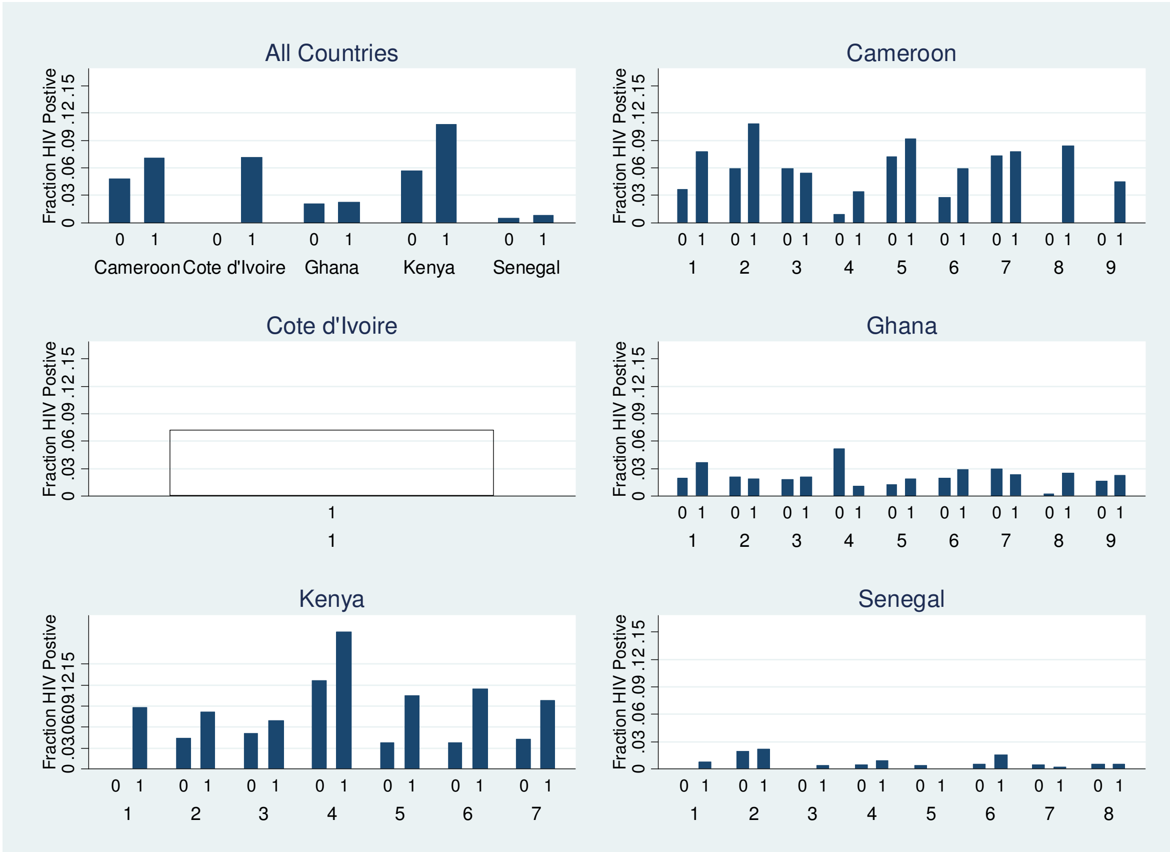
The theoretical prior regarding the effect of HIV on fertility is thus highly ambiguous. Even though parents may respond to increases in child mortality by higher fertility, concerns about revealing their own HIV status as well as concerns regarding their own ability to support their children during infancy imply a more restrictive family planning, especially for parents characterized by high human capital and/or inclined to invest substantially into their offsprings' human capital.

3. The Data

To evaluate the long term relation between HIV and fertility we combine data from the last rounds of the Demographic and Health Surveys (DHS) for which nationally representative HIV-data are available with data from the World Fertility Surveys (WFS). The World Fertility Surveys were conducted in 41 countries between 1975 and 1982, and were essentially a shorter and less comprehensive version of the later DHS surveys. The WFS were chosen because they offer many of the variables needed in the analysis that were collected when HIV prevalence was most probably close to zero in the countries considered (UNAIDS 2004). While the focus of the World Fertility Surveys was family planning, most of the original survey questions are very similar to the questions used in the later rounds of the DHS surveys.

Currently, 38 WFS surveys are publicly available, 8 of which can be matched to DHS data sets with HIV measurements: Cameroon, Cote d'Ivoire, Dominican Republic, Ghana, Haiti, Kenya, Lesotho and Senegal. Unfortunately, there is a complete mismatch between the sampling framework used in the WFS and DHS surveys for the Dominican Republic, Haiti, and Lesotho, which makes a dynamic regional analysis in these three countries impossible. We include only those areas which were targeted in both the DHS and WFS surveys, leaving us with 32 geographical sampling areas in the 5 remaining countries. Figure 1 shows the HIV prevalence for all regions in our sample; since prevalence rates vary differ largely between rural and urban areas, we show prevalence rates separately for the rural and urban populations in each region.

Figure 1: HIV Prevalence in Urban and Rural Areas



Notes: 0 is rural, 1 is urban. Bottom line indexes the region number. For Cote d'Ivoire, we have only one (urban) region, the metropolitan area of Abidjan.

As Figure 1 shows, the regions with the highest HIV prevalence rates in our sample are located in Cameroon and Kenya, while Senegal and Ghana have mostly low prevalence rates (1-2% prevalence). All countries show significant regional and urban/rural variation, with urban prevalence rates 5-10 times the rural rates in the most hard-hit areas in each country. The region with the highest prevalence rate in our sample is Nyanza (Kenya), with HIV prevalence rates of 19.6% (urban) and 12.7% (rural), respectively.

Table 1 shows descriptive statistics for the full sample as well as for the respective surveys in each country.

Table 1: Descriptive Statistics

Full Sample

	WFS[7]		DHS	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	28.54	9.81	27.95	9.50
Years of education	2.92	3.83	4.91	4.53
Partner	0.75	0.43	0.65	0.48
Urban residence	0.30	0.46	0.45	0.50
HIV: female prevalence	0.00	0.00	0.05	0.04
HIV: male prevalence	0.00	0.00	0.03	0.03
Number of observations	27,319		37,815	

Cameroon (9 regions)

	WFS 1978		DHS 2004	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	29.84	10.42	27.50	9.52
Years of education	2.48	3.27	6.45	3.58
Partner	0.78	.42	0.65	.48
Urban residence	0.27	.44	0.53	0.50
HIV: female prevalence	0.00	0.00	0.07	.04
HIV: male prevalence	0.00	0.00	0.04	.02
Number of observations	8,112		8,822	

Cote d'Ivoire (Abidjan only)

	WFS 1980		DHS 2005	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	25.83	8.36	27.58	8.62
Years of education	2.47	3.85	6.38	5.29
Partner	0.76	0.43	0.41	0.49
Urban residence	1.00	0.00	1.00	0.00
HIV: female prevalence	0.00	0.00	0.10	0.00
HIV: male prevalence	0.00	0.00	0.04	0.00
Number of observations	1,090		947	

[7] The HIV prevalence rates are assumed to be zero in the WFS. Even though there likely were some cases of HIV in the late 1970s, HIV AIDS was formerly recognized only in the early 1980s.

Ghana (9 regions)

	WFS 1979		DHS 2003	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	28.20	9.48	29.25	9.63
Years of education	4.14	4.67	5.39	4.68
Partner	0.72	0.45	.65	.48
Urban residence	0.34	0.47	.42	.49
HIV: female prevalence	0.00	0.00	.03	.01
HIV: male prevalence	0.00	0.00	.02	.01
Number of observations	6,107		5.691	

Kenya (7 regions)

	WFS 1977		DHS 2003	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	27.98	9.59	28.05	9.31
Years of education	3.56	3.75	7.47	4.09
Partner	0.70	0.46	.59	.49
Urban residence	0.20	0.40	.34	.47
HIV: female prevalence	0.00	0.00	.09	.04
HIV: male prevalence	0.00	0.00	.05	.03
Number of observations	8,038		7,753	

Senegal (8 regions)

	WFS 1978		DHS 2005	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	28.30	9.50	27.70	9.54
Years of education	0.80	2.22	2.34	3.79
Partner	0.83	0.38	.70	.46
Urban residence	.35	0.48	.43	.50
HIV: female prevalence	0.00	0.00	.01	.01
HIV: male prevalence	0.00	0.00	.00	.01
Number of observations	3,972		14,602	

While the average age is fairly similar across the WFS and DHS surveys, the average years of education have gone up significantly over time, from an average of 2.92 in the WFS to 4.91 in the DHS surveys. This increase largely represents the general upward trend in educational attainment across countries, but also some sampling differences across surveys. To provide a clearer picture of the differences in the samples used, we compare women of an age to be included both in the WFS and the DHS surveys in Table 2. For example, women who were 20 years of age in 1978 in Cameroon were 46 when the DHS 2004 was administered, making them eligible for inclusion in both the WFS and the DHS (as data in the WFS and DHS are typically collected from women age 15-49). Given a similar sampling approach in both surveys, we would therefore expect fixed variables such as education not to differ between the two waves for this subgroup of women.

Table 2: Comparability of DHS and WFS Samples

Full Sample

	WFS Ages 20-24		**DHS Ages 45-49**	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	21.836	1.452	46.713	1.428
Years of education	4.300	4.159	3.480	4.361
Partner	0.779	0.415	0.817	0.387
Urban residence	0.368	0.482	0.390	0.488
T-test of same average education across samples (p-value): 0.000				
Number of observations	5,324		2,672	

Cameroon (9 regions)

	WFS 1978		**DHS 2004**	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	21.813	1.485	46.795	1.411
Years of education	4.052	3.416	4.573	3.610
Partner	0.830	0.376	0.756	0.430
Urban residence	0.322	0.467	0.435	0.496
T-test of same average education across samples (p-value): 0.000				
Number of observations	1,577		620	

Cote d'Ivoire (Abidjan only)

	WFS 1980		**DHS 2005**	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	21.847	1.394	46.741	1.507
Years of education	3.256	4.322	7.389	5.963
Partner	.808	.395	0.741	0.442
Urban residence	1.000	0.000	1.000	0.000

T-test of same average education across samples (p-value): 0.000

Number of observations	281		54	

Ghana (9 regions)

	WFS 1979		DHS 2003	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	21.868	1.452	46.649	1.392
Years of education	5.822	4.623	4.491	5.265
Partner	0.759	0.428	.814	.389
Urban residence	0.365	0.482	.355	.479

T-test of same average education across samples (p-value): 0.000

Number of observations	1,216		501	

Kenya (7 regions)

	WFS 1977		DHS 2003	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	21.847	1.439	46.704	1.434
Years of education	5.053	4.160	4.959	4.520
Partner	0.721	0.449	0.726	0.446
Urban residence	0.288	0.453	0.255	0.436

T-test of same average education across samples (p-value): 0.401

Number of observations	1,492		486	

Senegal (8 regions)

	WFS 1977		DHS 2003	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Age	21.807	1.432	46.698	1.449
Years of education	1.280	2.745	1.389	3.071
Partner	0.809	0.394	0.902	0.297
Urban residence	0.389	0.488	0.410	0.492

T-test of same average education across samples (p-value): 0.288

Number of observations	758		1,011	

On average, the women in the DHS samples are slightly more likely to live in an urban area; there are some differences in the average years of education, which appear to be particularly pronounced in Abidjan (Ivory Coast), where the sample of women in the age group 45-49 is very small (54 women in total).

Overall, the women sampled in the two surveys look fairly similar; given that neither the DHS nor the WFS samples were stratified by age groups, some differences in the sub-samples are unavoidable[8] and will be further discussed when presenting the main result.

4. Regional Trends in HIV and Fertility

Average total fertility has fallen substantially between the early 1980 and the early 2000s. As Figure 2 shows, total fertility was between 4 and 8 in the WFS surveys, and between 2 and 6 in the latest DHS surveys; the average reduction in the total fertility rates in our sample is close to 2, with a significant variation both within and across countries.

Interestingly, the picture looks quite different when comparing completed (cohort) fertility across time and regions. In both the WFS and the DHS, the average woman aged 45 or older has given birth to around 6 children. This implies that the (unconditional) reproductive behavior of the 1930 birth cohorts (aged 45+ in 1980) was on average very similar to the reproductive behavior of women born in the late 1950s; the changes in total fertility rates observed over the time period thus mostly represent changes in behavior of the younger cohorts.

For the purpose of investigating the effects of HIV on fertility, total fertility is clearly the more interesting measure, since women whose completed fertility we can observe in the last rounds of the DHS had already passed age 30 when the HIV epidemic truly started. The drawback of using the total fertility rate is that they may in some cases pick up "tempo effects"; total fertility rates may fall or increase in the short run if women change the timing of their birth without changing their desired fertility. In the case of

[8] Both the WFS and DHS are nationally representative for the populations aged 15-49. With some mortality between ages 20-49 and a larger fraction of the sample drawn from the younger cohorts due to their larger relative size, a perfect match between the WFS sub-sample of the 20-24 year old and the DHS sample of the 45-49 old is virtually impossible.

HIV, this is not a trivial issue, since mothers may opt for earlier child birth to limit the likelihood of vertical HIV transmission; if this is true, total fertility numbers in HIV regions would be biased upwards relative to the historical numbers as well as final fertility outcomes. On the other hand, the age of first marriage and child birth seems to be going up in several countries, which implies that current fertility rate would appear low relative to the family sizes achieved in the long run by current cohorts.

Figure 2: Total Fertility Rate and Completed Fertility: WFS vs. DHS

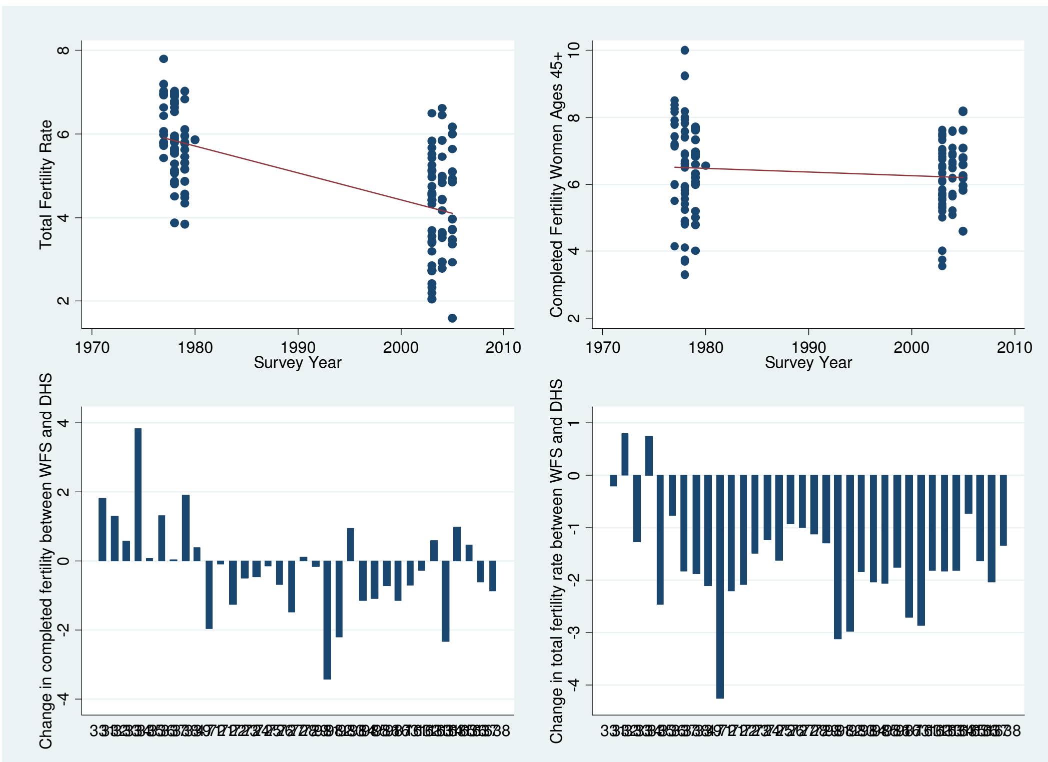


Figure 3 shows the basic correlation between HIV prevalence and changes in fertility rates on the regional level. While the correlation is slightly negative (the correlation coefficient -0.24), HIV prevalence does not appear to have any significant effect on changes in fertility on the regional level once we control for country specific time trends as shown in Table 3 below.

Figure 3: Changes in Fertility and Regional HIV Prevalence Rates

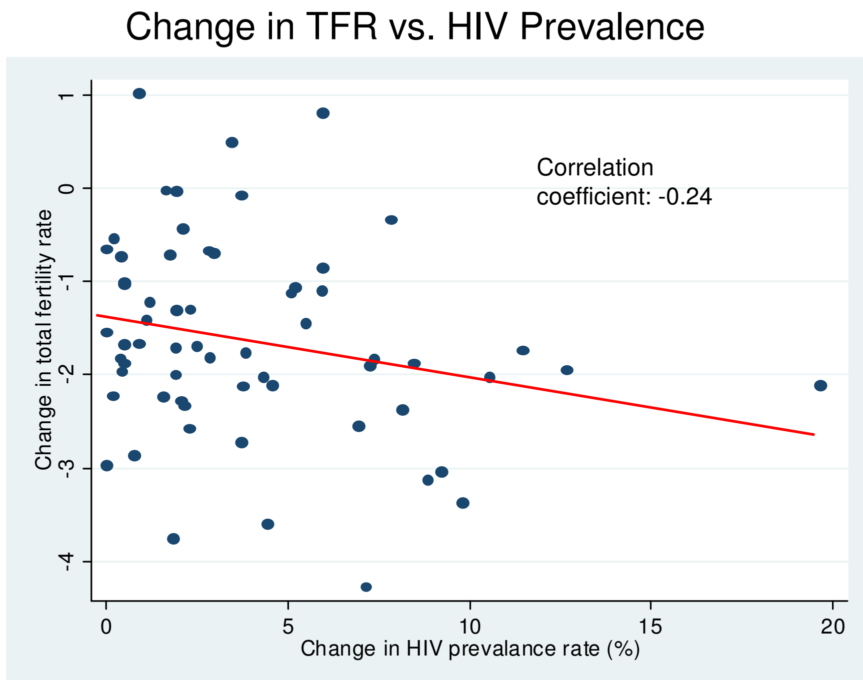


Table 3: Regional Difference-in-Differences: HIV and Total Fertility

Dependent Variable	Total Fertility Rate		
HIV prevalence	-0.066**	-0.080	-0.068
	(0.028)	(0.057)	(0.045)
Regional fixed effects	YES	YES	YES
Country time trend	NO	YES	YES
Regional time trend	NO	NO	YES
Observations	124	124	124
R-squared	0.85	0.90	0.96

Notes:
Regressions are based on 31 regions which we divide into their urban and rural populations; we use only regions where we have both an observation from a WFS and a DHS survey containing HIV data.
*** p<0.01, ** p<0.05, * p<0.1

5. Empirical Specification and Results

We start our empirical work with a standard model for estimating fertility, and augment it with both the woman's own HIV status (in order to get an idea of the biological effect once the woman has contracted the virus), as well as with the regional prevalence rate[9] (in order to measure the fertility response in reaction to the local community HIV prevalence rate). In addition, we include educational status of the woman as an explanatory variable, as it has been found to be a major determinant of fertility. In the context of HIV, education has also been found to influence the behavioral reaction to HIV. For example, de Walque (2007) finds that in the context of an HIV information campaign in rural Uganda, educated women were more responsive to the messages of the campaign, and used condoms more frequently than their less-educated peers. Similarly, Glick and Sahn (2007) find that the education gradient for prevention knowledge is substantial and seems to have increased over time in nine African countries investigated. In light of this evidence, we also include an interaction term between HIV status and the woman's education in all of our specifications.

Apart from these variables of interest, we also include variables from standard fertility regressions, such as the age of the woman and its square, her relationship status, and whether she is living in an urban or rural area.

The main model we would like to estimate is given by

$$fert_{ijkt} = \alpha + \beta hiv_{ijkt} + \gamma educ_{ijkt} + \chi hiv_{ijkt} * educ_{ijkt} + \kappa hiv_{jkt} + \lambda educ_{ijkt} * hiv_{jkt} + \phi X_{ijkt} + post + \delta j + \delta j * post + \varepsilon_{ijkt} \quad (1)$$

[9] Juhn, Kalemli-Ozcan, and Turan (2007) use the cluster HIV rate for this purpose. We prefer the regional HIV rate as on average there are only about 10 women per cluster, resulting in highly variable cluster HIV rates, and feel that such fluctuations are better smoothed out at the regional level.

where $fert_{ijkt}$ is the fertility measure for woman i in region j in country k period t. For most of the specifications, we look at births of the woman in the last five years[10]. Hiv_{ijkt} is the woman's own HIV status, whereas hiv_{jkt} is the unweighted regional HIV prevalence rate, which is set to zero in all WFS surveys by default as discussed above. *Educ* is years of education[11], and X is a matrix of additional controls. δ_j are regional fixed effects and *post* is an indicator equal to 1 if the data come from the DHS surveys, and zero otherwise. To control for the highly heterogeneous political and economic experiences over the last decades, we also use a regional or country specific time trend $(\delta_j * post)$ in all our specifications.

In Table 4, we present our main results for the empirical model outlined in equation (1). We focus on the impact of the regional HIV prevalence rate on the individual fertility decision of woman in order to investigate the question whether women react to the HIV prevalence rate in their geographical vicinity. A priori, it is not clear whether they would increase their fertility (for example, in order to reach a certain target number of children in the presence of increased uncertainty about child survival as suggested by Kalemli-Ozcan (2003)) or reduce it (as discussed in section 2 above), and to what extent this decision would be influenced by the woman's education status. Given that the papers by de Walque (2007) and Glick and Sahn (2007) posit that more educated women understand the messages from HIV prevention campaigns better and change their sexual behavior to a larger extent than less-educated women, it seems a reasonable hypothesis that fertility may be reduced more by more educated women, which we test with the interaction term between regional HIV prevalence and the woman's education.

In the first column, the results are presented when including all women irrespective of their own HIV status. The first main finding is that the regional HIV prevalence has a positive and statistically significant effect on average fertility. A 10% HIV prevalence in a region would therefore lead to a reduction in the number of children

[10] As a robustness check, we also looked at the more short-term measure of whether the woman is currently pregnant and found essentially the same results, which are available from the authors.
[11] We also try specifications with schooling categories; see Table 5 for further discussion.

born in the last five years by about 0.1. Given that the mean value for the fertility variable is about 1, this corresponds to a proportional reduction (in this case, of 10%) in fertility. Not surprisingly, women with a higher number of years of education have fewer children, although the magnitude of this decrease is not large: for women in our sample, one year more of education leads to a reduction in the children born in the last five years of only .01, or about 1% of the mean value. The second main finding is that the interaction of education with regional HIV prevalence is negative (as hypothesized before) and statistically significant, meaning that women with higher education increase their fertility less in response to HIV than less-educated women. Although the overall response to HIV prevalence found in our sample is an increase in fertility, this response turns negative for women with about 5 years of education. In our sample, about half of the women in the DHS survey have more than five years of education. This result is important, since it explains the rather mixed relationship between HIV and fertility on the aggregate level, and has to our knowledge, never been documented in the existing literature.

The other control variables included confirm the findings in previous fertility studies: older women have higher fertility but at a decreasing rate, married women have more children, and women living in urban areas have somewhat fewer children than people living in the countryside.

In the second column, we restrict our sample to women who are HIV-negative in order to arrive at a purely anticipatory behavioral effect (the sample used to arrive at the results in column 1 include also HIV-positive women who may see their fertility change for biological reasons or due to reactions about learning her own HIV-status). For this restricted sample, we lose about 800 observations (as about 5% of the roughly 18,000 women in the DHS sample have tested positive for HIV), whereas the results remain virtually of the same magnitude and statistical significance. Given that the DHS does not provide the tested individuals with the results of the HIV test, this result is not too surprising (if, for example, private testing is not widely available, or if approximately the same fraction of HIV-positive and HIV-negative women have learned about their HIV status from sources other than the DHS).

In the third column, we further restrict the sample to women aged 40 or younger. The reason for this restriction is that women over this age were not exposed to the HIV epidemic for a large part of their fertile period. Women older than 40 in the DHS would have been experiencing the effects of HIV at a time when most of her fertility is already completed, and the number of children born to her in the last five years is probably close to zero, irrespective of the regional HIV prevalence. For this reason, younger women who are in the prime of their fertile period and are currently facing the full effect of the HIV epidemic provide more information. This sample restriction leads to a significant increase in the magnitude of the coefficient for regional HIV prevalence, almost doubling in size. This means that for this sample, a 10% regional HIV prevalence translates into an increase in the number of children born in the last five years by .25 children, or roughly a more than 25% increase compared to the mean value found in the sample. Also the interaction term of mother's education with regional HIV prevalence increases in magnitude. The turning point at which the fertility response turns negative from positive is at about 7 years, in contrast to the 4-5 years found previously. In column 4 we further restrict the sample to women age 18 and over, as for women younger than that the fertility measure could be rather noisy. However, the results change only marginally as a result of this restriction.

In the last column, we restrict the sample to a cross-section of DHS surveys only, in order to get an idea of the potential bias when not controlling for regional fixed effects, and in order to facilitate comparison with the literature such as Juhn, Kalemli-Ozcan et al. (2008) who use the DHS data in this cross-sectional way. The main finding for this specification is that the results are very similar to the results when including regional fixed effects. The coefficients for age are virtually identical, whereas education has increased in significance as a determinant of fertility. A similar result holds for the urban dummy: women living in a city have now significantly lower fertility than their rural counterparts. For regional HIV prevalence, our main variable of interest, the coefficient in this cross-section is of the same magnitude as when including the WFS in the sample. The coefficient on the interaction term between mother's education and regional HIV prevalence is about 30% smaller than before. It is remarkable, however, how close the results for the cross-section sample and the sample combining WFS and DHS are.

Table 4: Multivariate Analysis: Children born and HIV prevalence

	Dependent Variable: Number of children born in the last 5 years				
	(1)	(2)	(3)	(4)	(5)
Age	0.220***	0.221***	0.317***	0.313***	0.285***
	(0.008)	(0.008)	(0.011)	(0.010)	(0.012)
Age squared	-0.004***	-0.004***	-0.006***	-0.006***	-0.006***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Years of education	-0.013***	-0.013***	-0.013***	-0.013***	-0.019***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Married	0.583***	0.588***	0.608***	0.636***	0.572***
	(0.027)	(0.027)	(0.029)	(0.033)	(0.041)
Urban	-0.104***	-0.101***	-0.107***	-0.133***	-0.224***
	(0.017)	(0.016)	(0.018)	(0.022)	(0.031)
Regional HIV prevalence	1.113*	1.297*	2.517***	2.798***	2.377***
	(0.616)	(0.658)	(0.800)	(0.945)	(0.816)
HIV * education	-0.225***	-0.242***	-0.349***	-0.375***	-0.254***
	(0.049)	(0.053)	(0.056)	(0.061)	(0.056)
DHS sample	-0.098***	-0.096**	-0.106**	-0.134***	-
	(0.036)	(0.036)	(0.041)	(0.049)	-
Constant	-2.222***	-2.253***	-3.401***	-3.322***	-2.901***
	(0.109)	(0.110)	(0.145)	(0.147)	(0.161)
Sample restrictions	None	HIV neg.	HIV neg. age < 41	HIV neg. 17< age< 41	HIV neg. 17< age< 41 DHS only
Observations	45180	44367	38124	32133	12209
R-squared	0.304	0.306	0.323	0.224	0.269

*** p<0.01, ** p<0.05, * p<0.1
Robust standard errors in parentheses

In Table 5, we present some robustness checks and also include the woman's own HIV status in the regression, as indicated in equation (1). In columns 1 and 2, we include a country specific time trend in the regression in order to control for heterogeneous country experiences with family planning programs and other country-wide effects. While the results remain very similar to those in the previous Table, the inclusion of a country time trend leads to the coefficient on the regional HIV prevalence rate to turn insignificant. As expected a, HIV-positive women experience a decline in fertility either for biological reasons or due to an ex-post response to learning about their HIV status.

The results change only marginally when own HIV status is omitted in column 2, which is intuitive given the relatively small fraction of women with positive HIV status in our sample.

Columns 3 and 4 of Table 5 repeat the specification in columns 1 and 2 but exclude the regions with the lowest HIV prevalence rates (under 1%) and with the highest HIV prevalence rates (over 7%) to test whether the results are robust to the exclusion of these extreme values. When focusing on regions with moderate HIV prevalence rates, the magnitude of the coefficient on regional HIV prevalence more than doubles in magnitude, indicating that the results are by no means driven by regions with very low or very high HIV prevalence rates, whereas the coefficient estimate for the interaction between education and HIV remains about the same size. As before, the results remain the same when excluding own HIV status.

One of the questions unanswered in Table 4 is the effect of different education levels on fertility in the context of HIV, as education is entered linearly into the regressions above. For this reason, we split education by level of attainment in columns 5 and 6 of Table 5. The categories used are "no schooling", which serves as the omitted group, "some primary", "primary completed", "some secondary", "secondary completed", and "tertiary". This stratification allows us to investigate in more detail which level of schooling is important in determining fertility in general, and when interacted with regional HIV status. In addition, this stratification also allows best-possible comparability of this variable between the WFS and DHS. When entering the education variable this way, we find that up to primary education there is little evidence on a negative impact on fertility, the sign of the coefficient begins to turn for women having some secondary education, and becomes significant for completed secondary education and tertiary education. A similar result holds when interacting the education categories with regional HIV prevalence. The results show that only women with completed secondary or tertiary education respond differently to the HIV prevalence than non-educated women.

Table 5: Robustness Checks

	Dependent Variable: Number of children born in the last 5 years					
Sample	All	HIV neg.	All	HIV neg.	All	HIV neg.
	(1)	(2)	(3)	(4)	(5)	(6)
Age	0.220***	0.221***	0.219***	0.220***	0.223***	0.224***
	(0.008)	(0.008)	(0.012)	(0.012)	(0.008)	(0.008)
Age squared	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***	-0.004***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Years of education	-0.013***	-0.013***	-0.017***	-0.0166***		
	(0.002)	(0.002)	(0.003)	(0.003)		
Married	0.580***	0.586***	0.491***	0.504***	0.576***	0.582***
	(0.026)	(0.026)	(0.041)	(0.044)	(0.026)	(0.027)
Urban	-0.114***	-0.112***	-0.207***	-0.201***	-0.114***	-0.112***
	(0.016)	(0.016)	(0.027)	(0.027)	(0.017)	(0.017)
HIV status	-0.121***		-0.139***		-0.128***	
	(0.026)		(0.036)		(0.026)	
HIV regional preval.	1.351	1.384	3.186***	3.521***	0.317	0.343
	(1.095)	(1.070)	(0.585)	(0.581)	(0.555)	(0.591)
HIV * education	-0.220***	-0.235***	-0.198**	-0.226***		
	(0.040)	(0.044)	(0.069)	(0.071)		
DHS wave	0.057	0.061			-0.116***	-0.115***
	(0.093)	(0.090)			(0.026)	(0.026)
Schooling categories						
Some primary					0.066	0.065
					(0.039)	(0.039)
Primary completed					0.0251	0.027
					(0.022)	(0.023)
Some secondary					-0.029	-0.027
					(0.025)	(0.024)
Second. completed					-0.116***	-0.112***
					(0.028)	(0.028)
Tertiary					-0.323***	-0.324***
HIV interactions					(0.037)	(0.037)
Some primary					0.057	0.292
					(0.964)	(1.033)
Primary completed					0.463	0.475
					(0.595)	(0.631)
Some secondary					-0.297	-0.398
					(0.590)	(0.622)
Second. completed					-1.738**	-1.869**
					(0.801)	(0.835)
Tertiary					-1.540**	-1.661**
					(0.688)	(0.739)
Constant	-2.302***	-2.319***	-2.199***	-2.238***	-2.413***	-2.433***
	(0.104)	(0.105)	(0.129)	(0.136)	(0.099)	(0.100)
Observations	45180	44367	10822	10405	45180	44367
R-squared	0.308	0.310	0.327	0.335	0.302	0.304

Column 1 and 2 include a country specific time trend. In columns 3 and 4, the sample is restricted to regions with prevalence rates above 1 and below 7% (DHS only). In columns 5 and 6, educational categories rather than years of schooling are used.
*** p<0.01, ** p<0.05, * p<0.1, Robust standard errors in parentheses

One cautionary note must be made concerning the interpretation of these results. The inclusion of the WFS prevents us from creating a wealth index (there is no income or expenditure information in the DHS; the common approach in papers using the DHS is to create a wealth index using principal component analysis), therefore we cannot separate the direct impact of education on fertility (for example through changes in preferences or because the content of fertility or HIV information campaigns is more easily processed) from an income effect as educated women have often been found to also have higher socioeconomic status. For example, women with relatively high education may be married to a man with high education and high income (or they themselves may have a higher-paying job), confounding the knowledge-aspect of education with a wealth effect; education may thus proxy for both knowledge and wealth.

6. Summary and Conclusion

In this paper we evaluate the effect of HIV prevalence on fertility in Sub-Saharan Africa using a new data set which combines existing DHS data with historical data from the World Fertility Surveys. The main result emerging from this paper is that a weak and statistically insignificant correlation between HIV prevalence and fertility on the regional level hides important heterogeneity across socioeconomic groups within and across regions. We find a positive fertility response to the regional HIV prevalence for non-educated mothers and mothers with primary schooling, but a negative fertility response for mothers with completed secondary schooling and higher. An intuitive explanation for these results in the light of the theoretical discussion presented in Section 2 of this paper as well as empirical evidence discussed in the introduction, is that more highly educated people better understand the risks and costs associated with HIV (De Walque, 2007), and thus adjust their fertility more than people with lower human capital. Our point estimates imply that there is little systematic difference between non-educated women and women with primary education, which goes somewhat against the literacy argument, and would point more towards a better understanding or information absorption by the more highly educated populations.

An alternative explanation is that HIV has differential effects on women's fertility choice due to differential planning horizons and/or investment preferences. Given that more highly educated parents tend to invest more into their children's human capital, the additional mortality risk posed by HIV may reduce the relative expected utility from child-rearing more for the highly educated than for women with low educational attainment.

Independent of the interpretation, the results in this paper further highlight the importance of education in understanding demographic change. Without sufficient education, fertility is not only likely to remain higher than what might be considered optimal from a development perspective, but also to increase further in the event of adverse shocks to the local health system.

References

Becker, G. S. (1960). An Economic Analysis of Fertility. Demographic and Economic Change in Developed Countries. G. S. Becker. Princeton, N.J., Princeton University Press.

Becker, G. S. (1965). "A Theory of the Allocation of Time." Economic Journal **75**: 493-517.

Becker, G. S. (1981). A Treatise on the Family. Cambridge, Harvard University Press.

Becker, G. S. and H. G. Lewis (1973). "On the Interaction between Quantity and Quality of Children." Journal of Political Economy **81**: S279-S288.

Cuddington, J. T. (1993). "Modeling the Macroeconomic Impact of the AIDS in Tanzania." World Bank Economic Review **7**(2): 173-189.

De Walque, D. (2006). "Who Gets AIDS and How? The Determinants of HIV Infection and Sexual Behaviors in Burkina Faso, Cameroon, Ghana, Kenya and Tanzania." World Bank Policy Research Working Paper **3844**.

De Walque, D. (2007). "How Does the Impact of an HIV/AIDS Information Campaign Vary with Educational Attainment? Evidence from Rural Uganda." Journal of Development Economics, **84**(2): 686-714.

Glick, P. and D. E. Sahn (2007). "Changes in HIV/AIDS Knowledge and Testing Behavior in Africa: how much and for whom?" Journal of Population Economics **20**: 383-422.

Gray, R. H., M. J. Wawer, D. Serwadda, N. Sewankambo, C. Li, F. Wabwire-Mangen, L. Paxton, N. Kiwanuka, G. Kigozi, J. Konde-Lule, T. C. Quinn, C. A. Gaydos and D. McNairn (1998). "Population Based Study of Fertility in Women with HIV-l Infection in Uganda." Lancet **351**(9096): 98-104.

Halperin, D. T. and R. C. Bailey (1999). "Male Circumcision and HIV Infection: 10 Years and Counting." The Lancet **354**: 1813-1815.

Juhn, C., S. Kalemli-Ozcan and B. Turan (2008). "HIV and Fertility in Africa: First Evidence from Population Based Surveys." NBER Working Paper **14248**.

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

Mahy, M. (1999). Perceptions of Child Mortality and their Effects on Fertility Intentions in Zimbabwe. Baltimore, Maryland, Johns Hopkins University.

Oster, E. (2007). "HIV and Sexual Behavior Change: Why Not Africa?" NBER Working Paper **13049**

Oster, E. (2008). "Routes of Infection: Exports and HIV Incidence in Sub-Saharan Africa." Mimeo.

Schultz, T. P. (1997). Demand for Children in Low Income Countries. Handbook of Population and Family Economics. M. R. Rosenzweig and O. Stark. Amsterdam, North-Holland. **1A:** 643.

UNAIDS (2008). 2008 Report on the Global AIDS Epidemic, UNAIDS.

Werker, E., A. Ahuja and B. Wendell (2006). "Male Circumcision and HIV/AIDS: The Macroeconomic Impact of a Health Crisis." Mimeo.

Willis, R. (1973). "A new Approach to the Economic Theory of Fertility Behavior." Journal of Political Economy **81**: S14-S64.
World Bank (2007). World Bank Development Indicators CD-ROM.
Young, A. (2005). "The gift of the dying: The tragedy of AIDS and the welfare of future African generations." Quarterly Journal of Economics **120**(2): 423-466.