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ABSTRACT

This paper models the effect of a HIV/AIDS epidemic on saving behavior and studies the welfare effects of testing for HIV. The model specifies a utility function that includes both regular consumption, and medical expenditures. Medical expenditures generate more utility if individuals are HIV infected, but they are only able to purchase the optimal medical consumption after being tested HIV positive. The paper describes different effects on aggregate savings according to different stages of the epidemic. We show that the HIV epidemic decreases savings if especially young individuals are (perceived to be) affected by the virus, but may increase savings if individuals perceive a sizable probability of getting infected later in life. By the same token, the welfare effects of testing young individuals differs greatly from the welfare effects of testing older individuals, the reason being that the savings responses to testing differ according to whether old or young individuals are tested.

Keywords: saving behavior, perceived risk, HIV/AIDS, HIV testing, mortality, life-cycle model.
JEL codes: D83, D91, I12, E21.

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1. Introduction

After its discovery in the late 1970s, the HIV/AIDS epidemic has rapidly developed to a widespread catastrophe in Sub-Saharan Africa. Over 25 million people died of AIDS related diseases and 38.6 million are living with HIV worldwide (UNAIDS, 2006). The pandemic especially increases mortality at a relatively young age. The highest risk of infection is between 15-35 years old, where agents are most sexually active but also most productive (UNAIDS, 2004). The incubation period of the HIV virus is about 7-10 years (Bonnel, 2000), which implies that once HIV infected, people face a long period of high expenses of specific food and medical treatment.

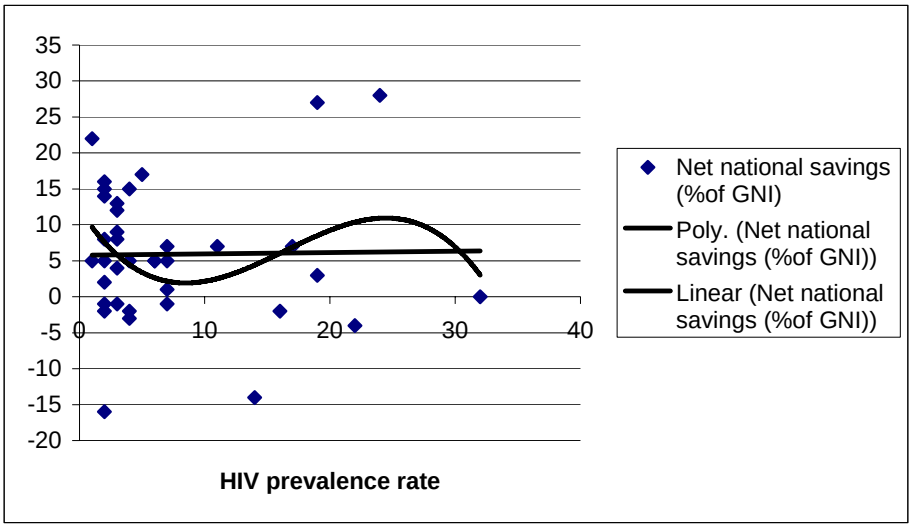
In many respects, the disease is of economic interest in developing countries where extensive social-insurance systems are lacking. In an influential paper Young (2005) claims that the widespread infection, and its associated lower fertility, increases the scarcity of labor and, therefore, enhances future consumption possibilities. He assumed, however, a constant macro economic savings rate, implying that the stock of physical capital will not be affected in the long run. There are, however, many reasons to believe that societies adjust their savings pattern when a virus like HIV spreads. The increase in medical expenditures due to infection forces households to reduce and finally exhaust their savings or assets (see Steinberg et al., 2002). In addition, savings for retirement are less necessary in societies where high mortality decreases the chances of getting old. As a counteracting force, however, savings may increase when the HIV epidemic spreads further. This occurs if individuals anticipate that in the future they may contract HIV and be confronted with high costs of medical treatment as a result. Kochar (2004) confirmed the existence of such an effect as he found that expectations of future illness increased overall savings in Pakistani households. However, these results do not tell much about the effect on aggregate savings, as perceptions of illness vary widely among individuals.

Most empirical studies to date found a negative effect of the HIV/AIDS epidemic on savings. Ferreire et al. (2003) attributed this decline to a reduction in life expectancy. Bonnel (2000), who estimated the macroeconomic effects of the HIV/AIDS epidemic using cross-country regressions, found that from 1990 to 1996 an increase in the HIV prevalence rate significantly reduced the change in the domestic saving rate in developing countries. However, he remarked that in a well-established epidemic savings could increase. In fact, recalculating his

model with data from a more recent period, i.e. 1997-2004, provides no significant results (see Annex 1).

Besides, plotting actual HIV prevalence rates against net national savings of 2003 for a number of African countries suggests that the relationship between HIV/AIDS and savings indeed can be of a non-monotonic nature (see Figure 1). In particular, an increasing prevalence rate might first decrease the national savings rate, then lead to an upswing in savings, and finally to a downfall again. Actually, our theoretical model to be presented below, predicts exactly such an evolution of savings over the spread of the virus[4].

Figure 1: Net national savings and HIV prevalence in Africa (2003)



Source: World Development Indicators, 2006

This paper employs a two-period lifetime optimization model to explain savings by a four-stage process partly supporting Bonnel's (2000) conjecture that savings are affected differently in the various stages of the epidemic. In the first stage that we distinguish, the disease is unknown. Some individuals die from the disease without knowing that AIDS killed them. These individuals are therefore not able to change saving behavior, so that aggregate savings are not affected. In the second stage of the epidemic, a group of young individuals falls ill, and get tested HIV positive. This group knows they contracted the virus and that they will

[4] Note that Zhang et al. (2003) found a similar result based on a different model, i.e. that increases in longevity have a non-monotonic effect on savings. In particular, starting at high mortality a mortality decline will first increase and later on decrease savings.

not survive the first period. Being diagnosed HIV positive, they face a rise in expenditures on medical treatment[5] without having been able to save in advance for these costs. Because this group will not save for future consumption, a decrease in aggregate savings characterizes this second stage. In the third stage, the population becomes aware of the future risk they face of contracting the virus and will save for a possible future fall of income and increase in expenditures. In this stage, the number of young individuals with a positive HIV status is still small. Therefore, the increase in savings of the other non-infected part of the population exceeds the decrease in savings of the HIV contaminated group. However, if the infection rate increases further, i.e. if many young individuals get infected, the decrease in savings by these diagnosed HIV infected individuals will exceed the increase in savings of the group that faces the risk of contracting HIV/AIDS later in life and aggregate savings will fall again.

A second focus of the paper is the effect of individual diagnostic testing for HIV/AIDS. It is estimated that only 10 percent of the HIV-infected people are also aware of their status. Increasing status knowledge could therefore mitigate a further spread of HIV. Apart from, the effect on the HIV prevalence rate, testing can have important direct effects on individuals' welfare, which is crucial for decision making on the intensity of HIV-testing. In this paper, we analyze these direct welfare effects of diagnostic HIV tests. We assume that individuals who are infected by the virus will derive less utility from the consumption of regular goods and derive more utility from the consumption of medical treatment than non-infected individuals. Furthermore, we assume that being diagnosed HIV positive is necessary for getting the appropriate medical consumption.

Individuals can be tested in both periods of their life. Testing in period 1 obviously resolves the uncertainty in period 1, but not in period 2. We assume that testing only takes place at the start of each period. If the test result turns out to be positive, individuals are receiving a negative utility shock caused by a "fear-of-death" or "stigmatization" parameter. On the other hand, these individuals are better able to attain optimal (medical) consumption. On top of that, the individuals who receive a positive test in the first period of their life do not have to save for an uncertain chance of survival. Surprisingly, testing individuals who turn out to be HIV negative does not necessarily imply a positive welfare effect for these individuals. The reason is that although individuals that are untested, will save less in the first period, are still

[5] Medical costs are a significant part of HIV affected households' expenditures. Steinberg et al. (2002), for instance, finds that affected households in South Africa on average spend 34% on medical treatment.

able to consume more in the second period of their lives. The latter is due to an (informal) "longevity" insurance system that we postulate for untested individuals, which redistributes savings from the diseased due to HIV/AIDS to the not-infected survivors. The positive effects of this redistributive insurance system have to be weighed against the negative utility effects of sub-optimal consumption choices if individuals are uncertain on being HIV infected or not.

Diagnostic HIV testing during the second period of individuals' life has, however, less ambiguous welfare effects. A higher frequency of testing during old age makes it more likely that an individual will be able to get the right medical consumption if he contracted the virus. This prospect makes it attractive to save more in order to be better prepared for possible higher medical consumption in the future. Due to more frequent future testing these savings have become more efficient in terms of individual utility, and so young individuals' expected lifetime utility will rise.

The remainder of the paper is organized as follows. In the next section, we present the basic set up of the model. In Section 3, we derive the course of savings over the four distinguished stages of the epidemic. In Section 4, we evaluate the marginal effects of diagnostic testing for HIV status knowledge on social welfare and Section 5 concludes.

2. Model

This section describes the model assumptions and briefly defines the four stages of the epidemic. We first present a broad outline of the model and then turn to specification issues.

2.1. Outline of the model

We consider a country where a large group of agents of the same age (their number normalized to one) optimizes consumption over two periods. In each period, agents face a certain probability, α_t^{act}, $(t = 1,\ 2)$, of contracting HIV, which might be different from their *perceived* probability of contracting the virus, α_t. We assume that the perceived HIV contamination "risk" in each period, α_t, and the probability of knowing one's status in that

period, β_t, is equal for all agents[6]. Agents die at the end of the period in which they get infected. We distinguish four different stages in the evolution of the epidemic.

S*tage 0*

This is the benchmark case, in which HIV does not exist. Individuals optimize a simple logarithmic lifetime utility function containing regular and medical consumption. They save to smooth consumption over their lifetime.

Stage 1

In this stage, HIV starts to spread but the virus is yet unknown and therefore HIV testing cannot take place. A small part of the young population, $\alpha_1^{act} > 0$, is infected without this being perceived by the population, i.e. $\alpha_1 = 0$. In this initial phase of the disease, agents are not aware of their infection, and so they keep on behaving as in stage 0. Individual saving behavior is therefore not influenced, but after the first period of life, the savings of the deceased fall to the surviving part of the population and increases its consumption possibilities.

Stage 2

In stage 2, HIV is diagnosed for the first time. Although the prevalence rate α_1^{act} is still very small, the population has become aware of the contamination risk that they face, although not fully. In particular, agents underestimate the probability of contracting HIV and assume that the probability of infection when old is negligible, i.e. $\alpha_1^{act} > \alpha_1 > \alpha_2 \approx 0$. Infected agents learn about their status only after a diagnostic HIV test. Starting in this phase, testing takes place: a fraction β_1 of all young individuals is randomly selected to be tested. As a result, a fraction $\beta\alpha_1^{act}$ of the young individuals will become aware of its positive status. On the other hand, a fraction $\beta_1(1-\alpha_1^{act})$ receives a negative test and is thus certain to reach the second period.[7] In this phase of the disease, where HIV becomes visible in society, individual savings are negatively affected in the following two ways. First, the fraction $\beta_1\alpha_1^{act}$ of young individuals who know they are infected will no longer save. Second, those young agents who

[6] We also assume that $\alpha_1, \alpha_2, \beta_1,$ and β_2 are independent. Although these are strong assumptions, we choose to keep the model as simple as possible.

[7] For simplicity, we abstract from other sources of mortality in the first period of life.

are not tested perceive to have a lower life expectancy as they now expect to have a lower probability (i.e. $1-\alpha_1$ instead of 1) of reaching the second period. As a result, their savings will decrease.

Stage 3 and 4

In this stage, HIV develops into a serious epidemic. Agents who have been tested negative or who have not been tested at all in the first period, take account of the higher probability of being infected in the second period, i.e. $\alpha_2 > 0$. In particular, if agents in the second period get a positive test result, they will want to buy more medical consumption to fight the consequences of the disease. Therefore, the higher-perceived value of α_2 will engender higher savings by the agents in this group. On the other hand, as the group of positive-tested individuals in the first period increases as well due to the spread of the disease, the group who does not save at all increases in size. In stage 3, the former effect on savings dominates the latter effect, i.e. aggregate savings increase. Stage 4 is defined by the property that the effect of the decrease in savings of the HIV positive agents in period 1 dominates the effect of the increase in savings by the individuals who have a chance of reaching the second period. We also assume that in phases 3 and 4 perceived and actual contamination rates converge, i.e. $\alpha_1 \to \alpha_1^{act}$ and $\alpha_2 \to \alpha_2^{act}$.

2.2. Specification of the model

Expected utility of a young individual who lives in a phase *j* of the epidemic depends on whether he is tested or not, and if tested, on the outcome of the test. The utility of an individual tested HIV positive is:

$$u_1^j(c_1^j, m_1^j) = \xi_i \ln c_1^j + \mu_i \ln m_1^j + \chi_1 \qquad (1)$$

where c (m) represents regular (medical) consumption with prices equal to 1 and p_m respectively. ξ and μ are preference parameters for respectively regular and medical consumption. The suffix to this parameter indicates that the utility of both regular and medical consumption depends on the health position of the individual. In particular, if the individual is HIV infected, indicated by *i*, he derives less utility from regular consumption than if he is healthy, indicated by *h*, but more utility from medical consumption, i.e. $\xi_h > \xi_i$ and $\mu_h < \mu_i$. Consequently, if agents get a positive test, they will substitute medical

consumption for regular consumption. A negative constant z_j is added to indicate that the positive-tested individual suffers from knowing to die prematurely and/or being stigmatized. Expected utility of a negative-tested individual is:

$$u^j(c_1^j, c_2^j, m_1^j, m_2^j) = \xi_h \ln c_1^j + \mu_h \ln m_1^j + \delta u_2^j(c_2^j, m_2^j) \tag{2}$$

where $\delta > 0$ is the discount factor and $u_2^j(c_2^j, m_2^j)$ stands for the expected second-period utility. Untested agents can be HIV-positive nevertheless. However, we implicitly assume that these agents do not have access to the kind of medical consumption that is suited for HIV patients. So, even if untested agents learn to have been infected in a period, they will not be able to consume more medical consumption. We plug this assumption into the model by assuming that a not-tested but infected individual has to take ex ante μ_h as the relevant parameter in the utility function, although ex post μ_i determines the realized utility. The expected utility of untested individuals in period 1 is specified in Equation (3).

$$\begin{aligned} u^j(c_1^j, c_2^j, m_1^j, m_2^j) &= \xi_1 \ln c_1^j + \mu_h \ln m_1^j + (1-\alpha_1)\delta u_2^j(c_2^j, m_2^j) \\ u_2^j(c_2^j, m_2^j) &= \alpha_2\beta_2(\xi_i \ln c_2^j + \mu_i \ln m_2^j - z_{2}) + \alpha_2(1-\beta_2)(\xi_i \ln c_2^j + \mu_h \ln m_2^j) \\ &\quad +(1-\alpha_2)(\xi_h \ln c_2^j + \mu_h \ln m_2^j) \end{aligned} \tag{3}$$

where $\xi_t \equiv \alpha_t\xi_i + (1-\alpha_t)\xi_h$. We assume that individuals who are untested in the first period take part in a mutual insurance system in which the savings of those who decease in the period are distributed among the untested survivors.

Agents only earn an income *w* in the first period and earn interest rate *r* on their savings. Given this and the specified utility function we can derive individual and aggregate savings for all distinguished stages of the spread of the virus.

3. The evolution of savings

Stage 0: $\alpha_j^{act} = \alpha_j = 0; \beta_j = 0,\ j = 1, 2$

If HIV prevalence is zero, individual and aggregate savings are readily found to be equal to:

$$S^0 = s^0 = \frac{\delta}{1+\delta} w \tag{4}$$

where aggregate savings, S^0, equals individual savings, s^0, as the size of a generation has been normalized to one.

Stage I: $\alpha_1^{act} > \alpha_1 = 0; \alpha_2^{act} = \alpha_2 = 0; \beta_j = 0,\ j = 1,\ 2$

HIV unexpectedly shows up. However, as the disease cannot be diagnosed yet, saving behavior does not change, the only difference with phase 0 being that the total savings of the deceased, i.e., $\alpha_1^{act} s^I$, will be distributed among the $(1-\alpha_1^{act})$ survivors.

Stage II: $\alpha_1^{act} > \alpha_1 > \alpha_2 \approx 0; \beta_1 > 0; \beta_2 = 0$

In this period, HIV tests for young individuals become available, and a percentage β_1 of young individuals will be tested. Three different groups become relevant for saving behavior. First, a fraction $\beta_1 \alpha_1^{act}$ of agents, to be indicated by group G1 in the sequel, who have been tested positive, will not save, as in they will not enter the second period. Second, $\beta_1(1-\alpha_1^{act})$ of individuals, group G2, who are sure to reach the second period will save $s^{II}(G2) = \frac{\delta w}{1+\delta}$. Third, the $1-\beta_1$ untested agents, indicated as groups G3 and G4, perceive to have a chance of $1-\alpha_1$ of reaching the second period. Groups G3 and G4 consist of agents that, respectively, do carry and do not carry the virus, but are not tested as being HIV positive or negative. Only ex post, the untested individuals can be identified as belonging to groups G3 or G4. Consequently, they have equal ex ante optimal savings. Maximizing expected utility for the groups G3 and G4 yields their individual savings:

$$s^{II}(G3;G4) = \frac{\delta(1-\alpha_1)}{1+\delta(1-\alpha_1)} w \qquad (5)$$

Aggregating over the groups gives the total savings in stage II of the epidemic:

$$S^{II} = \beta_1(1-\alpha_1^{act})\frac{\delta}{1+\delta} w + (1-\beta_1)\frac{\delta(1-\alpha_1)}{1+\delta(1-\alpha_1)} w \qquad (6)$$

As can be readily seen from Equation 2 and 3, it holds that $S^{II} < S^0$.

Stage III: $\alpha_1^{act} \geq \alpha_1 \geq \alpha_2 > 0, \beta_j > 0,\ j = 1,\ 2$

This third phase distinguishes itself from stage II by the fact that young individuals have become aware of the HIV contamination risk they face in *both* periods of their life. Individuals know that in period 2 they can be tested with a probability β_2 and they understand that a positive HIV status brings along a decline in utility of regular consumption and that medical treatment improves the way of life. This will affect savings of the distinguished groups.

The young agents that are tested HIV positive (group G1), behave the same as in stage 2 and will thus not save. The agents in group G2, who are sure to reach the second period, and the untested agents in group G3 and G4, who perceive to have a probability of $1-\alpha_1$ of reaching the second period, do change their saving behavior. Since they are now aware of the possibility to get positively tested in the second period of their life, they will save more to be able to better cope with the consequences of HIV infection. These 'HIV anticipatory saving' will initially be larger than the decrease in savings due to the risk of not reaching the second period.

For the $\beta_1(1-\alpha_1^{act})$ agents who have been tested negative in the first period (group G2), savings equal:

$$s^{III}(G2) = \frac{\delta\chi}{\delta\chi + \xi_h + \mu_h} w \tag{7}$$

where $\chi \equiv \xi_h + \mu_h + \alpha_2(\xi_i - \xi_h) + \beta_2\alpha_2(\mu_i - \mu_h)$. Comparing the savings of group G2 in stage II and stage III, it can easily be seen that savings is higher in stage III, i.e. $s^{III}(G2) > s^{II}(G2)$ if and only if the following condition holds

$$\xi_i - \xi_h + \beta_2(\mu_i - \mu_h) > 0 \tag{8}$$

Condition (8) implies that the relative decrease in utility of regular consumption when HIV infected is smaller than the relative increase in utility of medical consumption weighted for the fact that individuals can also make use of medical consumption. Thus, in a well established epidemic savings of HIV negative tested individuals (G2) are enhanced, whenever medical consumption is relatively important compared to regular consumption in case tested

HIV positive, under the condition that testing in the second period takes place at a certain level. In the further analyses, we assume that this condition holds.

Untested agents in the first period (group G3 and G4), save for the second period even though some of them will never enter this period. Their savings equal:

$$s^{III}(G3;G4) = \frac{(1-\alpha_1)\delta\chi}{(1-\alpha_1)\delta\chi + \xi_1 + \mu_h} w \qquad (9)$$

Comparing $s^{III}(G3;G4)$ with $s^{II}(G3;G4)$ shows that this phase will generate more savings for groups G3 and G4 than stage 2. Consequently, aggregate savings in stage III, specified in Equation (10) is higher than in stage II.

$$S^{III} = \beta_1(1-\alpha_1^{aat})s^{III}(G2) + (1-\beta_1)s^{III}(G3;G4) \qquad (10)$$

Aggregate savings in stage III may even rise to a level higher than in the situation without HIV, i.e. $S^{III} > S^0$. Whether this inequality actually holds depends on the parameters of the model, the degree of testing in the first period, β_1, being one of the critical parameters. In general, for any given probability of first-period testing, i.e., $0 \le \beta_1 \le 1$, $S^{III} > S^0$ will hold if $\alpha_2 \ge f(\beta_1)$. If testing increases, the number of agents who know for sure not to survive the first period will increase for a given first-period mortality rate. So, the best condition for an increase in savings above the benchmark level is when $\beta_1 = 0$. The worst condition seems to be the case with $\beta_1 = 1$, where all young individuals know their HIV status. To get an idea when savings will increase we consider both cases in turn. If $\beta_1 = 0$ it is straightforward to derive that $S^{III} > S^0$ if:

$$\alpha_2 \ge \frac{\alpha_1}{1-\alpha_1} \frac{\xi_i + \mu_h}{\xi_i - \xi_h + \beta_2(\mu_i - \mu_h)} \equiv f(0) \qquad (11)$$

Obviously, condition (11) can only hold if the perceived mortality rate in the first period α_1 is small enough.

The other extreme case is where $\beta_1 = 1$, i.e. where complete testing takes place in the first period. This takes away all uncertainty on the probability of dying in the first period, and only those who are sure to survive the first period will keep on saving. In this case, savings will increase above the benchmark level, if:

$$\alpha_2 \geq \frac{\alpha_1^{act}(1+\delta)}{1-\alpha_1^{act}(1+\delta)} \frac{\xi_b + \mu_b}{\xi_i - \xi_b + \beta_2(\mu_i - \mu_b)} \equiv f(1) \qquad (12)$$

According to Equations (11) and (12) savings rise to a level above the benchmark level if the perceived and actual first-period mortality rate is small enough, compared to the second-period contamination rate. This makes intuitively sense as the spread of the virus among young individuals decreases their savings, while the expected spread of the virus among old individuals increases savings. So, for a given testing rate β_1 and with a relatively small-perceived infection rate α_1 compared to α_2, aggregate savings may increase.

Stage IV

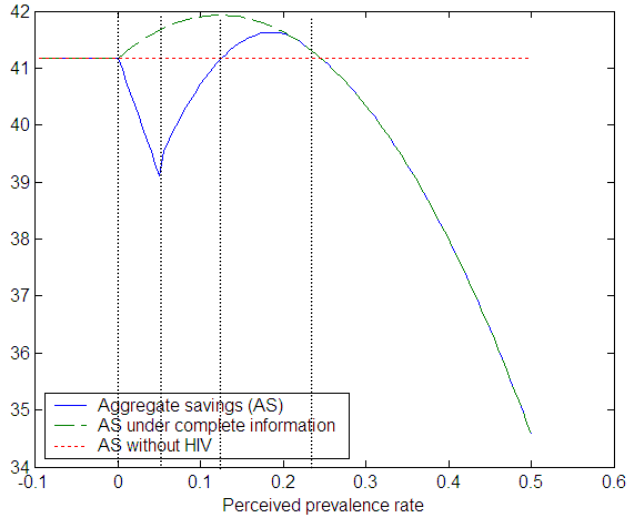
If the actual number of HIV-infected individuals, α_1^{act}, keeps rising, the number of individuals in group G2 will decline. Although individual savings will remain unchanged, the group composition changes, in this case implying that aggregate savings will eventually decrease. Moreover, notice from Equation (9) that with an increase in the perceived contamination rate when young, i.e. α_1, individual savings of untested individuals will decrease as well. In fact, if both α_1 and α_2 increase by the same proportion, then it is easy to see from Equation (9) that the savings-decreasing effect of the current rate α_1 will eventually dominate the savings-increasing effect. In stage IV, prevalence rates are at such levels that the savings-decrease effect dominates.

Figure 2 gives an example of a development of savings over the evolution of HIV/AIDS[8]. The solid line represents the four different phases of the epidemic as specified by the model

[8] In drawing Figure 2, we have assumed that populations gradually become aware of the HIV contamination risk they face. Agents first underestimate the actual HIV contamination risk, but when the disease spreads, actual and perceived HIV contamination risks converge. For the calculations in Figure 2 we assumed this convergence process over time to be specified by $\alpha_1(t) = \lambda\alpha_1^{act}(t) + (1-\lambda)\alpha_1(t-1)$. For α_2, an analogous specification holds.

above. The horizontal part of the line shows the situation without HIV/AIDS, where agents save a certain amount for future consumption (stage 0). Then stage I arrives where the disease overtakes some agents. Because the disease is still unknown, these infected agents are however not aware of their infection. As a result, they unexpectedly die premature, making it impossible for them to optimally use their lifetime resources. Their redundant or unused savings for the second period are transferred to the survivors. In stage II, testing makes it possible for HIV infected agents to know they will not survive the first period. This enables them to optimize lifetime utility by spending all income in the first period. The fall in aggregate savings represents the decline in savings of this particular group of agents. Next, a phase sets in where agents become (gradually) aware of the pervasiveness of the possibility of infection over their whole life. As a result, those who have a chance of surviving the first period will save more to take account of the additional costs in case of being contaminated by the virus in the second period of their life. In this phase, the savings-decreasing effect of higher young-age mortality (i.e. an increase in actual, α_1^{act}, and expected mortality, α_1 is counteracted by the savings-increasing effect of higher expected old-age mortality, α_2, so that savings increase above the benchmark level.

Figure 2: The different phases of aggregate savings due to the spread of HIV



In the figure, this occurs for values of $0.12 \leq \alpha_1^{act} \leq 0.24$. If the spread of HIV continues and manifests itself via an increase of the prevalence rates in both periods, the savings-decreasing effect of young-age mortality will be dominant and savings start to decrease. In Figure 2, the decline of savings sets in after the HIV prevalence rate reaches the value of 24%.

4. The social-welfare effects of testing for HIV

One of the important policy decisions in countries affected by HIV is the frequency of testing, in our model indicated by β_1 for young and by β_2 for old agents, respectively. The question we want to address here is whether intensifying testing directly increases social welfare. That is, we abstract from the (possible) long-run effect of testing on the HIV prevalence rate and analyze the effect of HIV testing on social welfare, using *ex post* individual utility as the relevant criterion.

We assume that implementing a test does not involve any cost. Testing when young resolves the uncertainty on the true values of the parameters in the utility function, making it possible to purchase the utility-maximizing ratio of regular and medical consumption. When tested positive, individuals will no longer have to save for an uncertain future, as they know for sure to die young, i.e. before the second period. However, if the utility function contains a 'fear-of-dying' or 'stigma' parameter, agents experience a negative utility shock if they are actually diagnosed HIV positive and realize that they will die prematurely. On the other hand, if individuals get a negative test result they will save more, as they will reach the second period with certainty. These individuals however, can no longer take part in the longevity insurance scheme, which means that, after surviving the first period, they will no longer get a transfer payment from their deceased contemporaries.

Increasing the frequency of testing during older age does not take away the uncertainty of later infection at the time when the saving decision is made. It does increase, however, the probability that an individual can consume the right amount of medical consumption when he turns out to be infected later in life. The prospect of utility maximizing consumption later in life incites individuals to save more. In this case, this appears to be welfare increasing.

4.1. Testing young individuals

We use *ex post* individual utility as the criterion to evaluate the effects of testing on social welfare. Individuals make their saving decisions at the beginning of the first period of life, however. Social welfare is then defined by:

$$W(\beta_1,\beta_2)=\beta_1[\alpha_1^{act}U(G1)+(1-\alpha_1^{act})U(G2)]+(1-\beta_1)[\alpha_1^{act}U(G3)+(1-\alpha_1^{act})U(G4)] \quad (13)$$

In Equation (13), $U(Gi),(i=1,..,4)$ indicates *ex post* utility of young agents distinguished by both their HIV status and their test status in the first period. In particular, as noted before, the groups $G1$ and $G2$ are composed of the individuals who have been tested HIV positive and negative, respectively. The groups $G3$ and $G4$ consist of the individuals who have not been tested in the first period. In the first period, they may turn out be HIV infected, $G3$, or to be healthy, $G4$. The marginal effect of first-period testing on social welfare obviously depends on the utility difference between tested and untested individuals, as specified in Equation (14):

$$\frac{\partial W(\beta_1,\beta_2)}{\partial \beta_1}=\alpha_1^{act}\big(U(G1)-U(G3)\big)+(1-\alpha_1^{act})\big(U(G2)-U(G4)\big) \quad (14)$$

It is straightforward to derive that for those infected with HIV the utility difference $U(G1)-U(G3)$ can be written as:

$$U(G1)-U(G3)=(\xi_i+\mu_i)\ln\frac{\xi_1+\mu_h+\delta(1-\alpha_1)\chi}{\xi_1+\mu_h}+\left[\xi_i\ln\frac{\xi_i}{\xi_1}+\mu_i\ln\frac{\mu_i}{\mu_h}+(\xi_i+\mu_i)\ln(\frac{\xi_1+\mu_h}{\xi_i+\mu_i})\right]+\tilde{\chi}_1 \quad (15)$$

The first term on the right-hand side of Equation (15) is the utility gain from lower savings. The term in brackets represents the utility gain due to consuming the optimal proportion of regular and medical consumption. The last term is the "stigma" parameter. Obviously, for the agents with a positive HIV-status testing is only utility improving, i.e. $U(G1)-U(G3)>0$, if the "stigma" parameter is small enough. In that case, the utility improving effects of getting the appropriate medical consumption and the prevention of too high savings dominate the stigma effect.

Being tested negative in the first period resolves the uncertainty in this period, but not in the second. Again, the utility improving effect of the revelation of their status is that they are able to purchase the optimal ratio of regular and medical consumption goods (the term in brackets in Equation (16)). On the other hand, if their status is revealed, they can no longer take part in the insurance system that insures them against longevity risk. As a result, the return on their savings will be lower. The effect of testing for this group can be written as:

$$U(G2)-U(G4)=(\xi_h+\mu_h)\ln\frac{w-s(G2)}{w-s(G3;G4)}+$$
$$[\alpha_2^{act}\delta(\xi_i+\mu_i)+(1-\alpha_2^{act})\delta(\xi_h+\mu_h)]\ln\frac{s(G2)}{s(G4)}+ \qquad (16)$$
$$\left[\xi_h\ln\frac{\xi_h}{\xi_1}+(\xi_h+\mu_h)\ln\frac{\xi_1+\mu_h}{\xi_h+\mu_h}\right]$$

where $s(G4)$ represents the savings of individuals from group $G4$, including the transfer from the deceased individuals in group $G3$, i.e. $s(G4)=\frac{s(G3;G4)}{1-\alpha_1^{act}}$.

The first term on the right-hand side of Equation (16) is negative due to the fact that savings will be higher if the individuals know for sure to reach the second period, i.e. $s(G2)>s(G3;G4)$. The next term represents the effect on disposable income in the second period, in case the individual is infected or not infected, respectively. Strikingly, although untested individuals save less than individuals tested HIV negative, if they survive, their disposable income in the second period is higher, i.e. $s(G4)>s(G2)$. This is due to the transfers they receive from the group of deceased individuals, $G3$.

In both periods, individuals tested HIV negative thus appear to have a lower disposable income compared to individuals who turn out to be HIV negative without having been tested. Obviously the last term, representing the utility effect of getting the 'right' consumption ratio when tested HIV negative, is positive again. So, for the group if HIV-negative individuals, testing generates a positive *ex post* welfare effect if this consumption-ratio effect is larger than the disposable income effect.

Notice that when the virus is not widespread yet, i.e. when α_1^{act} is small, more testing might turn out to produce a negative welfare effect, due to the decrease in disposable income of tested individuals. If the virus spreads, the first utility difference in Equation (16) will become relatively more important and the welfare characteristic of testing then depends largely on the relative strength of the fear-of-dying parameter.

4.2. Testing old individuals

Consider now a change of testing frequency in period 2. Changing the frequency of testing will incite all individuals who were tested HIV negative in the first period, or who were not tested at all, to increase their savings. For these groups the increase in savings is motivated by the expected increase in medical consumption when tested HIV positive in the second period of life. A second effect of future testing is the increased probability of being able to consume the right proportion of regular and medical consumption. Notice, however, that *ex post* group $G3$ will not enjoy this positive effect of testing because they die prematurely. For group $G2$ the utilitarian *ex-post* social-welfare effects of a change in β_2 is calculated as:

$$\begin{aligned}\frac{\partial U(G2)}{\partial \beta_2} = {} & (\xi_h + \mu_h + \delta\chi)\alpha_2(1-\beta_2)(\mu_i - \mu_h)\frac{w}{\chi}\frac{\partial S(G2)}{\partial \beta_2} + \\ & \delta\alpha_2\left[\xi_i \ln\frac{\xi_i}{\xi_2} + \mu_i \ln\frac{\mu_i}{\mu_h} + (\xi_i + \mu_i)\ln\frac{\xi_2 + \mu_h}{\xi_i + \mu_i}\right] + \\ & \delta(1-\alpha_2)\left[\xi_h \ln\frac{\xi_h}{\xi_2} + (\xi_h + \mu_h)\ln\frac{\xi_2 + \mu_h}{\xi_h + \mu_h}\right] - \alpha_2\delta z_2\end{aligned} \tag{17}$$

where the terms in brackets are again the utility effects of being able to get the right consumption ratios after having received a positive or a negative test, respectively. Obviously, these terms are positive. The first term indicates the effect of the additional savings on utility for group $G2$. It can be derived that $\partial S(G2)/\partial \beta_2 > 0$ under the assumption that medical consumption generates higher utility if individuals are HIV infected, i.e., $\mu_i - \mu_h > 0$ Given this result, we can infer from the first term on the right-hand side of Equation (17) that the additional savings engendered by a higher testing frequency β_2 leads to a gain in *ex-post* utility. Apparently, by saving more and having more income disposable for financing the higher expected medical consumption individual' utility increase. The only negative effect is then the negative utility shock $-\alpha_2\delta z_2$ produced by the information of being infected, i.e.,

the stigmatization effect. Equation (18) specifies the *ex-post* social-welfare effects of a change in β_2 for group $G4$.

$$\frac{\partial U(G4)}{\partial \beta_2} = (\xi_h + \mu_h + \delta(1-\alpha_1)\chi)\cdot \left[-\frac{\xi_h + \mu_h}{\xi_1 + \mu_h} + \frac{\alpha_2(\xi_i + \mu_i) + (1-\alpha_2)(\xi_h + \mu_h)}{(1-\alpha_1)\chi} \right] \frac{\partial S(G3;G4)}{w\partial \beta_2} + \delta\alpha_2 \left[\xi_i \ln \frac{\xi_i}{\xi_2} + \mu_i \ln \frac{\mu_i}{\mu_h} + (\xi_i + \mu_i) \ln \frac{\xi_2 + \mu_h}{\xi_i + \mu_i} \right] + \delta(1-\alpha_2) \left[\xi_h \ln \frac{\xi_h}{\xi_2} + (\xi_h + \mu_h) \ln \frac{\xi_2 + \mu_h}{\xi_h + \mu_h} \right] - \alpha_2 \delta z_2 \tag{18}$$

Maybe not surprisingly the effects that can be distinguished are qualitatively the same as with group $G2$, i.e. a savings effect (the first term), a consumption effect (the second and third term) and a direct negative utility shock (the last term). It is fairly easy to prove that the effect of higher savings on utility is again positive. Moreover, the two terms in Equation (18) representing the effect of being more able to purchase the correct consumption ratio represent a positive effect as well. So, also for this group testing implies for this group a trade-off between the 'stigmatization' and the opportunity of consuming more according to their medical condition.

Finally, also untested individuals do not survive the first period, i.e., group $G3$, will save more if the frequency of future testing increases. However, they will not experience the higher utility of consumption in the second period. Their increased savings fall due to the surviving members of the untested group, i.e., group $G4$. Therefore, intensifying testing will *ex post* have a negative effect on utility for group $G3$. Notice, however, that this group diminishes in size if the frequency of testing in the first period rises.

5. Conclusion

This paper employed a two-period lifetime optimization model to explain savings by a four-stage non-monotonic process partly supporting Bonnel's (2000) conjecture that the HIV/AIDS affects savings differently in the various stages of the epidemic. We in particular considered two issues: First, how aggregate private household savings react to changes in

HIV incidence in the specified four phases of the epidemic. Second, we analyzed the social-welfare effects of diagnostic testing for HIV. The period of life in which HIV strikes, appears to be an important determinant for both issues.

Regarding savings, if individuals perceive that HIV might predominantly affect them at young age, they will lower savings for old age as the expected lifetime is shortened. However, if individuals start taking account of the fact that HIV might also strike them at an older age, they will start to take more precautions in the sense that they save more in order to be able to purchase the appropriate medical treatment later in life. If the HIV contamination rate among the young is not too large, the 'HIV anticipatory saving effect' will be the dominant force, and lead to an increase in aggregate savings. Aggregate savings might even temporarily rise to a level that is above the benchmark case level without HIV. If this occurs, the general-equilibrium effects described by Young (2005), leading to higher wages and higher welfare for future generations can be strengthened although for this case of rising savings to occur, the mortality rate among the young should be limited. If the spread of HIV among the young aged intensifies, the effect of decreasing old-age savings takes over again and annihilates the HIV anticipatory saving effect in the end. Then the 'gift of the dying' (in the words of Young, 2005) no longer consists of a larger capital stock associated with higher savings, but an increasing scarcity of labor.

Regarding the welfare effects of intensifying HIV testing, the results again largely depend on whether testing takes place when individuals are young or old. When individuals are young, testing resolves (at least partly) the uncertainty on surviving the first period of life. For those individuals tested positive, this implies that there is no longer a need to save for old-age consumption. These individuals are instead able to focus on getting the right medical treatment and thus merely reallocate their disposable income from non-medical to medical consumption. This is obviously utility enhancing whenever the disutility of knowing to die prematurely is relatively low. For HIV negative individuals, the effects of a higher testing frequency are not that clear cut. When tested negative, they can benefit from consuming the correct mix of regular and medical consumption in the first period. However, total consumption in this period will be lower as they know for sure to survive the first period and therefore save more for old age. Moreover, the total return on their savings, and therefore their old-age income, is lower than for untested individuals, because they cannot participate in the insurance scheme. The story is different, however, when the frequency of testing during

old age is at stake. In that case, for all survivors to the second period the uncertainty on their HIV status in the second period will be diminished. As a result, higher savings are now more 'efficient' in the sense that these higher savings can be allocated to the optimal mix of medical and regular consumption with a larger probability.

In conclusion, there is a striking analogy between the effects of HIV on savings and the welfare effects of testing for HIV. In both cases, the effects are negative during young age: HIV decreases savings and testing does not necessarily increase welfare, as tested individuals cannot share in the 'gift of the dying' through a longevity insurance scheme. If individuals perceive a higher probability of HIV contraction later in life, savings may increase and the savings will rise even more if the frequency of testing during old age increases. The higher savings then imply a welfare improvement.

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Annex

Table 1: Statistical model of the change in domestic saving rate

	Period: 1990-1996 (Bonnel (2000))		Period: 1997-2004	
	Estimate	t-statistics	Estimate	t-statistics
Constant	0.46	0.1	-3.13	-0.64
Gross domestic savings (1990)	-0.28**	-2.8	-0.11*	-1.57
Secondary enrolment rate (1990)	-0.10**	-2.0	-0.02	-0.48
Growth rate of GDP per capita (1980-90)	86.60**	2.4	161.53***	4.85
Log of number of phones (1994)	2.49*	1.8	0.68	0.55
Log of HIV prevalence rate (1997)	-1.18	-1.5	0.41	0.51
Log of HIV prevalence rate squared	-0.61**	-2.6	0.20	0.57
Dummy variable for Southern Africa	10.20**	2.2	1.07	0.24

Dependent Variable: change in domestic savings rate