

Focus paper

School of Economics

www.econ.ed.ac.uk

An Equilibrium Model of the African HIV-AIDS Epidemic

Jeremy Greenwood, Philipp Kircher, Cezar Santos and Michèle Tertilt



According to the UNAIDS 2012 report, globally, 34 million people were living with HIV at the end of 2011. HIV/AIDS is a major cause of death, having killed about 1.7 million people in that same year. The number of new infections was even higher (2.5 million), suggesting an even more severe problem in the future. Sexual HIV transmission accounts for the overwhelming majority of the newly infected. The United Nations named combatting HIV/AIDS one of its eight Millennium Development Goals. The natural question is then: what are the effective policies? Prevention policies have been argued to be more cost-effective than treatment¹. The obvious next question is: Which prevention policies have a greater impact?

In a recent research paper Greenwood, Kircher, Santos and Tertilt (2013) use some modern tools of quantitative macroeconomics to shed light on the issue. With a calibrated model, the analysis of several policies is conducted. Earlier purely theoretical work focused on reductions in transmission risk and emphasized that it can lead to higher overall prevalence because people could get excessively risky². In its 2012 report, UNAIDS warns that such “potential risk compensation effects are being closely scrutinized, but the dynamics are complex to track.” The constructed model can be used to study precisely this sort of dynamics.

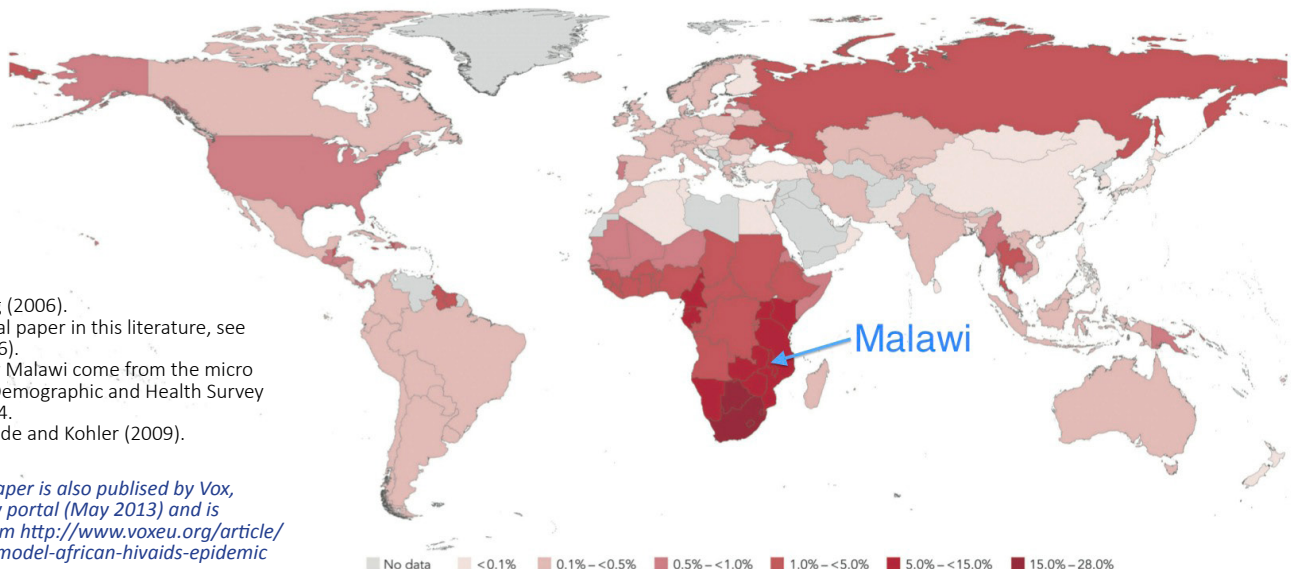
HIV/AIDS in Africa

The continent most affected by the epidemic is Africa (see Figure 1), which hosts about two thirds of all HIV/AIDS infected people. Furthermore, the majority of the HIV-positive population in Africa is female, compared to less than one third

in most developed countries – see World Development Indicators. This is due to the fact that most infections in Africa are due to heterosexual sex, the key mechanism in the study surveyed here.

The Republic of Malawi is an African country with a relatively high HIV/AIDS rate. There is very good data available for Malawi related to both the epidemic and general sexual behavior³. So, the facts are clear: 11.8% of the population is infected (10.2% for males and 13.3% for females). Sexual behavior conducive to the spread of the disease is relatively common in Malawi. For example, condoms were used by less than half of all respondents in their last sexual act. The high prevalence of risky behavior does not necessarily imply that people are uninformed or irrational. In fact, research has shown that people in Malawi are relatively good in assessing their own probability of being infected with HIV⁴.

Figure 1



¹See Canning (2006).

²For a seminal paper in this literature, see Kremer (1996).

³The data for Malawi come from the micro data of the Demographic and Health Survey (DHS) in 2004.

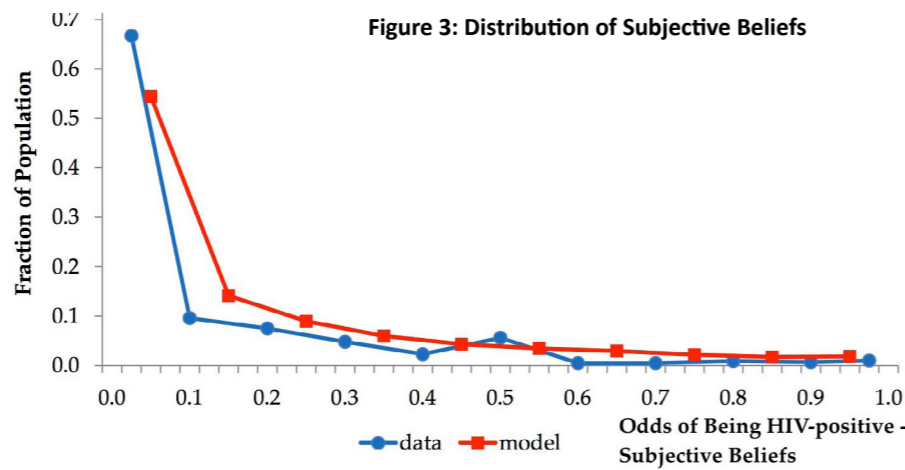
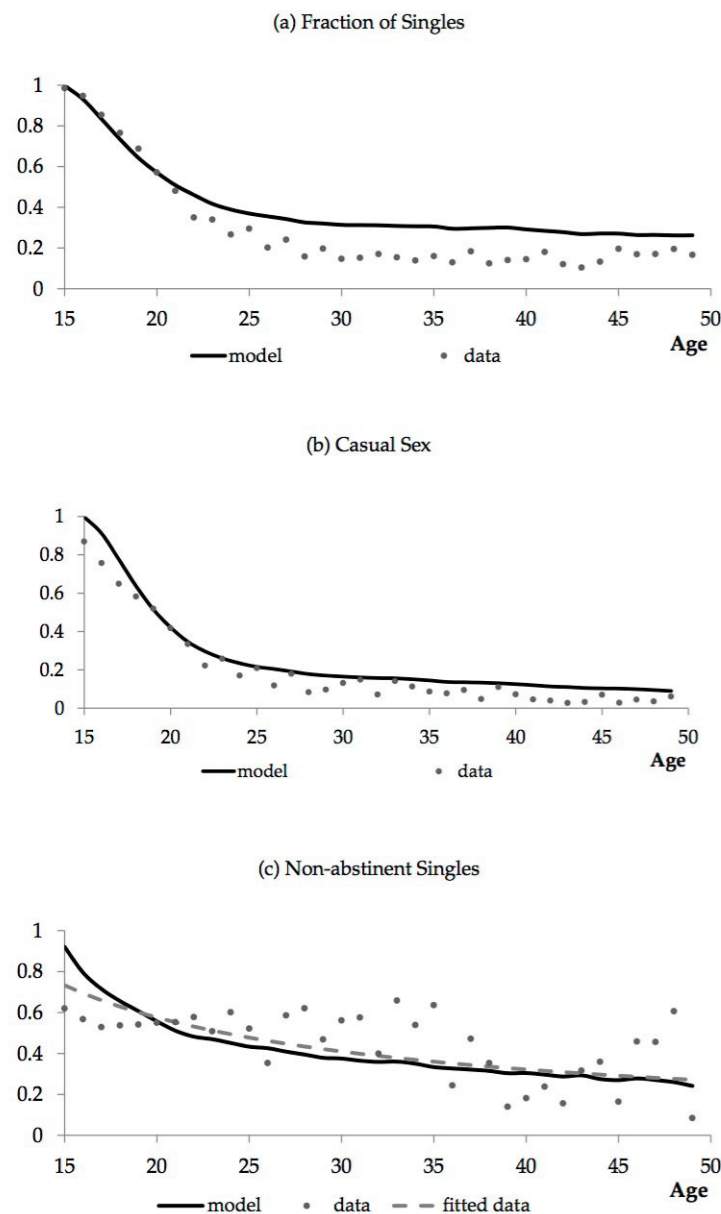
⁴See Delavande and Kohler (2009).

Using Economics to Model the HIV/AIDS Epidemic

Traditionally, two approaches have been taken to study the transmission of HIV/AIDS in Africa: epidemiological studies and field experiments. Epidemiological studies are sophisticated in their treatment of equilibrium but usually lack a feedback loop that captures behavioral responses such as using more condoms when the risk of getting infected is higher. Field experiments are often conducted on a small scale and do not readily allow for the assessment of general equilibrium effects.

The main benefit that economics can bring to the field of epidemiology is the assumption that humans pick their sexual behavior on the basis of a rational benefit/cost calculation. This assumption allows one to study the potential

Figure 2: Sexual Behavior by Age



behavioral responses of individuals with respect to particular policies. Moreover, at the heart of the HIV/AIDS epidemic is an externality, the transmission of a virus. General equilibrium modeling is well suited for the study of externalities. One can analyze how individual shifts in behavior feed back on each other in equilibrium. Thus, the great advantage of choice-theoretic equilibrium modeling is the joint assessment of both behavioral change and equilibrium adjustment in response to proposed policy interventions.

The model constructed in Greenwood, Kircher, Santos and Tertilt (2013) has three main ingredients. First, individuals select the type of sexual activity that they wish to participate in. They do this based upon beliefs about the riskiness of each type of activity. There are four types of sexual activity. A person may have a long-term relationship with a partner. They may also have short-term relationships. These short-term relationships are further subdivided into ones that use a condom and ones that do not. Finally, a person can select to be abstinent.

Second, beliefs about the riskiness of various forms of sexual activity are formed rationally. In the analysis a person's past sexual history is private information. Still, the fact that someone desires, say, a short-run sexual encounter involving no condom may signal something about his past sexual behavior; for example, just think about someone seeking unprotected sex at an African truck stop. Thus, people form rational forecasts about the likelihood of a partner having HIV/AIDS and the odds of getting HIV/AIDS if s/he engages in a particular type of relationship.

Third, the analysis is general equilibrium in nature. There are "markets" for the different types of sexual activities. People have differing tastes over various types of relationships and search accordingly on the various markets to fulfill their desires. They do this recognizing that some of these markets will be riskier than others. For example, a short-term relationship using a condom is safer than one that does not.

The constructed model is then tuned to fit aspects of the Malawian data. In particular, it is calibrated to match the HIV/AIDS rates for men and women separately, the fraction of sexual relationships that are short term, the fraction of short-term sexual encounters that use a condom, and the fraction of deaths that arise from HIV/AIDS. The model's ability to match some lifecycle observations is also examined. These include the HIV/AIDS infection rate by age and the likelihood of a casual

sexual encounter by age (see Figure 2). The distribution of a symptom-free person's belief about being HIV/AIDS infected is also compared to its data counterpart (see Figure 3). The model does very well at matching the data along these dimensions.

Lessons Learnt

The quantitative part of the study highlights the importance to take into account behavioral adjustments and equilibrium effects as they strongly affect the predicted effectiveness of a policy. The relevance of these effects is easy to see when compared to an epidemiological version without behavioral adjustment or small scale interventions without equilibrium effects⁵.

To be more concrete, consider the effects of a general transmission reduction caused by, say, treating other sexually transmitted diseases (STDs). The idea is that the presence of other STDs makes a person more susceptible to contracting HIV. The World Health Organization and UNAIDS consider that "STD management continues to be an essential component of HIV prevention programs and should continue to be a key component for AIDS control programs."⁶

Table 1 shows the simulation results for this policy in the quantitative model. As the transmission risk for both men and women declines by about 13%, the HIV incidence decreases by 1.5 percentage points from 11.5 to 9.9%. Note that this decrease in HIV prevalence masks the finding that agents engage in riskier behavior. The fraction of sex that is casual increases even though there are less singles around. The reason is that the fraction of non-abstinent singles increases. Moreover, out of the singles having sex, condom usage falls. The upshot of this experiment is that agents can dramatically change their behavior in response to the policy and that these behavioral changes can have non-trivial effects, which can be seen as follows.

Compare the benchmark results with the epidemiological version of the experiment. In the epidemiological experiment, the decline in HIV prevalence is much larger to 9.4%, a 0.5% difference compared to the benchmark. The reason for this difference is exactly the lack of behavioral changes described above.

The field experiment goes in the opposite direction: it predicts a much smaller decrease in HIV incidence compared to the benchmark. The reason is that, in the field experiment,

Table 1: Treating Other STDs

	Benchmark	Lower Risk	Epidem.	Small Field
Odds of not getting infected – men	0.940	0.948	0.948	0.948
Odds of not getting infected – women	0.895	0.902	0.902	0.902
HIV/AIDS rate, %	11.5	9.9	9.4	11.1
- Men	10.2	8.7	8.3	9.8
- Women	12.8	11.1	10.6	12.4
Fraction of sex that is casual, %	23.9	24.2	--	24.3
Casual sex with condom, %	33.0	29.7	--	30.9
Singles who have casual sex, %	54.0	57.6	--	56.0
Men who are single, %	42.8	42.1	--	42.6
Women who are single, %	38.7	37.9	--	38.6

the reduced number of infections does not lead to an overall decrease in the population prevalence rate. Therefore, it does not feed back into lower infection rates for the treated population. It is interesting to note that eight of the nine studies of STD treatment for HIV prevention surveyed by Padian et al. (2010) delivered flat results. The simulations presented here highlight a novel reason that may explain these flat results, namely the missing general equilibrium effects in randomized field experiments.

This study also showcases channels beyond the simple effect that some agents increase their risky sexual activity. For example, encouraging marriage may backfire and raise HIV prevalence mainly because some risky people now join the previously safe haven of marriage. While their move towards marriage is usually seen as a

reduction in their own risky behavior, it increases the infection risk for their marriage partners who previously had a higher chance of finding a safe match. Such change in the mixing patterns seriously affects the effectiveness of the policy.

Overall, this research program aims to develop tools to aid researchers and practitioners in their attempts to think through the various channels that are present in different interventions. Research using computational general equilibrium models to assess the implications that interventions might have on the spread of HIV/AIDS (or other diseases) is in its infancy and results have to be interpreted with caution. However, the model does provide a useful tool for elaborate thought experiments to discover areas that might need further investigation.

References

- Canning, David. 2006. "The Economics of HIV/AIDS in Low-Income Countries: The Case for Prevention." *Journal of Economic Perspectives* 20 (3): 212-142.
- Delavande, Adeline and Hans-Peter Kohler. 2009. "Subjective Expectations in the Context of HIV/AIDS in Malawi." *Demographic Research* 20: 817-874.
- Greenwood, Jeremy, Philipp Kircher, Cezar Santos, and Michèle Tertilt. 2013. "An Equilibrium Model of the African HIV/AIDS Epidemic." CEPR Discussion Paper no. 9423. London, Centre for Economic Policy Research.
- Grosskurth, H., F. Moshia, J. Todd, E. Mwijarubi, A. Klokke, K. Senkoro, P. Mayaud, J. Chagalucha, A. Nicoll, J. ka Gina, G. and Newell, K. Mugeye, D. Mabey, and R. Hayes. 1995. "Impact of Improved Treatment of Sexually Transmitted Diseases on HIV Infection in Rural Tanzania: Randomized Controlled Trial." *Lancet* 346 (8974): 530-536.
- Kremer, Michael. 1996. "Integrating Behavioral Choice into Epidemiological Models of AIDS." *The Quarterly Journal of Economics* 111 (2): 549-573.
- Oster, Emily. 2005. "Sexually Transmitted Infections, Sexual Behavior, and the HIV/AIDS Epidemic." *Quarterly Journal of Economics* 120 (2): 467-515.
- Padian, Nancy S., S. I. McCoy, J. E. Balkus, and J. N. Wasserheit. 2010. "Weighing the Gold in the Gold Standard: Challenges in HIV Prevention Research." *AIDS* 24 (5): 621-635.
- UNAIDS. 2012. Report on the Global AIDS Epidemic.
- UNAIDS/WHO. 2000. "Consultation on STD Interventions for Preventing HIV: What is the Evidence?"

⁵In the model, the field experiment assumes that only a small fraction of the population is treated and changes their behavior, but that this fraction interacts in equilibrium with everyone else at pre-existing infection rates. The epidemiological experiment assumes that people make no behavioral adjustments and therefore uses the policy functions from the benchmark calibration but the infection probabilities and assessments of transmission risks are governed by the new transmission probabilities.

⁶See UNAIDS/WHO (2000). For other studies regarding the relationship between HIV/AIDS and other STDs, see Oster (2005) and Grosskurth et al. (1995).