An Equilibrium Model of the African HIV/AIDS Epidemic

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September 2009

Motivation

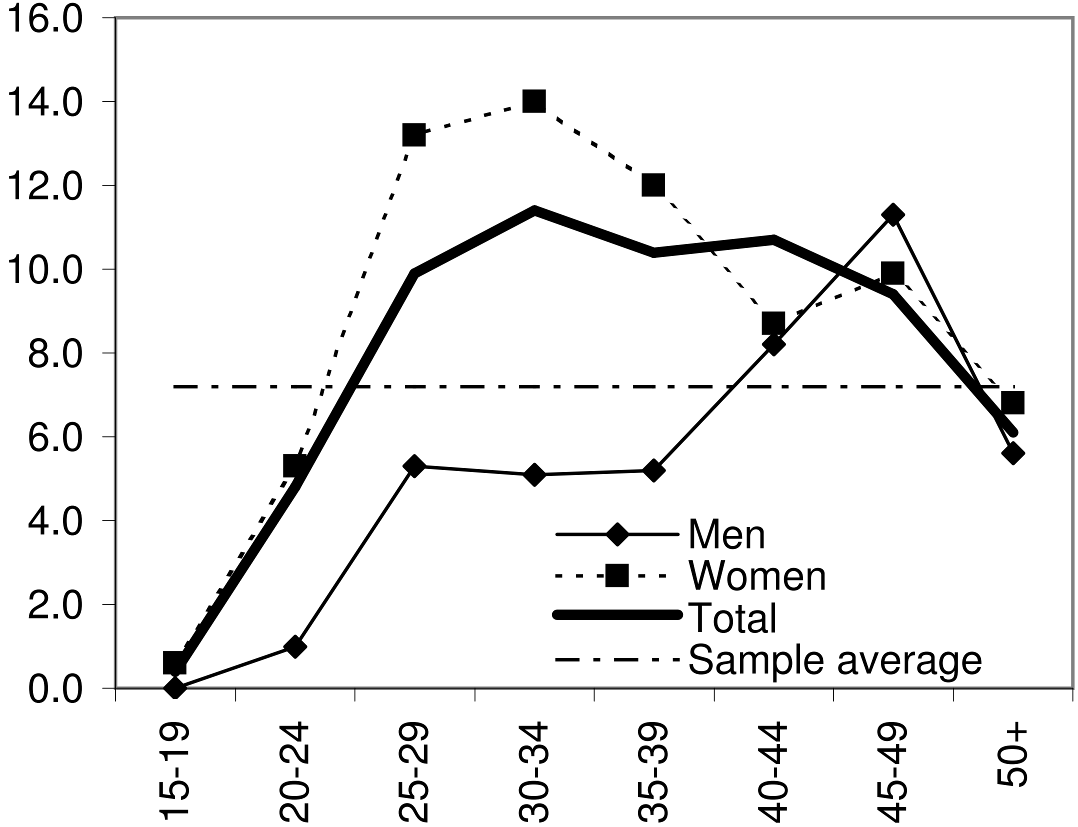
- HIV is killing 2 million people annually world wide. 2.7 million new infections each year.
- Most affected continent: Africa.
- Most transmissions: heterosexual sex.
- About 60% of all HIV+ are female, compared to about 30% in North America and Western Europe.
- Canning (2006) argues for prevention over treatment.
- What are most effective prevention policies?

What We Do

- Build model of sexual behavior.
- Allow for behavioral responses and general equilibrium effects.
- Parameterize model to capture stylized features of sex, marriage, and HIV in Malawi.
- Focus on gender asymmetries.
- Use model to explore prevention policies.
- Main finding: policies may backfire.

Why Focus on Gender Asymmetries?

2006 HIV prevalence by age and sex



Related Literature

- Cross-sectional studies: Oster (QJE 2005), Lakdawalla et al (QJE 2006), Auld et al (BE 2006).
- Large literature using epidemiological simulations.
- Some randomized field experiments: Duflo et al (2006), Thornton et al (AER 2008), Dupas et al (2009).
- Few theoretical studies: Kremer (QJE 1996), Magruder (2008).
- Malawi: de Paula et al (2009), Delavande et al (2008).

Environment

- Rational model of sexual behavior
- Risky behavior choices:
  - sex vs. abstinence
  - casual relationships vs. marriage
  - condom use
- Men and women.
- People differ in attitude towards risky behavior.
- HIV determined in equilibrium.
- Embedded in OLG model w/ stochastic aging.

Model: Sex

- Search effort to find partner.
- Utility from sex: $u > p$.
- All sex within marriage is unprotected.
  Additional utility benefit/cost of LT relationship: ℓ.
- In LT relationship: have sex every period until exogenous break-up (probability ξ) or death.

A married woman comments on her friends extramarital partnerships: "Yes, she does use the condoms to protect herself from diseases because if she takes diseases, she will transmit them to her husband. **She does not protect herself with her husband, for it is a marriage***" (Tawfik and Watkins 2003).*

Market Structure

- Three markets: protected, unprotected, long term.
- Each characterized by a price and the fraction of healthy people: $(t, \bar{\phi}_m, \bar{\phi}_f)$.
- Sequential market structure: go to LT market first, if not matched, can search again in ST market.
- Can search both in unprotected and protected ST markets simultaneously.

Model: HIV

- Transmission risk: $1 - \gamma_u > 1 - \gamma_p$.
  May differ by gender.

- ϕ – prior probability of being healthy.

- Lag from infection to symptoms – probability of showing symptoms conditional on infection is α.

- Lag from symptoms to death: δ_2.

- Assume people with symptoms do not have sex.

Model: Bayesian Updating

- A person does not know whether s/he is sick.
- Use prior belief, the fact that no symptoms occurred, and sex choices to update belief.

Updating when abstinent:

$$\frac{\text{Pr(healthy}|\phi)}{\text{Pr(no symptoms this period}|\phi)} = \frac{\text{healthy}}{\text{healthy or sick w/o symptoms}}$$

$$\frac{\phi}{\phi + (1-\phi)(1-\alpha)} = \phi'$$

Model: Updating after Sex

- short term market:

$$\phi' = \frac{\phi\bar{\phi} + \phi(1-\bar{\phi})\gamma}{\phi\bar{\phi} + \phi(1-\bar{\phi})\gamma + (1-\phi)(1-\alpha) + \phi(1-\bar{\phi})(1-\gamma)(1-\alpha)}$$

- where $\bar{\phi}$ are odds a randomly selected partner (opposite sex) in a given market is healthy.
- Both γ and $\bar{\phi}$ may differ by market (u vs. p) and gender.
- Updating in LT market only relevant after break-up (not allowing affairs makes our life much easier here).

Model: Search Effort

In LT market:

$$V_l = \max_{\pi} \left[\underbrace{\pi \widetilde{V}_l}_{\text{matched}} + \underbrace{(1-\pi)V_s}_{\text{unmatched}} - C_l(\pi) \right]$$

where search cost is: $C(\pi) = \frac{\omega}{1+\kappa} \left(\frac{\pi}{1-\pi} \right)^{1+\kappa}$

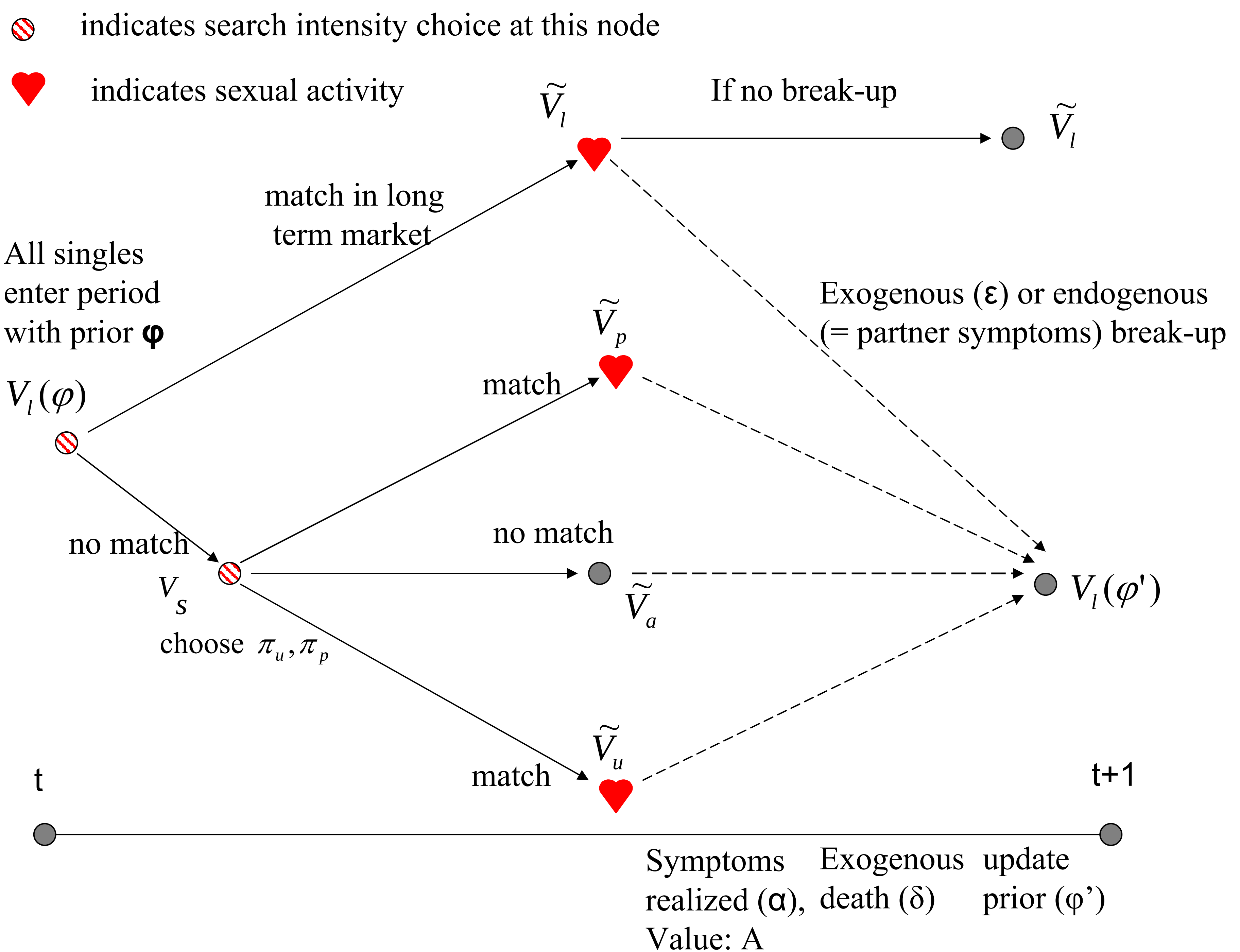
Similar in short term market.

Life-time Value of Unprotected Sex

$$
\begin{aligned}
\widetilde{V}_u(\phi) \; = \; & \frac{(y - t_u)^{1-\sigma}}{1-\sigma} + u \\
& + \{1 - \alpha[(1-\phi) + \phi(1-\bar{\phi}_{f,u})(1-\gamma_u)]\}\beta V_l(\phi') \\
& + \underbrace{\alpha[(1-\phi) + \phi(1-\bar{\phi}_{f,u})(1-\gamma_u)]}_{\text{Pr[symptoms]}}\beta A,
\end{aligned}
$$

with

$$
\phi' = \Phi\left(\phi, \bar{\phi}_{f,u}, \gamma_u\right).
$$


indicates search intensity choice at this node
indicates sexual activity
$\tilde{V}_l$
If no break-up
$\tilde{V}_l$
match in long term market
All singles enter period with prior **φ**
Exogenous (ε) or endogenous (= partner symptoms) break-up
$\tilde{V}_p$
match
$V_l(\varphi)$
no match
no match
V_s
$V_l(\varphi')$
$\tilde{V}_a$
choose π_u, π_p
$\tilde{V}_u$
match
t
t+1
Symptoms realized (α), Value: A
Exogenous death (δ)
update prior (φ')

Model: Demographics

- Measure μ_i of type i agents is born each period.
- Stochastic aging: With probability η, a young person becomes mature.
- Some people die from HIV each period.
- Some people die from natural causes each period (δ). For simplicity, couples “die together.”

Stationary Equilibrium

- Prices adjust to clear all three markets (i.e. # of men having sex in given market = # of women having sex).
- Aggregate HIV rate for each of the three markets is consistent with individual behavior.

Numerical Strategy

Goal: use parameterized version of model to assess prevention policies.

<u>STEP 1:</u> construct numerical benchmark that captures stylized features of sex, marriage, and HIV in Malawi.

a) some parameters chosen based on direct data analogs.

b) remaining parameters chosen to roughly match some key moments.

<u>STEP 2:</u> conduct policy experiments

Focus on qualitative findings.

Malawi Data

- Most data is from DHS 2004.
- Supplemented with data from MDICP (2001, 2004).
- Survey data shows people in Malawi know how HIV gets transmitted and what they can do to reduce risk.

Parameterization (Step 1a)

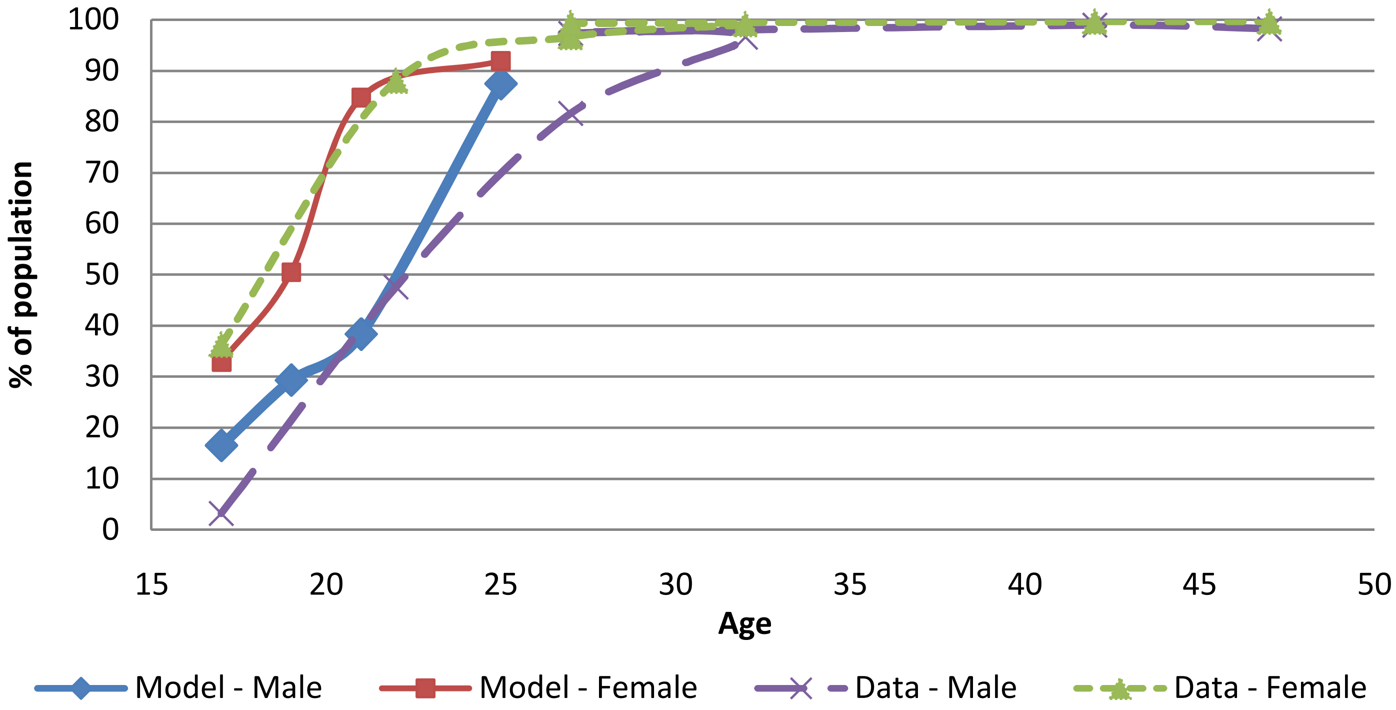
- quarterly model.
- $\epsilon = 0.03$, twice reported divorce risk (b/c polygyny and affairs are not modeled).
- $y = 300$ (quarterly income per working age person).
- $\delta = 0.003$ (non HIV-related death hazard).
- $\gamma_u^m = 0.94$, $\gamma_p^m = 0.98$, $\gamma_u^f = 0.91$, $\gamma_p^f = 0.95$ (corresponds to transmission risk per unprotected sex act of 0.0019 (for men) and 0.0035 (for women).
- α = 0.025 (10 yrs from infection to symptoms).
- δ_2 = 0.125 (2 yrs from symptoms to death).

Parametrization (Step 1b)

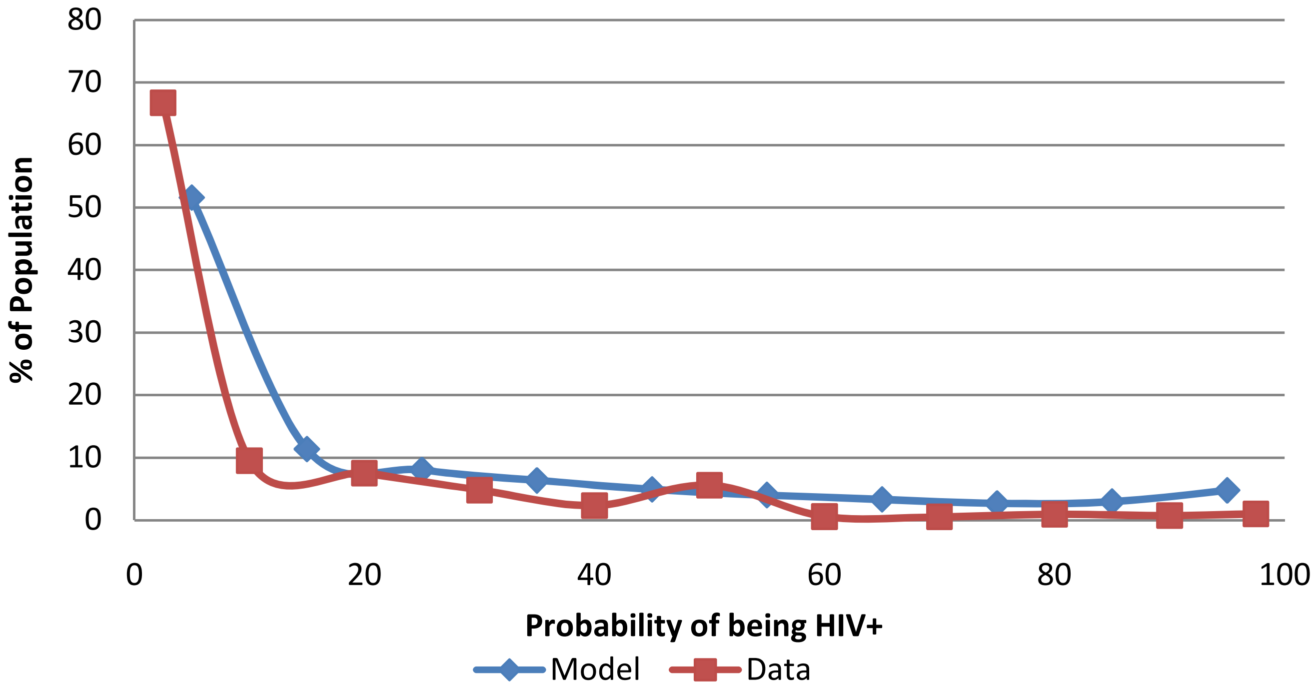
- 2 types of people: $\beta_1 > \beta_2$ (impatient group is small).
- remaining parameters: $A, p, u, \ell, \beta, \iota, \eta, \omega_{ST}, \omega_{LT}, \kappa$

	model	data
HIV rate	12	12
Males	11.4	10.2
Females	13.3	13.3
% singles	28	33
% singles that has casual sex (quarter/4weeks)	51	16
% singles that has casual sex (1 year)	60	37
Fraction of all sex that is casual	16	18
Condom use for casual sex	25	39
% people that die from natural causes	64	54

Fraction Ever Married, by Age



Distribution of Beliefs



HIV Rates across Markets

	Model	Data
Female - short term	46	31
Female - long term	11	13
Female - no sex	7	5
Male - short term	38	16
Male - long term	10	14
Male - no sex	8	2

Prices: 158 (protected), 230 (marriage), 264 (unprotected)

Prevention Policies

- Male Circumcision.
- Treatment of Other STIs.
- Promoting Marriage.

Main finding: all policies have potential to backfire.

Reason: 3 different forces:

- Direct effect (if sex gets safer).
- Behavioral response (people change sexual behavior).
- GE effects (prices and prevalence in different markets).

Male Circumcision May Hurt Women

	benchmark	safer sex for men
γ_u^m	0.94	0.96
HIV rate (men)	11.4	11.1
HIV rate (women)	13.3	15.8
% of men who are single	30.4	50.8
% of women who are single	26.1	41.4
% singles who have casual sex	51.3	68.2
Fraction of sex that is casual	15.6	35.4
% of casual sex with condom	24.8	15.4
transfer, protected	158	166
transfer, unprotected	264	298
transfer, long term	230	283

Note: most empirical studies only measure effect of circumcision on males.

Treatment of other STIs (reduces transmission risk)

	benchmark	small change	large change
female-to-male transmission, γ_u^m	0.94	0.95	0.96
male-to-female transmission, γ_u^f	0.91	0.92	0.93
HIV rate (society)	12.3	18.6	11
% of men who are single	30.4	49.4	52.8
% of women who are single	26.1	42.6	46.6
% singles who have casual sex	51	73	74
Fraction of sex that is casual	15.6	36.5	40.6
% casual sex with condom	24.8	17	14.8

Behavioral change may crowd out gains from risk reduction.

Promoting Marriage and Faithfulness

- What exactly does it mean?
- We explore three different policies
  - Increased in marital joy.
  - Decrease in divorce risk.
  - Decrease in search cost of finding marriage partner.
- We find that lots of interesting things can happen.
- Different ways of promoting marriage have very different effects.
- In particular a) and b) may lead to HIV increase
- Non-monotonicities
- entry vs. exit

Promoting Marriage

	bench	exp 1	exp 2	exp 3
utility from marriage	5	5.5	7	10
HIV rate (society)	12.3	10.5	15.9	9.5
% females who are single	26.1	22.8	23.2	14.9
% males who are single	30.4	26.3	29	15.5
% singles who have casual sex	51.4	46.5	66.9	**75.2**
Fraction of sex that is casual	15.6	12	17	9.3
condom use	24.8	23.7	**16.8**	12.9
transfer, unprotected	264	264	291	163
transfer, long term	230	233	281	137
HIV, male, protected	40	41	29	17
HIV, male, unprotected	35	33	22	12
HIV, male, marriage	10	9	16	11

Conclusion

- Equilibrium model of sexual behavior.
- Captures stylized features of sex, marriage, and HIV in Malawi.
- Policy Experiments: unless perfectly implemented, policies may lead to *more* HIV.
- Reason: more risk-taking behavior, but also change in mixing pattern.
- Gender asymmetries important. Male circumcision may lead to less HIV for males, but more for women.