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Appendix

The structure of the model is represented by the following se of differential equations.

$$\frac{dX_{ki}^{00}}{dt} \quad \Lambda_{ki}(t) \quad \sigma_{ki}X_{ki}^{01} \quad (\mu + \lambda 1_{ki}(t) + \rho_{ki}(t))\, X_{ki}^{00}(t) \quad C_{ki}^{01}(T2) + R_{ki}^{00}(t)$$

$$\frac{dX_{ki}^{10}}{dt} \quad \lambda 1_{ki}(t) X_{ki}^{00}(t) \quad \sigma_{ki}X_{ki}^{11} \quad (\mu + \ 1 \quad \rho_{ki}(t))\, X_{ki}^{10}(t) \quad C_{ki}^{11}(T2) + R_{ki}^{01}(t)(0.2)$$

$$\frac{dX_{ki}^{20}}{dt} \quad \gamma 1 X_{ki}^{10}(t) \quad \sigma_{ki}X_{ki}^{21} \quad (\mu \quad \gamma 2 \quad \rho_{ki}(t))\, X_{ki}^{20}(t) + C_{ki}^{21}(T2)$$

$$\frac{dX_{ki}^{30}}{dt} \quad \gamma 2 X_{ki}^{20}(t) \quad \sigma_{ki}X_{ki}^{31} \quad (\mu \quad \gamma 3 \quad \rho_{ki}(t))\, X_{ki}^{30}(t) + C_{ki}^{31}(T2)$$

$$\frac{dX_{ki}^{01}}{dt} \quad \rho_{ki}(t) X_{ki}^{00}(t \quad (\mu \quad \sigma_{ki} \quad \lambda 2_{ki}(t))\, X_{ki}^{01}(t \quad C_{ki}^{01}(T$$

$$\frac{dX_{ki}^{11}}{dt} \quad \lambda 2_{ki}(t) X_{ki}^{01}(t) \quad \rho_{ki}(t) X_{ki}^{10}(t) \quad (\mu \quad \sigma_{ki} \quad)\, X_{ki}^{11}(t) \quad C_{ki}^{11}(T2$$

$$\frac{dX_{ki}^{21}}{dt} \quad \gamma 1 X_{ki}^{11}(t) \quad \rho_{ki}(t) X_{ki}^{20}(t) \quad (\mu \quad \sigma_{ki} \quad \gamma 2)\, X_{ki}^{21}(t) \quad C_{ki}^{21}(T2)$$

$$\frac{dX_{ki}^{31}}{dt} \quad \gamma 2 X_{ki}^{21}(t) \quad \rho_{ki}(t) X_{ki}^{30}(t) \quad (\mu \quad \sigma_{ki} \quad \gamma 3)\, X_{ki}^{31}(t) \quad C_{ki}^{31}(T2) \qquad (0.8$$

$$\frac{dX_{ki}^{40}}{dt} \quad \gamma 3 X_{ki}^{30}(t) \quad \sigma_{ki}X_{ki}^{41} \quad (\mu \quad \alpha)\, X_{ki}^{40}(t \quad C_{ki}^{41}(T2) \qquad (0.9)$$

$$\frac{dX_{ki}^{41}}{dt} \quad \gamma 3 X_{ki}^{31}(t) - (\mu \quad \sigma_{ki} \quad \alpha)\, X_{ki}^{41}(t) \quad C_{ki}^{41}(T2) \qquad (0.10)$$

Screening and treatment of Gc

With: $C_{ki}^{h1}(T2) \quad C_{ki}\% \cdot F_{k} \quad X_{ki}^{h1}(t) \cdot (t \quad \theta_1), \forall h, k$

$$for \;\; \theta \quad \begin{cases} t & f\ t \neq T2 \\ T2 & \end{cases}$$

Condom use per partnership:

$\beta new_{k,i,j}^{h}(t) \qquad (Cond_{k} \quad (T2)\% \cdot (t \quad \theta_2)) \quad 1 \quad (Cond_{k',j,i}(T1)\% \quad (t \quad \theta_1))\beta_{k,i,j}^{h}$

$\xi new_{k} \qquad Cond_{k',j,i}(T2)\% \quad (t \quad \theta_2)) \qquad (Cond_{k',j,i}(T1)\% \quad (t \quad \theta_1))\xi_{k,i,j},$

$\forall h, k$

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with $Cond_{k',j,i}(t) \quad Cond_{k,i,j}(t)\ \forall k,i,j$

$$\text{'or } \theta_1: \begin{cases} t & \text{if } t \neq T: \\ T1 \quad 1 & \text{if } t \geq T1 \end{cases}$$

$$for\ \ \theta_2: \begin{cases} t & \text{if } t \neq T2 \\ T2 \quad 1 & \text{if } t \geq T2 \end{cases}$$

Here $X_{ki}^{hs}(t)$ represents the number of individuals of sex k(k 1: female; k 2: male) and activity class i (i :low rate of partner change; i 2: higher rates of partner change) in disease states h (HIV status) and s (STD status) at time An individual is in state h 0 if susceptible to HIV in state h = 1 if in phase 1 of HIV infection, in state h 2, or h 3 if in phase 2 and 3 of HIV infection respectively. An individual in state h 4 is diagnosed with full blown AIDS. An individual is susceptible to the STD if s 0 and currently infected with the STD if s 1. C_{ki}% represents the fraction of individuals in risk group k, i screened/diagnosed and treated at time $T2$ (coverage) F_{ki} is the frequency of screening in activity class i of sex k per year. $Cond_{k,i,j}\%(T1)$ and $Cond_{k,i,j}\%(T2)$ are the fraction of individuals k, i who start using condoms in partnership with someone of opposite sex k' and activity class j at time T1 and T2.

An individual susceptible to both infections ($X_{ki}^{00}(t)$) can get infected either by the STD or HIV at a rate $\rho_{ki}(t)$ (eqn 0.7) and $\lambda 1_{ki}(t)$ (eqn 0.8) respectively. It is assumed that HIV positives and negatives are equally likely to acquire an STD infection. However, HIV negative individuals ($X_{ki}^{01}(t)$ or $X_{ki}^{00}(t)$) are more likely to get HIV from HIV' 'STD' $X_{ki}^{11}(t)$, $X_{ki}^{21}(t)$ $X_{ki}^{31}(t)$) partners. S') positive individuals ($X_{ki}^{01}(t)$) are more susceptible to infection with HIV ($\lambda 2_{ki}(t)$) (eqn 0.9). At time t 0 .e. 1980), $\sum_{i=1}^{2} X_{1i}^{00}(0)$ 122605

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and $\sum_{i=}^{2} X_{2i}^{00}(0)$ 115558 and the HIV epidemic is seeded with $X_{11}^{10}(0) = 1$, $X_{12}^{10}(0)$ 2, $X_{21}^{10}(0) = 1$ $X_{22}^{10}(0)$ 1 while the STD is already at its initial equilibrium prevalence before the introduction of HIV. The other state variables are equal to 0. Once infected, an STD positive of sex k and activity class i remains infected and infectious for a period of time of $1/\sigma_{ki}$ respectively after which period, the individual joins the susceptible class again. Whether STD positive or negative, HIV seroconverters remain symptomless for an average period of time $(1/\gamma1+1/\gamma2+1/\gamma3)$ before progressing to the AIDS stage. Individuals in the population die at a natural rate μ (μ=average sexual life expectancy) The AIDS related mortality, α is equal to 1/life expectancy of patient with full blown AIDS.

The per capita rate of STD infection is defined as follows:

$$\rho_{ki}(t) \quad m_{ki}(t) \sum \xi new_{k'ji} \varphi_{kij}(t) \frac{\sum_{h=0}^{3} X_{k'j}^{h1}(t)}{\sum_{hs} X_{k'j}^{hs}(t) \quad \sum_{s} X_{k'j}^{4s}(t)} \tag{0.11}$$

The per capita rates of HIV infection for those withou (STD and with (STD current infection with the cofactor STD are defined as follows:

$$\lambda 1_{ki}(t) \quad m_{ki}(t) \sum \varphi_{kij}(t) \frac{\sum_{h=1}^{3} \beta new_{k'ji}^{h}(X_{k'j}(t)^{h0} + RR_{HIV/STD} \cdot X_{k'j}(t)^{h1}(t))}{\sum_{hs} X_{k'j}^{hs}(t) \quad \sum_{s} X_{k'j}^{4s}(t)} \tag{0.12}$$

$$\lambda 2_{ki}(t) \quad RR_{HIV/STD} \cdot \lambda 1_{ki}(t) \tag{0.13}$$

As seen in equations(0.7-0.8), the rates of infection depend on the annual rate of partner acquisition $(m_{ki}(t))$ at time of an individual of sex k and sexual activity level i; the probability of choosing an infected partner, which is a function of the mixing pattern $\varphi_{kij}(t$

(the probability that a member of class i and sex k has selected a partner of sex k' and class j at time t); the probability that this partne is infected (prevalence of infection in risk group k,i); and the per partner transmission probability of the STD ($\xi new_{k'ji}$) or HIV ($\beta new_{\ \ ji}$) from a partner of sex k', activity class j to a susceptible of sex k and activity class

AIDS patients are assumed not to contribute to transmission because of the severity of their illness. The term $RR_{HIV/STD}$ in (0.13) and in the right hand side of (0.12) represents the relative increase in HIV susceptibility of HIV STD and in infectivity of STD$^+$/HIV$^+$ respectively

New recruits join the susceptible sexually active population at a rate $\Lambda_{ki}(t$ The expression for the new recruits to the sexually active population is:

$$\Lambda_{ki}(t) \quad Q_{ki}RPf\left[X^{01}_{1i}(t \quad \tau) + X_{1i}(t \quad \tau) \quad (1 \quad) \left(X^{10}_{ki}(t\right.\right.$$
$$\left.\left. + X^{11}_{ki}(t \quad + X^{20}_{1i}(t \quad \tau) + X^{21}_{1i} \quad \tau)\right)\right] \tag{0.14}$$

Here Q_{ki} is the initial distribution in sexual activity for each sex in the absence of AIDS induced mortality. R denotes the sex ratio (assumed to be 1:1 at birth which gives R 0.5) f denotes the per capita birth rate of sexually active women f=0.3). P is the proportion of uninfected infants who surviv to join the sexually active age classes[49] ($P = \exp^{-b\tau}$ where τ is the age at sexual maturity (15 years) and b is the death rate over the interval [0,τ]). he net rate of prostitute renewal is given b

$$R^{00}_{ki} \quad \gamma 3 \cdot X^{30}_{ki}(t)/2, for\ k \quad 1, i \quad 2 \tag{0.15}$$

$$R^{00}_{ki} \quad 0, otherwise \tag{0.16}$$

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$$R^{01}_{ki} \quad \gamma 3 \quad X^{31}_{ki}(t)/2 \quad \text{'or } k \quad i \tag{0.17}$$

$$R^{0}_{k} \quad 0, otherwise \tag{0.18}$$

We define the elements of the mixing matrix as[49]

$$\varphi_{kij} \quad \frac{W_{kij}\left(N_{k'j}(t \quad N^{4}_{k'j}(t)\right) m_{k'j}(0)}{\Sigma \quad W_{k} \quad (N \qquad N^{4} \quad t)) \, r \quad 0} \tag{0.19}$$

The W_k lefine a set of weights which represent he preference of someone of sex k in activit class i for someone of the opposite sex in acti ty class

The elements of the mixing matrix $\varphi_{kij}(t$ must satisfy the ollowing cons aint ime t[49]

$$0 \quad \varphi_{kij}(t \tag{0.20}$$

$$\sum \varphi_{kij}(t$$

$$N_{ki}(t) \quad N^{4}_{ki}(t \qquad (t)m_{ki}(\qquad N^{4}_{k'j}(t \quad \varphi_{k'} \quad m_{k'} \tag{0.22}$$

As describe in ref [49] we adopt a procedure whic he nean rate of partner change in he lowest female activity group remains unchanged (for all t) to act as a reference point to lefine a rate o hange as mortality influences population s an structure onditic 0.22) to h and k a the cros produc he preference iatr henc the mixing matrix) shoulc be e ual for males and females (details in re 49])

For Cotonou we used the weights: $W_{111}(1980)$ 3.335, W_1 1980) W_{12} 1980) $W_{122}(1980$ 33, $W_{211}(1980)$ 17,$W_{212}(1980$ and $W_{221}(1980)$ W 2(1980)=6.5. he responding elements of the mixing matrix are given in Table 1. We also usec he following

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recovery rate of Gc: σ 5.5, σ_{12} 8.8, σ_{21} 5.5, σ_{22} 8.8 For the high prevalence scenari

we used the weights: $W_{111}(1980)$ 2, $W_{112}(1980)$ W 1980 1. W $_2(1980)$

$W_{211}(1980)$ 2, $W_{212}(1980)$ =1 and $W_{221}(1980)$ $W_{222}(1980)$ To obtai he same

Gc equilibrium prevalence in 1980 than for Cotonou, the following Gc recovery rates were

used: σ_{11} 6.5, σ_{12}= 8.4, σ_{21} 6.5, σ_{22} 8.4.

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