WEB MATERIAL

The Impact of Screening and Partner Notification on Chlamydia in the United States, 2000 to 2015: Evaluation of Epidemiological Trends Using a Pair-Formation Transmission Model

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Web Appendix 1. Pair Model Structure

1.1 Natural History
The natural history (in Web Figure 1) is represented using the susceptible-infected-susceptible framework, and is presented where infected are divided into asymptomatic (I) and symptomatic (X), and we further separate chlamydia naive (never experiences an infection, S₀) and those who have their first chlamydia infection (I₀, X₀) from those who have recovered from chlamydia (ever infected, now susceptible, Sₙ), and those who have subsequent infections (Iₙ, Xₙ). We assume that the susceptibility of ever infected, Sₙ, is the same as those who are never infected S₀. People can recover from infection either through testing and treatment, or through natural recovery. We assume that symptom status does not affect sexual activity (no reduction in frequency of acts during symptom presence of treatment seeking).

Web Figure 1. Flowchart of the natural history of chlamydia
1.2 Interventions

The model has incorporated the following interventions: rate of testing ($\sigma$), proportion of index cases who are successfully treated ($n$), proportion of their partners who are notified ($g$), and proportion of notified partners who are then successfully (tested and) treated ($r_p$). Parameter for index case testing is stratified by sex (superscript m for male, f for female), symptom status (superscript a for asymptomatic and s for symptomatic) and age (subscript j), and parameter for partner notification is stratified by sex of the index case and age (if there is good evidence that partner notification depends on the symptom status of the index case, this can be also added to the model). Treatment success is separately defined for index case and their partner (which includes both the probability of being tested, and complying with treatment).

When referring to any infected, we use here superscript Y (for $I^0$, $I^\pi$, $X^0$, $X^\pi$) and any susceptible S (for $S^0$, $S^\pi$). The possible outcomes of treating a dually infected heterosexual couple ($P^{YY}$) are presented in Web Figure 2. The framework follows that presented in Heijne (2013, supplement material)(1), and how the respective rates for women and men are calculated is presented in Web Table 1. These are further stratified by symptom status of the index case in the differential equations.
**Web Figure 2.** Outline of the possible outcomes resulting from testing an infected index case with an infected partner.

![Diagram showing the possible outcomes resulting from testing an infected index case with an infected partner.]

**Web Table 1.** Interventions in the model

| Outcome       | Rate for Women                              | Rate for Men            |
|---------------|---------------------------------------------|-------------------------|
| $P_{YY} \rightarrow P_{SS}$ | $\alpha_j \rho g_j^r r_p$                            | $\alpha_j^m \rho g_j^m r_p$ |
| $P_{YY} \rightarrow P_{SY}$  | $\alpha_j \rho g_j^r (1 - r_p) + (1 - g_j^f)$                        | $\alpha_j^m \rho g_j^m (1 - r_p) + (1 - g_j^f)$ |
| $P_{YY} \rightarrow P_{YS}$  | $\alpha_j (1 - r_i) g_j^r r_p$                            | $\alpha_j^m (1 - r_i) g_j^m r_p$ |
| $P_{YY} \rightarrow P_{YY}$  | $\alpha_j (1 - r_i) (g_j^r (1 - r_p) + (1 - g_j^f))$                        | $\alpha_j^m (1 - r_i) (g_j^m (1 - r_p) + (1 - g_j^f))$ |
1.3 Age Structure

The model population is divided into age categories: 15-17, 18-24, 25-39, and 40- years old women and men. The population upper age band is capped at 55 (or similar, we should agree on a sensible age limit to which behavioral and prevalence data still exist). The age structure is illustrated in Web Figure 3. People enter the population in the youngest age group as a sexually active or inactive at the 15-18 year-old women or men who have never experienced an infection. Only sexually active people can form heterosexual pairs. We further assume once people initiate sexual activity in the model, they remain in the sexually active pool until they age out of the model population.

Web Figure 3. Flow chart of the age structure and aging process in the model. Aging is represented with arrows, and the population >25 years old is assumed to be sexually active respective to their age category parameters.
There are limited number of pair compartments (not all possible age-pairs are represented in the model), and the individuals in a pair may not age to the next age category at the same time. To preserve the true aging rate in the model, there are aging-events in a pair that lead to partnership dissolution (if there is no corresponding compartment the pair can age into) as described in Web Figure 4 and Web Table 2 describes how this is applied to the various pairs in the model, and Web Table 3 summarizes the dissolutions events (due to aging)

Web Figure 4. Illustration of aging events in a pair for pairs with 15-18 years old women and 19-24 years old men

\[
\begin{align*}
\alpha_1 &= 1/4 \text{ years} \\
\alpha_2 &= 1/6 \text{ years}
\end{align*}
\]
**Web Table 2.** Aging processes in the different pair combinations. Pair compartments \( j > 4 \) note for mixed-age pairs

| Pair Compartments by Age Group | Aging out of the Pair Compartment Noted in the Difference Equations as \( O_{j_i} \) | Aging in to the Pair Compartment Noted in the Difference Equations as \( \Lambda_{j_i} \) |
|-------------------------------|--------------------------------|----------------------------------|
| **F: 15-17 (j=1) + M: 15-17 (j=1)** | \(- (\alpha'_1 + \alpha'^m_1) \, P_{1i} \) | NA |
| **F: 18-24 (j=2) + M: 18-24 (j=2)** | \(- (\alpha'_2 + \alpha'^m_2) \, P_{2i} \) | \(+ 2\alpha'_1 \alpha^m_1 \, P_{1i} + (\alpha'_1 - \alpha'_2 \alpha'^m_2) \, P_{5i} \) |
| **F: 25-39 (j=3) + M: 25-39 (j=3)** | \(- (\alpha'_3 + \alpha'^m_3) \, P_{3i} \) | \(+ 2\alpha'_2 \alpha^m_2 \, P_{2i} + (\alpha'_2 - \alpha'_3 \alpha'^m_3) \, P_{6i} \) |
| **F: 40-55 (j=4) + M: 40-55 (j=4)** | \(- (\alpha'_4 + \alpha'^m_4) \, P_{4i} \) | \(+ 2\alpha'_3 \alpha^m_3 \, P_{3i} + (\alpha'_3 - \alpha'_4 \alpha'^m_4) \, P_{7i} \) |
| **F: 15-17 (j=1) + M: 18-24 (j=2)**; \( \rightarrow j=5 \) | \(- (\alpha'_1 + \alpha'^m_1) \, P_{5i} \) | \(+ (\alpha'^m_1 - \alpha'_1 \alpha'^m_2) \, P_{4i} \) |
| **F: 18-24 (j=2) + M: 25-39 (j=3)**; \( \rightarrow j=6 \) | \(- (\alpha'_2 + \alpha'^m_3) \, P_{6i} \) | \(+ 2\alpha'_1 \alpha^m_1 \, P_{5i} + (\alpha'_2 - \alpha'_3 \alpha'^m_3) \, P_{2i} \) |
| **F: 25-39 (j=3) + M: 40-55 (j=4)**; \( \rightarrow j=7 \) | \(- (\alpha'_3 + \alpha'^m_4) \, P_{7i} \) | \(+ 2\alpha'_2 \alpha^m_3 \, P_{6i} + (\alpha'_3 - \alpha'_4 \alpha'^m_4) \, P_{3i} \) |

*) Special case when both individuals in a pair will age out: \( 2\alpha'_1 \alpha'^m_1 \, P_{4i} \); they will age out of the model as a pair, whilst the pair will dissolve in other cases.
**Web Table 3.** Aging processes in the unpaired compartments

| Age Group | Aging out from the Current Unpaired Compartment. | Aging in from the Previous Unpaired Compartment. | Dissolution of Partnership into Unpaired Groups Due to Aging Events. |
|-----------|-------------------------------------------------|-------------------------------------------------|---------------------------------------------------------------|
| F: 15-17  | $-\alpha_1^f F_1$                               | NA                                              | $+ (\alpha_2^m - \alpha_1^f \alpha_2^m) P_{5i}$ |
| M: 15-17  | $-\alpha_1^m M_1$                               | NA                                              | $+ (\alpha_1^f - \alpha_1^m \alpha_2^m) P_{1i}$ |
| F: 18-24  | $-\alpha_2^f F_2$                               | $+\alpha_1^f F_1$                              | $+ (\alpha_1^f - \alpha_1^m \alpha_2^m) P_{4i}$ |
| M: 18-24  | $-\alpha_2^m M_2$                               | $+\alpha_1^m M_1$                              | $+ (\alpha_2^f - \alpha_2^m \alpha_3^m) P_{2i}$ |
| F: 25-39  | $-\alpha_3^f F_3$                               | $+\alpha_2^f F_2$                              | $+ (\alpha_2^f - \alpha_2^m \alpha_3^m) P_{3i}$ |
| M: 25-39  | $-\alpha_3^m M_3$                               | $+\alpha_2^m M_2$                              | $+ (\alpha_3^f - \alpha_3^m \alpha_4^m) P_{5i}$ |
| F: 40-55  | $-\alpha_4^f F_4$                               | $+\alpha_3^f F_3$                              | $+ (\alpha_3^f - \alpha_3^m \alpha_4^m) P_{5i}$ |
| M: 40-55  | $-\alpha_4^m M_4$                               | $+\alpha_3^m M_3$                              | $+ (\alpha_4^m - \alpha_4^m \alpha_5^m) P_{6i}$ |

Aging rate for women and men ($\alpha_j^f$ and $\alpha_j^m$) is the same for a given age group (j), but for clarity these are differentiated with the superscripts. Assumptions: given there is an age-dependent partnerships dissolution rate (and that we do not have data on dissolution of long-term partnerships), this determines the partnership dissolution. We are modeling pair formation in more detail as described below.
1.4 Partnerships, Overview

As outlined in Web Figure 3, people can exist in three different relationship types (which impact their sexual activity): never had sex (not sexually active) in the two youngest age groups (15-18, 19-24), unpaired (single people) who can form casual partners (modeled as frequency dependent partnerships) and which represent short-term relationships, and long-term partnerships, which are governed by set of rules defined below.

There is a change in sexual activity defined by age (younger having higher activity than older), and partnership status (long-term vs casual), but we assumed people stay in their respective activity class (high or low activity). There is a population-average decrease in sexual activity in older ages, but cessation of sexual activity is not explicitly modeled.

1.5 Pair Formation

Long-term partnerships are represented with pair compartments. Pairs are formed within one's own risk group (i). There are 7 possible pair combinations by age group, j, as presented in Web Table 4. Partnerships are preferably formed within their own age group with some partnerships formed with younger women and older men resulting in asymmetry for pairing. Pair formation parameters were set to represent data from the United States (parameters in Web Appendix 4, Web Table 5, illustration in Web Figure 5).

Web Table 4. Age mixing between age groups. j signals the age group, and for j>4, the pairs have across age group pairing. Mixing across ages occurs only with a younger woman and an older man (e.g. F, j=1 + M, j=5)

|                | M 15-17 (j=1) | M 18-24 (j=2) | M 25-39 (j=3) | M 40-55 (j=4) |
|----------------|---------------|---------------|---------------|---------------|
| F 13-17 (j=1) |                | j=5; proportional only | -             | -             |
|                | preference + proportional |                      |               |               |
| F 18-24 (j=2) | -             | j=2; preference + proportional only | j=6; proportional only | -             |
| F 25-39 (j=3) | -             | -             | j=3; preference + proportional | j=7; proportional only |
| F 40-55 (j=4) | -             | -             | -             | j=4; preference + proportional |
Web Figure 5. Model pair formation set so that it represents data (CPS 2015 and 2016) on long-term partnerships in the United States (defined as married or cohabiting partnerships)

Footnote for Web Figure 5: Due to age structure asymmetry in the model (with long-term partnerships possible between younger women and older men but not the reverse), the model is overestimating the proportion of women in long-term partnerships among those aged 15-24 and 25-39 and underestimating the proportion of women in long-term partnerships for the group aged 40-54.

Data: Current Population Survey (CPS) estimates of cohabiting and married partnerships in the United States (2,3); W: Women, M: Men
1.5.1 Mixing

Pair forming and preferences may differ across age groups, and we first take the geometric mean of the preferred age mixing \( (e_j) \) given one's pair formation "tendency" \( (\varrho_j) \). For the assortative mixing component, \( \varphi^a_j \):

for \( j=1:4 \)
\[
\varphi^a_j = \sqrt{e_j^f \cdot \varrho_j \cdot e_j^m \cdot \varrho_j}
\]

And proportional mixing, \( \varphi^p_j \)

for \( j=1 \)
\[
\varphi^p_{j=1} = \sqrt{(1 - e_j^f) \cdot \varrho_j \cdot (e_j^m) \cdot \varrho_j}
\]

for \( j=2:3 \)
\[
\varphi^p_{j=2:3} = \sqrt{(1 - e_j^f) \cdot \varrho_j \cdot (1 - e_j^m) \cdot \varrho_j}
\]

for \( j=4 \)
\[
\varphi^p_{j=4} = \sqrt{e_j^f \cdot \varrho_j \cdot (1 - e_j^m) \cdot \varrho_j}
\]

for \( j=5:7 \)
\[
\varphi^p_{j=5:7} = \sqrt{(1 - e_{j-4}^f) \cdot \varrho_{j-4} \cdot (1 - e_{j-3}^m) \cdot \varrho_{j-3}}
\]
1.5.2 Actualized Pair Formation Rate to Paired Compartments

Actualized pair formation rate for each unpaired compartment is determined by the mixing and availability of unpaired people. Pairs are formed from the unpaired people following the principle of harmonic mean, as described by Kretzschmar (1994)(4):

\[
\phi_{FM} = 2\rho \frac{F_M}{\Sigma F + \Sigma M}
\]

M notes unpaired men and F unpaired women who are sexually active. Z represents a summary of the different disease states, for a given sex, age and risk group. Pairs are selected preferentially from your own age group \((\psi_j)\) "pool" after which the remaining selection happens from unpaired people in the "proportional pool". The proportional pool includes the other unpaired age groups also selecting from the given type of sex and age group; see Web Table 6.

To calculate the pair formation rate for each disease stage in an age group, a generalized pair formation rate \(\phi_{jW}^{GW}\) is defined where and W and Q symbolize any disease state in the model.

for j=1:4

\[
\phi_{jW}^{GW} = 2\psi_j F_j^W M_j^W \frac{F_j^W M_j^W}{U_{prop,j}} + 2\psi_j F_j^W M_j^W \frac{F_j^W M_j^W}{U_{prop,j}}
\]

for j=5:7

\[
\phi_{jW}^{GW} = 2\psi_j F_{j-4}^W M_{j-3,i}^W \frac{F_{j-4}^W M_{j-3,i}^W}{U_{prop,j}}
\]

Where, the pool of available unpaired people available for the proportionate mixing is calculated as follows (note that \(U_{prop,j} = U_{prop,j+4}\)):

\[
U_{prop,j=1} = \sum_z F_{1i}^z + \sum_z M_{1i}^z + \sum_z M_{2i}^z
\]

\[
U_{prop,j=2} = \sum_z F_{3i}^z + \sum_z M_{3i}^z + \sum_z F_{2i}^z + \sum_z M_{4i}^z
\]

\[
U_{prop,j=3} = \sum_z F_{3i}^z + \sum_z M_{3i}^z + \sum_z F_{2i}^z + \sum_z M_{4i}^z
\]

\[
U_{prop,j=4} = \sum_z F_{4i}^z + \sum_z M_{4i}^z + \sum_z F_{3i}^z
\]
1.5.3 Actualized Pair Formation Rate from the Unpaired Compartments

To calculate the actualized rate of pair formation rate from the unpaired compartments, \( \rho'_j \), and \( \rho''_j \), for women and men, respectively, we need to tally the rate of pair formation occurring at each time-step given the age-mixing and availability of unpaired partners of the preferred type.

For women:

for \( j=1 \)

\[
\rho'_{j=1,l} = 2\varphi_1 \frac{\sum_z M_{1i}^z}{\sum_z F_{1i}^z + \sum_z M_{1i}^z} + 2\varphi_2 \frac{\sum_z M_{2i}^z}{U_{prop,j=1}} + 2\varphi_3 \frac{\sum_z M_{3i}^z}{U_{prop,j=5}}
\]

for \( j=2 \)

\[
\rho'_{j=2,l} = 2\varphi_2 \frac{\sum_z M_{2i}^z}{\sum_z F_{2i}^z + \sum_z M_{2i}^z} + 2\varphi_3 \frac{\sum_z M_{3i}^z}{U_{prop,j=2}} + 2\varphi_4 \frac{\sum_z M_{4i}^z}{U_{prop,j=6}}
\]

for \( j=3 \)

\[
\rho'_{j=3,l} = 2\varphi_3 \frac{\sum_z M_{3i}^z}{\sum_z F_{3i}^z + \sum_z M_{3i}^z} + 2\varphi_4 \frac{\sum_z M_{4i}^z}{U_{prop,j=3}} + 2\varphi_5 \frac{\sum_z M_{4i}^z}{U_{prop,j=7}}
\]

for \( j=4 \)

\[
\rho'_{j=4,l} = 2\varphi_4 \frac{\sum_z M_{4i}^z}{\sum_z F_{4i}^z + \sum_z M_{4i}^z} + 2\varphi_5 \frac{\sum_z M_{4i}^z}{U_{prop,j=4}}
\]

For men:

for \( j=1 \)

\[
\rho''_{j=1,l} = 2\varphi_1 \frac{\sum_z M_{1i}^z}{\sum_z F_{1i}^z + \sum_z M_{1i}^z} + 2\varphi_2 \frac{\sum_z M_{1i}^z}{U_{prop,j=1}}
\]
for $j=2$

$$\rho_{j=2,n} = 2\varphi_1 \frac{\sum_z F_{z1}^Z}{\sum_z F_{z1}^Z + \sum_z M_{z1}^Z} + 2\varphi_2 \frac{\sum_z F_{z2}^Z}{U_{\text{prop},j=2}} + 2\varphi_3 \frac{\sum_z F_{z1}^Z}{U_{\text{prop},j=5}}$$

for $j=3$

$$\rho_{j=3,n} = 2\varphi_3 \frac{\sum_z F_{z31}^Z}{\sum_z F_{z31}^Z + \sum_z M_{z31}^Z} + 2\varphi_3 \frac{\sum_z F_{z31}^Z}{U_{\text{prop},j=3}} + 2\varphi_3 \frac{\sum_z F_{z31}^Z}{U_{\text{prop},j=6}}$$

for $j=4$

$$\rho_{j=4,n} = 2\varphi_4 \frac{\sum_z F_{z41}^Z}{\sum_z F_{z41}^Z + \sum_z M_{z41}^Z} + 2\varphi_4 \frac{\sum_z F_{z41}^Z}{U_{\text{prop},j=4}} + 2\varphi_7 \frac{\sum_z F_{z41}^Z}{U_{\text{prop},j=7}}$$

### 1.6 Pair Dissolution

Partnership duration is determined by the pair dissolution rate $\gamma_{ji}$. and aging events. For this analysis pair dissolution, described in the difference equations as $\gamma_{ji}$ is set at zero, and the dissolution events are driven by the aging events described in tables. We do not know the true rate of partnership dissolution, and duration of long-term partnerships is a function of formation and dissolution. We set the partnership formation and age mixing to produce patterns observed in the United States.

Aging events are described in more detail in section 1.3.

### 1.7 Force of Infection

Chlamydia transmission can happen within a pair where one partner is infected. In pairs the transmission probability during a time step is dependent on number of acts in a time step ($n_{ji}$), transmission probability in an act ($b$), the proportion of acts where condom is used ($u_{ji}$), and the efficacy of condom use against transmission ($e$). For this analysis, condom use was set to zero, and the acts represent unprotected sex.

Transmission probability from female to male is defined as:

$$\beta_{ji}^{F} = 1 - (1 - b)^{n_{ji}}(1 - u_{ji})^n(1 - e)^{n_{ji}}$$

And from male to female, accounting for a higher relative risk of transmission $R_m$

$$\beta_{ji}^{M} = 1 - (1 - R_m b)^{n_{ji}}(1 - u_{ji})^n(1 - e)^{n_{ji}}$$
For casual partnerships, $\beta_{ji}^{cm}$ and $\beta_{ji}^{cf}$, this corresponds to transmission probability per partnership (with instantaneous partnership formation and dissolution, modeled as frequency dependent force of infection), whereby the casual contacts consist of $n_{ji}^c$ acts per partnership, and $u_{ji}^c$ defines the proportion of acts where condom is used (set to zero for this analysis; assuming modeled acts are unprotected sex). Although in the model casual partnerships are implemented as instantaneous they are approximating a short-term relationship and transmission risk from that.

The generalized force of infection equation, $\lambda_{ji}^c$, for casual partnerships by age (j), risk (i) and relationship status (t, for unpaired having casual partnerships and paired having concurrent casual partnership) is modeled as frequency dependent, and mixing is proportional to the partnerships offered by the opposite sex, noted with $m_{jit}^c$ depending on the partnerships offered by the opposite sex, noted as $'$. In the difference equations $\lambda_{ji}^c$ and $\lambda_{ji}^f$, mark for unpaired and paired people casual partnerships, respectively, for women and the same, $\lambda_{ji}^m$ and $\lambda_{ji}^{m'}$, for men.

$$\lambda_{ji}^c = c_{ji}^c \beta_{ji}^{cm} \sum_{jit} m_{jit}^c \frac{Y_{jit}^c}{N_{jit}^c}$$

$c_{ji}^c$ notes for casual partners for unpaired single people, and force of infection for the concurrent casual partners among the paired people is modeled similarly, but with a different partner change rate for concurrency $c_{ji}^f$. The number of partnerships between men and women are balanced using the Garnett-Anderson method, with balance set to 0.5 (equal balance by both sexes).(5)
1.8 Time-Varying Parameters

1.8.1 Chlamydia Testing and Screening

We assumed that testing rate of chlamydia among patients with symptoms has not changed over time.

We wanted a flexible curve able to capture potential changes in screening, and have used a modified Bezier curve:

\[ Y_j(t) = (1-t)^3P_0 + 3(1-t)^2tP_1 + 3(1-t)t^2P_2 + t^3P_3 \]

Control points of the Bezier curve are defined as

\[ P_0 = y_0 \]
\[ P_1 = (-5y_0 + 18y_1 - 9y_2 + 2y_3) / 6 \]
\[ P_2 = (-2y_0 - 9y_1 + 18y_2 - 5y_3) / 6 \]
\[ P_3 = y_3 \]

For the increasing screening scenario the middle control points were constrained so that they were between the start and end control points as

\[ y_1 = y_0 + (y_3 - y_0 \text{ Beta}(1,1)) \]
\[ y_2 = y_1 + (y_3 - y_1 \text{ Beta}(1,1)) \]

For the less constrained scenario the control points were defined as independent priors, but restrained so that the subsequent control points were higher than the first, e.g.

\[ y_1 = y_0 + y_1 \]

We assume that men's screening rate is proportional to women \( Y_j(t) \) of the same age group.

In addition, in the difference equations the testing rate incorporates the test sensitivity, so that any testing rate

\[ \sigma(t) = \sigma(t) * \text{sens}(t) \]
1.8.2 Test Sensitivity and Case Reporting

Test sensitivity and reporting of diagnosed cases were modeled as logistic growth. \( K \) defines the upper limit and \( R_0 \) defines the starting condition and \( r \) the increase per time step.

\[
R(t) = \frac{K R_0 e^{rt}}{K R_0 (e^{rt} - 1)}
\]

1.8.3 Changes in Rate of Sexual Initiation among 15-18 Years Old Individuals

The change was modeled as a linear change in the proportion of the population entering the model as sexually experienced, and change in the rate sexual debut among the model 15-18 years old individuals. Where we define the start estimate as \( D_1 \) and a relative change to this as \( D_2 \).

\[
D(t) = (D_1 D_2 - D_1) t + D_1
\]
Web Appendix 2. Difference Equations

These are generalized equations displaying the components across age (j) and risk (i) groups.

For the two youngest age groups (15-18 and 19-24), a proportion of the age-class (1-p) is not sexually active ($S^-$), and this is represented as a separate compartment. B tallies the number of people removed from the model due to aging out of the model, and these returned to the model population in the youngest age group as susceptible individuals to retain a steady population size.

F describes single women compartments, M describes the single men compartments and P describes the heterosexual pairs where the superscripts note the infection status of the people in a pair with the first letter describing women and the second men in a given pair. For force of infection $\lambda^f$ and $\lambda^m$ differentiate the force of infection for unpaired single people (former) and for paired people having concurrent partners (latter).

Equations for the chlamydia susceptible unpaired population are described below.

for j=1 ; 15-18 year-olds who are sexually not active (~):

$$\frac{d}{dt} F_{1i}^{-S^0} = (1 - p_i^f)(B^f) - (\alpha_i^f + \omega_i^f) F_{1i}^{-S^0}$$

$$\frac{d}{dt} M_{1i}^{-S^0} = (1 - p_i^m)(B^m) - (\alpha_i^m + \omega_i^m) M_{1i}^{-S^0}$$

for j=1 ; 15-18 year-olds who are sexually active:

$$\frac{d}{dt} F_{1i}^{S^0} = p_i^f (B^f) + \omega_i^f F_{1i}^{-S^0} - (\alpha_i^f + \rho_i^f + \lambda_i^f) F_{1i}^{S^0} + \sum_{m_i} y_{1i} P_{1i}^{S_0 m} + \sum_{m_i} y_{5i} P_{5i}^{S_0 m} + \Delta_i^f$$

$$\frac{d}{dt} M_{1i}^{S^0} = p_i^m (B^m) + \omega_i^m M_{1i}^{S^0} - (\alpha_i^m + \rho_i^m + \lambda_i^m) M_{1i}^{S^0} + \sum_{m_i} y_{1i} P_{1i}^{S_0 m} + \Delta_i^m$$

for j=2; 19-24 year-olds:

$$\frac{d}{dt} F_{2i}^{-S^0} = \alpha_i^f F_{1i}^{-S^0} - (\alpha_i^2 + \omega_i^2) F_{2i}^{-S^0}$$
\[
\frac{d}{dt} P_{2i}^S = \alpha_1 F_{2i}^o + \omega_2 F_{2i}^- - (\alpha_2 + \rho_{2i} + \lambda_{2i}^F) P_{2i}^S + \sum_{m} \gamma_{2i} P_{2i}^{S_m} + \sum_{m} \gamma_{6i} P_{6i}^{S_m} + \Delta_{2i}^f
\]

\[
\frac{d}{dt} M_{2i}^{S^o} = \alpha_1^m M_{2i}^{S^o} - (\alpha_2^m + \omega_2^m) M_{2i}^{S^o}
\]

\[
\frac{d}{dt} P_{3i}^S = \alpha_3^f (P_{3i}^- + P_{3i}^o) - (\alpha_3 + \rho_{3i}^f + \lambda_{3i}^F) P_{3i}^S + \sum_{m} \gamma_{3i} P_{3i}^{S_m} + \sum_{m} \gamma_{6i} P_{6i}^{S_m} + \Delta_{3i}^f
\]

\[
\frac{d}{dt} M_{3i}^{S^o} = \alpha_3^m (M_{3i}^- + M_{3i}^o) - (\alpha_3^m + \rho_{3i}^m + \lambda_{3i}^M) M_{3i}^{S^o} + \sum_{m} \gamma_{3i} P_{3i}^{S_m} + \sum_{m} \gamma_{6i} P_{6i}^{S_m} + \Delta_{3i}^m
\]

for \(j=3\); 25-39 years old, where everyone is sexually active:

\[
\frac{d}{dt} P_{4i}^S = \alpha_4^f F_{3i}^o - (\alpha_4^f + \rho_{4i}^f + \lambda_{4i}^F) P_{4i}^S + \sum_{m} \gamma_{4i} P_{4i}^{S_m} + \Delta_{4i}^f
\]

\[
\frac{d}{dt} M_{4i}^{S^o} = \alpha_4^m (M_{3i}^- + M_{3i}^o) - (\alpha_4^m + \rho_{4i}^m + \lambda_{4i}^M) M_{4i}^{S^o} + \sum_{m} \gamma_{4i} P_{4i}^{S_m} + \sum_{m} \gamma_{6i} P_{6i}^{S_m} + \Delta_{4i}^m
\]

for \(j=4\); 40-54 years old:

In the non-naive unpaired compartments, to make the equations generalizable across the age categories, the following rules are added:

- For women, \(a_j^f = 1\) when \(j<4\) and \(a_j^f = 0\) when \(j=4\) (women in the oldest age group form partnerships with only men of the same age group). For men \(a_j^m = 1\) when \(j>1\) and \(a_j^m = 0\) when \(j=1\) (youngest age group forms partnership with only women of the same age group).
- \(\kappa_j = 1\) when \(j>1\) and \(\kappa_j = 0\) when \(j=1\) (rate of aging from the previous compartment)
for \( j = 1:4 \)

Women who are not in a pair:

\[
\frac{d}{dt} F^{i0}_{ji} = \kappa'_j \alpha^f_{j-1} F^{i0}_{j-1} - (\alpha^f_j + \mu^f_j + \rho^f_j + \gamma^f_j + v^f) F^{i0}_{ji} + (1 - f^f) \lambda^f_{ji} F^{i0}_{ji} + \sum_{m} \gamma_{ji} P^{i0m}_{ji} + \alpha'_j \sum_{m} \gamma_{j+4,i} F^{i0m}_{j+4,i} + \Delta^f_{ji}
\]

\[
\frac{d}{dt} F^{X0}_{ji} = \kappa'_j \alpha^f_{j-1} F^{X0}_{j-1} - (\alpha^f_j + \mu^f_j + \rho^f_j + \lambda^f_j) F^{X0}_{ji} + f^f \lambda^f_{ji} F^{X0}_{ji} + \sum_{m} \gamma_{ji} P^{X0m}_{ji} + \alpha'_j \sum_{m} \gamma_{j+4,i} P^{X0m}_{j+4,i} + \Delta^f_{ji}
\]

\[
\frac{d}{dt} F^{Sn}_{ji} = \kappa'_j \alpha^f_{j-1} F^{Sn}_{j-1} - (\alpha^f_j + \mu^f_j + \rho^f_j + \gamma^f_j + v^f) F^{Sn}_{ji} + (1 - f^f) \lambda^f_{ji} F^{Sn}_{ji} + \sum_{m} \gamma_{ji} P^{Snm}_{ji} + \alpha'_j \sum_{m} \gamma_{j+4,i} P^{Snm}_{j+4,i} + \Delta^f_{ji}
\]

\[
\frac{d}{dt} F^{In}_{ji} = \kappa'_j \alpha^f_{j-1} F^{In}_{j-1} - (\alpha^f_j + \mu^f_j + \rho^f_j + \gamma^f_j + v^f) F^{In}_{ji} + (1 - f^f) \lambda^f_{ji} F^{In}_{ji} + \sum_{m} \gamma_{ji} P^{Imm}_{ji} + \alpha'_j \sum_{m} \gamma_{j+4,i} P^{Imm}_{j+4,i} + \Delta^f_{ji}
\]

\[
\frac{d}{dt} F^{Xn}_{ji} = \kappa'_j \alpha^f_{j-1} F^{Xn}_{j-1} - (\alpha^f_j + \mu^f_j + \rho^f_j + \lambda^f_j) F^{Xn}_{ji} + f^f \lambda^f_{ji} F^{Xn}_{ji} + \sum_{m} \gamma_{ji} P^{Xnm}_{ji} + \alpha'_j \sum_{m} \gamma_{j+4,i} P^{Xnm}_{j+4,i} + \Delta^f_{ji}
\]

Men who are not in a pair:

\[
\frac{d}{dt} M^{i0}_{ji} = \kappa'_j \alpha^m_{j-1} M^{i0}_{j-1} - (\alpha^m_j + \mu^m_j + \rho^m_j + \gamma^m_j + v^m) M^{i0}_{ji} + (1 - f^m) \lambda^m_{ji} M^{i0}_{ji} + \sum_{f} \gamma_{ji} P^{f0}_{ji} + \alpha'_j \sum_{f} \gamma_{j+3,i} P^{f0}_{j+3,i} + \Delta^m_{ji}
\]

\[
\frac{d}{dt} M^{X0}_{ji} = \kappa'_j \alpha^m_{j-1} M^{X0}_{j-1} - (\alpha^m_j + \mu^m_j + \rho^m_j + \gamma^m_j + v^m) M^{X0}_{ji} + (1 - f^m) \lambda^m_{ji} M^{X0}_{ji} + \sum_{f} \gamma_{ji} P^{X0}_{ji} + \alpha'_j \sum_{f} \gamma_{j+3,i} P^{X0}_{j+3,i} + \Delta^m_{ji}
\]

\[
\frac{d}{dt} M^{Sn}_{ji} = \kappa'_j \alpha^m_{j-1} M^{Sn}_{j-1} - (\alpha^m_j + \mu^m_j + \rho^m_j + \lambda^m_j) M^{Sn}_{ji} + (1 - f^m) \lambda^m_{ji} M^{Sn}_{ji} + \sum_{f} \gamma_{ji} P^{Sn}_{ji} + \alpha'_j \sum_{f} \gamma_{j+3,i} P^{Sn}_{j+3,i} + \Delta^m_{ji}
\]
\[
\frac{d}{dt} M_{ji}^{in} = \kappa_j' \alpha_{j-1}^{m} M_{j-1}^{in} - (\alpha_j^{m} + \mu_j^{m} + \rho_j^{m} + \sigma_j^{ma} + v^{m})M_{ji}^{in} + (1 - f^{m})\lambda_j^{m} M_{ji}^{sn} + \sum_{f_l} \gamma_{ji}^{f} p_{j}^{f,n} + \alpha'_j \sum_{f_l} y_{j+3,i}^{f} p_{j+3,i}^{f,n} + \Delta_{ji}^{m}
\]

\[
\frac{d}{dt} M_{ji}^{xn} = \kappa_j' \alpha_{j-1}^{m} M_{j-1}^{xn} - (\alpha_j^{m} + \mu_j^{m} + \rho_j^{m} + \sigma_j^{ms} + v^{m})M_{ji}^{xn} + f^{m} \lambda_j^{m} M_{ji}^{sn} + \sum_{f_l} \gamma_{ji}^{f} p_{j}^{f,xn} + \alpha'_j \sum_{f_l} y_{j+3,i}^{f} p_{j+3,i}^{f,xn} + \Delta_{ji}^{m}
\]

There are 36 pair combinations (6 possible states in the natural history model) further stratified by age mixing (j=1:7) and risk (i=1:2).

\[
\frac{d}{dt} p_{ji}^{s,s_0} = A_{ji} - O_{ji} + (1 - (\alpha_j^{f} + \lambda_j^{m})) \phi_{ji}^{s,s_0} - (y_{ji} + \lambda_j^{f} + \lambda_j^{m}) p_{ji}^{s,s_0}
\]

\[
\frac{d}{dt} p_{ji}^{s,q_0} = A_{ji} - O_{ji} + (1 - (\beta_j^{f} + \lambda_j^{m})) \phi_{ji}^{s,q_0} + (1 - f^{m})\lambda_j^{m} (\phi_{ji}^{s,q_0} + p_{ji}^{s,q_0}) - (y_{ji} + \beta_j^{f} + r_j \sigma_j^{ma} + v^{m} + \lambda_j^{f}) p_{ji}^{s,q_0}
\]

\[
\frac{d}{dt} p_{ji}^{s,x_0} = A_{ji} - O_{ji} + (1 - (\beta_j^{f} + \lambda_j^{m})) \phi_{ji}^{s,x_0} + f^{m} \lambda_j^{m} (\phi_{ji}^{s,x_0} + p_{ji}^{s,x_0}) - (y_{ji} + \beta_j^{f} + r_j \sigma_j^{ms} + v^{m} + \lambda_j^{f}) p_{ji}^{s,x_0}
\]

\[
\frac{d}{dt} p_{ji}^{s,S} = A_{ji} - O_{ji} + (1 - (\alpha_j^{f} + \lambda_j^{m})) \phi_{ji}^{s,S} + (r_j \sigma_j^{ms} + v^{m}) (p_{ji}^{s,x_0} + p_{ji}^{s,S}) + (r_j \sigma_j^{ma} + v^{m}) (p_{ji}^{s,q_0} + p_{ji}^{s,S})
\]

\[
\frac{d}{dt} p_{ji}^{S,q_0} = A_{ji} - O_{ji} + (1 - (\alpha_j^{f} + \lambda_j^{m})) \phi_{ji}^{S,q_0} + (r_j \sigma_j^{fs} + v^{f}) (p_{ji}^{x,S} + p_{ji}^{x,q_0}) + (r_j \sigma_j^{fa} + v^{f}) (p_{ji}^{s,q_0} + p_{ji}^{s,S}) - (y_{ji} + \lambda_j^{f} + \lambda_j^{m}) p_{ji}^{S,q_0}
\]

\[
\frac{d}{dt} p_{ji}^{s,x_0} = A_{ji} - O_{ji} + (1 - (\beta_j^{f} + \lambda_j^{m})) \phi_{ji}^{s,x_0} + f^{m} \lambda_j^{m} (\phi_{ji}^{s,x_0} + p_{ji}^{s,x_0}) - (y_{ji} + \beta_j^{f} + r_j \sigma_j^{ms} + v^{m} + \lambda_j^{f}) p_{ji}^{s,x_0}
\]

\[
\frac{d}{dt} p_{ji}^{s,S_0} = A_{ji} - O_{ji} + (1 - (\beta_j^{f} + \lambda_j^{m})) \phi_{ji}^{s,S_0} + (r_j \sigma_j^{fs} + v^{f}) (p_{ji}^{x,S_0} + p_{ji}^{x,x_0}) + (r_j \sigma_j^{fa} + v^{f}) (p_{ji}^{s,q_0} + p_{ji}^{s,S}) - (y_{ji} + \lambda_j^{f} + \lambda_j^{m}) p_{ji}^{s,S_0}
\]

\[
\frac{d}{dt} p_{ji}^{S,q_0} = A_{ji} - O_{ji} + (1 - (\alpha_j^{f} + \lambda_j^{m})) \phi_{ji}^{S,q_0} + (r_j \sigma_j^{fs} + v^{f}) (p_{ji}^{x,S} + p_{ji}^{x,q_0}) + (r_j \sigma_j^{fa} + v^{f}) (p_{ji}^{s,q_0} + p_{ji}^{s,S}) - (y_{ji} + \lambda_j^{f} + \lambda_j^{m}) p_{ji}^{S,q_0}
\]
\[
\frac{d}{dt} p_j^{s,n,x_0} = A_{ji} - O_{ji} + (1 - (\beta_{ji} + \lambda_{ji})) \phi_{ji}^{s,n,x_0} + f^m \lambda_{ji}^{m} (\phi_{ji}^{s,n,x_0} + p_{ji}^{s,n,x_0}) + (\sigma_{ji}^{fa} r_i (g_{ij}(1 - r_p) + (1 - g_{ij})) + \sigma_{ji}^{ms} (1 - r_i) g_{ij}^{m} r_p + v^f) (p_{ji}^{s,n,x_0} + p_{ji}^{s,n,x_0}) + (\sigma_{ji}^{fs} r_i (g_{ij}(1 - r_p) + (1 - g_{ij})) + \sigma_{ji}^{ms} (1 - r_i) g_{ij}^{m} r_p

+ v^f) (p_{ji}^{s,n,x_0} + p_{ji}^{s,n,x_0}) - (y_{ji} + \beta_{ji}^f + r_i \sigma_{ji}^{ms} + v^m + \lambda_{ji}^m) p_{ji}^{s,n,x_0}
\]

\[
\frac{d}{dt} p_j^{s,n} = A_{ji} - O_{ji} + (1 - (\beta_{ji} + \lambda_{ji})) \phi_{ji}^{s,n} + (1 - f^m) \lambda_{ji}^{m} (\phi_{ji}^{s,n} + p_{ji}^{s,n}) + (\sigma_{ji}^{fa} r_i (g_{ij}(1 - r_p) + (1 - g_{ij}))

+ \sigma_{ji}^{ma} (1 - r_i) g_{ij}^{m} r_p + v^f) (p_{ji}^{s,n} + p_{ji}^{s,n}) + (\sigma_{ji}^{fa} r_i (g_{ij}(1 - r_p) + (1 - g_{ij})) + \sigma_{ji}^{ma} (1 - r_i) g_{ij}^{m} r_p + v^f) (p_{ji}^{s,n} + p_{ji}^{s,n})

- (y_{ji} + \beta_{ji}^f + r_i \sigma_{ji}^{ms} + v^m + \lambda_{ji}^m) p_{ji}^{s,n}
\]

\[
\frac{d}{dt} p_j^{s,x_0} = A_{ji} - O_{ji} + (1 - (\beta_{ji} + \lambda_{ji})) \phi_{ji}^{s,x_0} + f^m \lambda_{ji}^{m} (\phi_{ji}^{s,x_0} + p_{ji}^{s,x_0}) + (\sigma_{ji}^{fa} r_i (g_{ij}(1 - r_p) + (1 - g_{ij}))

+ \sigma_{ji}^{ma} (1 - r_i) g_{ij}^{m} r_p + v^f) (p_{ji}^{s,x_0} + p_{ji}^{s,x_0}) + (\sigma_{ji}^{fa} r_i (g_{ij}(1 - r_p) + (1 - g_{ij})) + \sigma_{ji}^{ma} (1 - r_i) g_{ij}^{m} r_p + v^f) (p_{ji}^{s,x_0} + p_{ji}^{s,x_0})

- (y_{ji} + \beta_{ji}^f + r_i \sigma_{ji}^{ms} + v^m + \lambda_{ji}^m) p_{ji}^{s,x_0}
\]

\[
\frac{d}{dt} p_j^{s,x_0} = A_{ji} - O_{ji} + (1 - (\beta_{ji} + \lambda_{ji})) \phi_{ji}^{s,x_0} + (1 - f^f) \lambda_{ji}^{f} (\phi_{ji}^{s,x_0} + p_{ji}^{s,x_0}) + (\gamma_{ji} + \beta_{ji}^m + r_i \sigma_{ji}^{fa} + v^f + \lambda_{ji}^m) p_{ji}^{s,x_0}
\]

\[
\frac{d}{dt} p_j^{p^{0,0}} = A_{ji} - O_{ji} + \phi_{ji}^{p^{0,0}} + (1 - f^f) (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{s,x_0} + p_{ji}^{s,x_0}) + (1 - f^m) (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{p^{0,0}} + p_{ji}^{p^{0,0}}) + (\sigma_{ji}^{fa} (1 - r_i) g_{ij}^{f}(1 - r_p) + (1 - g_{ij}))

+ \sigma_{ji}^{ma} (1 - r_i) g_{ij}^{m} r_p + v^f) (p_{ji}^{p^{0,0}} + p_{ji}^{p^{0,0}}) + (\sigma_{ji}^{fa} (1 - r_i) g_{ij}^{f}(1 - r_p) + (1 - g_{ij})) + \sigma_{ji}^{ma} (1 - r_i) g_{ij}^{m} r_p + v^f) (p_{ji}^{p^{0,0}} + p_{ji}^{p^{0,0}})

- (y_{ji} + \beta_{ji}^f + r_i \sigma_{ji}^{ms} + v^m + \lambda_{ji}^f) p_{ji}^{p^{0,0}}
\]

\[
\frac{d}{dt} p_j^{p^{0,x_0}} = A_{ji} - O_{ji} + \phi_{ji}^{p^{0,x_0}} + (1 - f^f) (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{s,x_0} + p_{ji}^{s,x_0}) + f^m (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{p^{0,x_0}} + p_{ji}^{p^{0,x_0}}) + (\sigma_{ji}^{fa} (1 - r_i) g_{ij}^{f}(1 - r_p) + (1 - g_{ij}))

+ \sigma_{ji}^{ma} (1 - r_i) g_{ij}^{m} r_p + v^f + \lambda_{ji}^m) p_{ji}^{p^{0,x_0}}
\]

\[
\frac{d}{dt} p_j^{s,n,x_0} = A_{ji} - O_{ji} + (1 - (\beta_{ji} + \lambda_{ji})) \phi_{ji}^{s,n,x_0} + (1 - f^m) \lambda_{ji}^{m} (\phi_{ji}^{s,n,x_0} + p_{ji}^{s,n,x_0}) + (\sigma_{ji}^{fa} r_i (g_{ij}(1 - r_p) + (1 - g_{ij}))

+ \sigma_{ji}^{ma} (1 - r_i) g_{ij}^{m} r_p + v^f) (p_{ji}^{s,n,x_0} + p_{ji}^{s,n,x_0}) + (\sigma_{ji}^{fa} r_i (g_{ij}(1 - r_p) + (1 - g_{ij})) + \sigma_{ji}^{ma} (1 - r_i) g_{ij}^{m} r_p + v^f) (p_{ji}^{s,n,x_0} + p_{ji}^{s,n,x_0})

- (y_{ji} + \beta_{ji}^f + r_i \sigma_{ji}^{ms} + v^m + \lambda_{ji}^f) p_{ji}^{s,n,x_0}
\]
\[ \frac{d}{dt} p_{ji}^{\sigma \alpha} = A_{ji} - O_{ji} + (1 - (\beta_{ji}^m + \lambda_{ji}^m)) \phi_{ji}^{\sigma \alpha} + (1 - f') \lambda_{ji}^f (\phi_{ji}^{\sigma \alpha} + P_{ji}^{\sigma \alpha}) + (\sigma_{ji}^{fa}(1 - r_i) g_{ji}^{\alpha} r_p + \sigma_{ji}^{ma} r_i (g_{ji}^m(1 - r_p) + (1 - g_{ji}^m)) + v^m (P_{ji}^{\alpha \alpha} + P_{ji}^{\alpha \alpha}) - (y_{ji} + \beta_{ji}^m + r_i \sigma_{ji}^{fa} + v^f + \lambda_{ji}^m) P_{ji}^{\sigma \alpha} \]

\[ \frac{d}{dt} p_{ji}^{\rho \alpha} = A_{ji} - O_{ji} + \phi_{ji}^{\rho \alpha} + (1 - f') (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{\rho \alpha} + P_{ji}^{\rho \alpha}) + (1 - f^m) (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{\rho \rho} + P_{ji}^{\rho \rho}) + (\sigma_{ji}^{fa}(1 - r_i) (g_{ji}^f(1 - r_p) + (1 - g_{ji}^f)) + \sigma_{ji}^{ma} (1 - r_i) (g_{ji}^m(1 - r_p) + (1 - g_{ji}^m)) \]

\[ \frac{d}{dt} p_{ji}^{\alpha \alpha} = A_{ji} - O_{ji} + \phi_{ji}^{\alpha \alpha} + (1 - f') (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{\alpha \alpha} + P_{ji}^{\alpha \alpha}) + (1 - f^m) (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{\sigma \sigma} + P_{ji}^{\sigma \sigma}) + (\sigma_{ji}^{fa}(1 - r_i) (g_{ji}^f(1 - r_p) + (1 - g_{ji}^f)) + \sigma_{ji}^{ma} (1 - r_i) (g_{ji}^m(1 - r_p) + (1 - g_{ji}^m)) \]

\[ \frac{d}{dt} p_{ji}^{\alpha \sigma} = A_{ji} - O_{ji} + \phi_{ji}^{\alpha \sigma} + (1 - f') (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{\alpha \sigma} + P_{ji}^{\alpha \sigma}) + (1 - f^m) (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{\sigma \sigma} + P_{ji}^{\sigma \sigma}) + (\sigma_{ji}^{fa}(1 - r_i) (g_{ji}^f(1 - r_p) + (1 - g_{ji}^f)) + \sigma_{ji}^{ma} (1 - r_i) (g_{ji}^m(1 - r_p) + (1 - g_{ji}^m)) \]
\[
\frac{d}{dt} p_{i}^{m} = A_{ji} - O_{ji} + \phi_{ji}^{m} + (1 - f'_{ji})(\beta_{ji}' + \lambda_{ji}')(\phi_{ji}^{s} + P_{ji}^{sm}) + (1 - f^{m})(\phi_{ji}^{m} + \lambda_{ji}^{m})(\phi_{ji}^{s} + P_{ji}^{sm}) + (\sigma_{j}^{m} (1 - \tau_{i}) g_{ij}' (1 - \tau_{p}) + (1 - g_{ij}')(1 - \tau_{i}) g_{ij}^{m} (1 - \tau_{p}) + (1 - g_{ij}')) p_{ji}^{m} - (g_{ji} + \tau_{i} \sigma_{j}^{f}) + \tau_{i} \sigma_{j}^{ma} + u' + u^{m}) p_{ji}^{m}
\]

\[
\frac{d}{dt} p_{ji}^{x} = A_{ji} - O_{ji} + \phi_{ji}^{x} + (1 - f'_{ji})(\beta_{ji}' + \lambda_{ji}')(\phi_{ji}^{s} + P_{ji}^{sm}) + (1 - f^{m})(\phi_{ji}^{m} + \lambda_{ji}^{m})(\phi_{ji}^{s} + P_{ji}^{sm}) + (\sigma_{j}^{m} (1 - \tau_{i}) g_{ij}' (1 - \tau_{p}) + (1 - g_{ij}')(1 - \tau_{i}) g_{ij}^{m} (1 - \tau_{p}) + (1 - g_{ij}')) p_{ji}^{x} - (g_{ji} + \tau_{i} \sigma_{j}^{f}) + \tau_{i} \sigma_{j}^{ma} + u' + u^{m}) p_{ji}^{x}
\]

\[
\frac{d}{dt} p_{ji}^{x0} = A_{ji} - O_{ji} + \phi_{ji}^{x0} + f'_{ji}(\beta_{ji}' + \lambda_{ji}')(\phi_{ji}^{s} + P_{ji}^{sm}) + (1 - f^{m})(\phi_{ji}^{m} + \lambda_{ji}^{m})(\phi_{ji}^{s} + P_{ji}^{sm}) + (\sigma_{j}^{m} (1 - \tau_{i}) g_{ij}' (1 - \tau_{p}) + (1 - g_{ij}')(1 - \tau_{i}) g_{ij}^{m} (1 - \tau_{p}) + (1 - g_{ij}')) p_{ji}^{x0} - (g_{ji} + \tau_{i} \sigma_{j}^{f}) + \tau_{i} \sigma_{j}^{ma} + u' + u^{m}) p_{ji}^{x0}
\]

\[
\frac{d}{dt} p_{ji}^{x0s0} = A_{ji} - O_{ji} + \phi_{ji}^{x0s0} + f'_{ji}(\beta_{ji}' + \lambda_{ji}')(\phi_{ji}^{s} + P_{ji}^{sm}) + (1 - f^{m})(\phi_{ji}^{m} + \lambda_{ji}^{m})(\phi_{ji}^{s} + P_{ji}^{sm}) + (\sigma_{j}^{m} (1 - \tau_{i}) g_{ij}' (1 - \tau_{p}) + (1 - g_{ij}')(1 - \tau_{i}) g_{ij}^{m} (1 - \tau_{p}) + (1 - g_{ij}')) p_{ji}^{x0s0} - (g_{ji} + \tau_{i} \sigma_{j}^{f}) + \tau_{i} \sigma_{j}^{ma} + u' + u^{m}) p_{ji}^{x0s0}
\]

\[
\frac{d}{dt} p_{ji}^{x0s} = A_{ji} - O_{ji} + \phi_{ji}^{x0s} + f'_{ji}(\beta_{ji}' + \lambda_{ji}')(\phi_{ji}^{s} + P_{ji}^{sm}) + (1 - f^{m})(\phi_{ji}^{m} + \lambda_{ji}^{m})(\phi_{ji}^{s} + P_{ji}^{sm}) + (\sigma_{j}^{m} (1 - \tau_{i}) g_{ij}' (1 - \tau_{p}) + (1 - g_{ij}')(1 - \tau_{i}) g_{ij}^{m} (1 - \tau_{p}) + (1 - g_{ij}')) p_{ji}^{x0s} - (g_{ji} + \tau_{i} \sigma_{j}^{f}) + \tau_{i} \sigma_{j}^{ma} + u' + u^{m}) p_{ji}^{x0s}
\]

\[
\frac{d}{dt} p_{ji}^{x0s0} = A_{ji} - O_{ji} + \phi_{ji}^{x0s0} + f'_{ji}(\beta_{ji}' + \lambda_{ji}')(\phi_{ji}^{s} + P_{ji}^{sm}) + (1 - f^{m})(\phi_{ji}^{m} + \lambda_{ji}^{m})(\phi_{ji}^{s} + P_{ji}^{sm}) + (\sigma_{j}^{m} (1 - \tau_{i}) g_{ij}' (1 - \tau_{p}) + (1 - g_{ij}')(1 - \tau_{i}) g_{ij}^{m} (1 - \tau_{p}) + (1 - g_{ij}')) p_{ji}^{x0s0} - (g_{ji} + \tau_{i} \sigma_{j}^{f}) + \tau_{i} \sigma_{j}^{ma} + u' + u^{m}) p_{ji}^{x0s0}
\]
\[
\frac{d}{dt} p_{ji}^{x_{i}0} = A_{ji} - O_{ji} + \phi_{ji}^{x_{i}0} + f' (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{x_{i}0} + p_{ji}^{x_{i}0}) + f_m (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{x_{i}m} + p_{ji}^{x_{i}m}) + (\sigma_{ji}^f (1 - r_i) (g_{ij}^f (1 - r_p) + (1 - g_{ij}^f) + \sigma_{ji}^{ms} (1 - r_i) (g_{ij}^m (1 - r_p) + (1 - g_{ij}^m))) p_{ji}^{x_{i}0} - (y_{ji} + r_i \sigma_{ji}^f s + r_i \sigma_{ji}^{ms} + v_f + v_m) p_{ji}^{x_{i}0}.
\]

\[
\frac{d}{dt} p_{ji}^{x_{i}n_0} = A_{ji} - O_{ji} + (1 - (\beta_{ji}^m + \lambda_{ji}^m)) \phi_{ji}^{x_{i}n_0} + f' (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{x_{i}n_0} + p_{ji}^{x_{i}n_0}) + f_m (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{x_{i}m} + p_{ji}^{x_{i}m}) + (\sigma_{ji}^f (1 - r_i) (g_{ij}^f (1 - r_p) + (1 - g_{ij}^f) + \sigma_{ji}^{ms} (1 - r_i) (g_{ij}^m (1 - r_p) + (1 - g_{ij}^m))) p_{ji}^{x_{i}n_0} - (y_{ji} + r_i \sigma_{ji}^f s + v_f + v_m) p_{ji}^{x_{i}n_0}.
\]

\[
\frac{d}{dt} p_{ji}^{x_{i}n_0} = A_{ji} - O_{ji} + \phi_{ji}^{x_{i}n_0} + f' (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{x_{i}n_0} + p_{ji}^{x_{i}n_0}) + (1 - f_m) (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{x_{i}m} + p_{ji}^{x_{i}m}) + (\sigma_{ji}^f (1 - r_i) (g_{ij}^f (1 - r_p) + (1 - g_{ij}^f) + \sigma_{ji}^{ms} (1 - r_i) (g_{ij}^m (1 - r_p) + (1 - g_{ij}^m))) p_{ji}^{x_{i}n_0} - (y_{ji} + r_i \sigma_{ji}^f s + v_f + v_m) p_{ji}^{x_{i}n_0}.
\]

\[
\frac{d}{dt} p_{ji}^{x_{i}n_0} = A_{ji} - O_{ji} + \phi_{ji}^{x_{i}n_0} + f' (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{x_{i}n_0} + p_{ji}^{x_{i}n_0}) + f_m (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{x_{i}m} + p_{ji}^{x_{i}m}) + (\sigma_{ji}^f (1 - r_i) (g_{ij}^f (1 - r_p) + (1 - g_{ij}^f) + \sigma_{ji}^{ms} (1 - r_i) (g_{ij}^m (1 - r_p) + (1 - g_{ij}^m))) p_{ji}^{x_{i}n_0} - (y_{ji} + r_i \sigma_{ji}^f s + v_f + v_m) p_{ji}^{x_{i}n_0}.
\]

\[
\frac{d}{dt} p_{ji}^{x_{i}n_0} = A_{ji} - O_{ji} + \phi_{ji}^{x_{i}n_0} + f' (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{x_{i}n_0} + p_{ji}^{x_{i}n_0}) + (1 - g_{ij}^f) + v_m) (p_{ji}^{x_{i}n_0} + p_{ji}^{x_{i}n_0} + (\sigma_{ji}^f (1 - r_i) (g_{ij}^f (1 - r_p) + (1 - g_{ij}^f) + \sigma_{ji}^{ms} (1 - r_i) (g_{ij}^m (1 - r_p) + (1 - g_{ij}^m))) p_{ji}^{x_{i}n_0} - (y_{ji} + r_i \sigma_{ji}^f s + v_f + v_m) p_{ji}^{x_{i}n_0}.
\]

\[
\frac{d}{dt} p_{ji}^{x_{i}n_0} = A_{ji} - O_{ji} + \phi_{ji}^{x_{i}n_0} + f' (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{x_{i}n_0} + p_{ji}^{x_{i}n_0}) + (1 - f_m) (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{x_{i}m} + p_{ji}^{x_{i}m}) + (\sigma_{ji}^f (1 - r_i) (g_{ij}^f (1 - r_p) + (1 - g_{ij}^f) + \sigma_{ji}^{ms} (1 - r_i) (g_{ij}^m (1 - r_p) + (1 - g_{ij}^m))) p_{ji}^{x_{i}n_0} - (y_{ji} + r_i \sigma_{ji}^f s + v_f + v_m) p_{ji}^{x_{i}n_0}.
\]

\[
\frac{d}{dt} p_{ji}^{x_{i}n_0} = A_{ji} - O_{ji} + \phi_{ji}^{x_{i}n_0} + f' (\beta_{ji}^f + \lambda_{ji}^f) (\phi_{ji}^{x_{i}n_0} + p_{ji}^{x_{i}n_0}) + f_m (\beta_{ji}^m + \lambda_{ji}^m) (\phi_{ji}^{x_{i}m} + p_{ji}^{x_{i}m}) + (\sigma_{ji}^f (1 - r_i) (g_{ij}^f (1 - r_p) + (1 - g_{ij}^f) + \sigma_{ji}^{ms} (1 - r_i) (g_{ij}^m (1 - r_p) + (1 - g_{ij}^m))) p_{ji}^{x_{i}n_0} - (y_{ji} + r_i \sigma_{ji}^f s + v_f + v_m) p_{ji}^{x_{i}n_0}.
\]
Web Appendix 3. Trends in Chlamydia Tests and Screening Coverage

Setting parameters for test sensitivity were informed by data from the Infertility Prevention Project (Web Figure 6), and trends for screening coverage were informed by data from different sources presented in Web Figure 7.

Web Figure 6. Data on proportion of chlamydia tests performed using NAAT in clinics taking part in the Infertility Prevention Project 2000–2011. Average proportion of NAATs in 2000 was 19%.

NAAT: Nucleic acid amplification technique
Web Figure 7. Screening coverage among women 15–24 years of age from different sources a. The denominator and age group vary across the estimates.

a) Source data References (6–12)
Web Appendix 4. Model Calibration and Supplementary Results

As part of the model calibration we defined the prior distributions used in Web Table 5. Of the 54 parameters varied, the following are time-varying: screening, for 3 youngest age groups among women (4 parameters per age group); reporting, assumed the same for all women (3 parameters); chlamydia test sensitivity, assumed the same for everyone (2 parameters); initiation of sexual activity among 15-18 years old individuals, by sex (2 parameters per sex). There are 33 time-invariant parameters varied in the calibration governing aspects such as natural history and partner change rate. This includes the scalar parameters for men (screening and reporting). There are further 60 parameters that were fixed (this includes parameters such as time step).

Web Table 6 and Web Figures 13-16 describe the posterior distributions. Correlation matrices for the different calibration scenarios are presented in Web Figures 8-11 and the calibrated model outputs against the target data is shown in Web Figure 12. Additional results are shown in Web Figures 17-19.

We also calculated AIC (Akaike Information Criteria) for each calibration scenarios. Specifically, we calculated the AIC based on the maximum likelihood from each calibration scenario as

- More constrained priors on reporting and screening, AIC = 717
- Less constrained priors on reporting, more constrained priors on screening, AIC = 683
- More constrained priors on reporting, less constrained priors on screening, AIC = 728
- Less constrained priors on reporting and screening, AIC = 707

With a note that given the number of parameters varied was the same in each calibration scenario, the AIC differences are due to differences in the maximum likelihood.

Web Table 5. Description of parameters governing testing, natural recovery and transmission probability.

| Parameter/Variable | Symbol | Description | Distribution | Parameter | References |
|--------------------|--------|-------------|--------------|-----------|------------|
| Population size    | N      | Population size, aged 15-54 | Fixed         | 171,470,000 | (13)       |
| Time step          | dt     | Time step implemented in the model | Fixed         | A week     |            |
| Testing symptomatic individuals (pw) |   |                         |              |           |            |
| Women              | $\sigma_j^{fs}$ | Testing of symptomatic women | $1/(52\ast(0.079+0.072\ast\text{Beta}(4,4)))$ | 0.17 (constrained range 0.13-0.24) pw | (14)       |
| Men                | $\sigma_j^{fm}$ | Testing of symptomatic men | $1/(52\ast(0.079+0.072\ast\text{Beta}(4,4)))$ | 0.17 (constrained range 0.13-0.24) pw | (14)       |
### Testing asymptomatic 15-18 years old women (pw)

**σ_{f=1}**  
Time-varying parameter, see section screening for further detail.

#### For the more constrained scenario

| Time Event       | Beta Distribution | Parameter Range | Median (IQR) |
|------------------|-------------------|-----------------|--------------|
| Start (2000)     | Beta(1,1200)/2    |                 |              |
| Mid-controlpoint, 1 | Beta(1,1)       | range 0-1       |              |
| Mid-controlpoint, 2 | Beta (1,1)      | range 0-1       |              |
| End (2015)       | Beta(15,1000)/2   |                 |              |

For the less constrained scenario

| Time Event       | Beta Distribution | Parameter Range | Median (IQR) |
|------------------|-------------------|-----------------|--------------|
| Start(2000)      | Beta(1,1200)/2    |                 |              |
| Mid-controlpoint, 1 | Beta(1,1200)/2   | med: 0.015 (IQR 0.006-0.03) py |
| Mid-controlpoint, 2 | Beta(15,1000)/2  | med: 0.38 (IQR 0.31-0.45)py   |
| End (2015)       | Beta(15,1000)/2   |                 |              |

### Testing asymptomatic 19-24 women (pw)

**σ_{f=2}**  
Time-varying parameter, see section screening for further detail.

#### For the more constrained scenario

| Time Event       | Beta Distribution | Parameter Range | Median (IQR) |
|------------------|-------------------|-----------------|--------------|
| Start (2000)     | Beta(1,1200)/2    |                 |              |
| Mid-controlpoint, 1 | Beta(1,1)       | range 0-1       |              |
| Mid-controlpoint, 2 | Beta (1,1)      | range 0-1       |              |
| End (2015)       | Beta(15,1000)/2   |                 |              |

For the less constrained scenario

| Time Event       | Beta Distribution | Parameter Range | Median (IQR) |
|------------------|-------------------|-----------------|--------------|
| Start(2000)      | Beta(1,1200)/2    | med: 0.015 (IQR 0.006-0.03) py |
| Mid-controlpoint, 1 | Beta(1,1200)/2   | med: 0.015 (IQR 0.006-0.03) py |
| Mid-controlpoint, 2 | Beta(15,1000)/2  | med: 0.38 (IQR 0.31-0.45)py   |
| End (2015)       | Beta(15,1000)/2   | med: 0.38 (IQR 0.31-0.45)py   |

### Testing asymptomatic 25-39 women (pw)

**σ_{f=3}**  
Time-varying parameter, see section screening for further detail.

#### For the more constrained scenario

| Time Event       | Beta Distribution | Parameter Range | Median (IQR) |
|------------------|-------------------|-----------------|--------------|
| Start (2000)     | Beta(1,1400)/2    |                 |              |

See Web Figure 2
| Parameter                        | Distribution | Parameters | Notes                        |
|---------------------------------|--------------|------------|------------------------------|
| Mid-controlpoint, 1             | Beta(1,1)    | range 0-1  |                              |
| Mid-controlpoint, 2             | Beta(1,1)    | range 0-1  |                              |
| End (2015)                      | Beta(4,1200)/2 | med: 0.08 (IQR 0.05-0.11) | py                           |

For the less constrained scenario
Same as for the more constrained scenarios

Testing asymptomatic 40-54 women (pw)

| Parameter                        | Distribution | Parameters | Notes                        |
|----------------------------------|--------------|------------|------------------------------|
| $\sigma_{j=4}^{f/a}$             |              |            |                              |
| No screening assumed among women aged ≥40 |              | Fixed      | 0                            |

Screening in men

| Group               | Screening Comparison                                    | Distribution | Parameters | Notes                        |
|---------------------|--------------------------------------------------------|--------------|------------|------------------------------|
| Men 15-18, 19-24    | Scaler vs the same age group of women                   | Beta(3,30)   | med: 0.08 (IQR 0.05-0.12)   |                             |
| Men 25-39           | Scaler vs W, aged 25-39                                 | Beta(3,100)  | med: 0.03 (IQR 0.02, 0.04)  |                             |
| Men 40-54           | No screening assumed for men aged ≥40                   | Fixed        | 0                        |                              |

Partner notification

Proportion of partners of index case that get correctly notified and correctly tested (among those in a long-term pair)

| Group               | Parameter | Distribution | Parameters | Notes                        |
|---------------------|-----------|--------------|------------|------------------------------|
| Women               | $g_{j}^{f}$ |              |            |                              |
| PN, index case F 15-18 | Beta(4,3) | med: 0.58 (IQR 0.44-0.70) | Expert opinion |
| PN, index case F 19-24 | Beta(4,3) | med: 0.58 (IQR 0.44-0.70) |               |
| PN, index case F 25-39 | Beta(4,3) | med: 0.58 (IQR 0.44-0.70) |               |
| PN, index case F 40-54 | Beta(4,3) | med: 0.58 (IQR 0.44-0.70) |               |
| Men                 | $g_{j}^{m}$ |              |            |                              |
| PN, index case M 15-18 | Beta(4,3) | med: 0.58 (IQR 0.44-0.70) |               |
| PN, index case M 19-24 | Beta(4,3) | med: 0.58 (IQR 0.44-0.70) |               |
| PN, index case M 25-39 | Beta(4,3) | med: 0.58 (IQR 0.44-0.70) |               |
| PN, index case M 40-54 | Beta(4,3) | med: 0.58 (IQR 0.44-0.70) |               |

Test sensitivity

| Parameter | Distribution | Parameters | Notes                        |
|-----------|--------------|------------|------------------------------|
| sens      |              | x*y+(1-x)z |                              |
| x         | Proportion of tests done using a NAAT                   | Fixed      | 0.17                        | See Web Figure 1            |
| y         | Sensitivity of NAAT                                     | Beta(45,1) | med: 0.98 (IQR 0.97-0.99)   | (15,16)                     |
| z         | Sensitivity of non NAAT                                 | Beta(17,2) | med: 0.90 (IQR 0.86-0.95)   |                              |
| sensmax   | Maximum sensitivity of a chlamydia test                | Fixed      | 1                            |                              |

Treatment success (efficacy of antibiotics)

| Parameter | Distribution | Parameters | Notes                        |
|-----------|--------------|------------|------------------------------|
| r_{i}     | Index case   | Beta(190,8) | med: 0.96 (IQR 0.95-0.97)   | (17)                         |
| r_{p}     | Partner of index case                                 | Beta(190,9) | med: 0.96 (IQR 0.95-0.97)   | Expert opinion               |

Reporting

Proportion of diagnosed cases reported per year. Time-varying parameter, see

Expert opinion
| Women | repW | Proportion of diagnosed cases reported in 2000. Time-varying, see section on time-varying parameters |
|-------|------|--------------------------------------------------------------------------------------------------|
| Less constrained | Beta (7, 3) | med: 0.71 (IQR 0.61-0.80) |
| More constrained | Beta (7, 3) /2+0.5 | med: 0.86 (IQR 0.80-0.90), lower limit 0.50 |
| Maximum reporting | Fixed 1 |
| Men | repM | Relative to women |
| Natural recovery (pw) | | |
| Women | $v^f$ | $1/(52*(1.13+0.5*Beta(4, 4.696)))$ | med: 0.74 (constrained range 0.61-0.88) py (18) (14) |
| Men | $v^m$ | $1/(52*(1.13+0.5*Beta(4, 4.696)))$ | med: 0.74 (constrained range 0.61-0.88) py |
| Transmission probability | | |
| $b$ | Per act probability | Beta(5.5, 50) | med: 0.094 (IQR 0.07 – 0.12) (18) |
| $R_m$ | Relative transmission probability increase from men to women | Fixed | RR=2 (18); Assumption |
| Proportion with symptoms | | |
| Women | $f^f$ | Proportion symptomatic | 0.159+0.152*Beta(5, 5.55) | med: 0.23 (constrained range 0.16,0.31) (14) |
| Men | $f^m$ | 0.159+0.152*Beta(5, 5.55) | med: 0.23 (constrained range 0.16,0.31) (14) |
| Sexual debut | | |
| Women | $p^f$ | Had sex before age 15 | Beta(16, 30) | med: 0.35 (IQR 0.30-0.39) Calibrated to (19) |
| $\omega_1^f$ | Rate of sexual initiation, calculated from: proportion sexually active by 18 (of those not yet active) used to derived a rate | Beta(8,11) | med: 0.42 (IQR 0.34-0.50) |
| $R^f$ | Relative change in sexual debut | Uniform(0.77-1.3) |
| $\omega_2^f$ | Rate of sexual initiation, calculated from the proportion sexually active by 25 (of those not yet active) used to derived a rate | Beta (120, 10) | med: 0.93 (IQR 0.91-0.94) (20) |
| Men | $p^m$ | Had sex before age 15 | Beta (16, 30) | med: 0.35 (IQR 0.30-0.39) Calibrated to (19) |
| $\omega_1^m$ | Rate of sexual initiation, calculated from: proportion sexually active by 18 (of those not yet active) used to derived a rate | Beta (8,11) | med: 0.42 (IQR 0.34-0.50) |
| $R^m$ | Relative change in sexual debut | Uniform(0.77-1.3) |
| $\omega_2^m$ | Rate of sexual initiation, calculated from: proportion sexually active by 25 (of those not yet active) used to derived a rate | Beta (120, 10) | med: 0.93 (IQR 0.91-0.94) (20) |
### Casual partners (py)

| Casual partners (py) | $c_{ji}^p$ | High-risk (HR) | Low-risk (LR) |
|---------------------|------------|----------------|---------------|
|                     |            | Single, 15-18 HR | Beta(3,30) | med: 4.2 (IQR 2.6-6.2) py | (11); Assumption |
|                     |            | Single, 19-24 HR | Beta(3,30) | med: 4.2 (IQR 2.6-6.2) py |
|                     |            | Single, 25-39 HR | Beta(3,60) | med: 2.1 (IQR 1.6-3.1) py |
|                     |            | Single, 40-54 HR | Beta(3,400) | med: 0.4 (IQR 0.2-0.5) py |
|                     |            | Single, 15-18 LR | Beta(1,40) | med: 0.9 (IQR 0.4-1.8) py |
|                     |            | Single, 19-24 LR | Beta(1,40) | med: 0.9 (IQR 0.4-1.8) py |
|                     |            | Single, 25-39 LR | Beta(1,160) | med: 0.2 (IQR 0.1-0.5) py |
|                     |            | Single, 40-54 LR | Beta(1,160) | med: 0.2 (IQR 0.1-0.5) py |

### Among paired (concurrency)

|                  |                  |
|------------------|------------------|
| High-risk (HR)   |                  |
|                  |                  |
| Low-risk (LR)    |                  |

**Proportion of population who is HR**

- **High-risk (HR)**: Paired, 15-54 HR  
  - Beta(10,70)  
  - RR= med: 0.12 (IQR 0.1-0.15)
- **Low-risk (LR)**: Paired, 15-54 LR  
  - Beta(10,100)  
  - RR= med: 0.09 (IQR 0.0.70-0.11)

**Number of acts per casual partnership**

- Fixed: 15 per partnership  
  - Assumption

**Condom use in casual partnerships**

- Proportions of acts protected by condoms. Only unprotected acts modeled in this analysis.
  - Fixed: 0

**Long-term partnerships**

- Long-term partnerships formed within one's own age group or women with one age group older.

**Age mixing - input preference**

- Age mixing and partner formation set to represent partnerships among cohabiting and married people in the United States
  - See Web Figure 18 (2,3,11)

#### Women

- $e_{ij}^f$
  - Aged 15-18: Fixed 0.8
  - Aged 19-24: Fixed 0.2
  - Aged 25-39: Fixed 0.98
  - Aged 40-54 (only formed with own age): Fixed 1

#### Men

- $e_{ij}^m$
  - Aged 15-18 (only formed with own age): Fixed 1
  - Aged 19-24: Fixed 0.8
  - Aged 25-39: Fixed 0.5
  - Aged 40-54: Fixed 0.98

#### Pair formation rate "tendency" (pw)

- $e_{ij}$
  - Aged 15-18: Fixed 0.002
  - Aged 19-24: Fixed 0.0015
Aged 25-39 | Fixed | 0.004
---|---|---
Aged 40-54 | Fixed | 0.007

| Actualized pair formation rate from unpaired | \( \rho_{ji} \) | Adjusted pair formation to assure it is balanced: See section pair formation |
|---|---|---|
| Pair formation rate to paired | \( \phi_{ji} \) | Adjusted pair formation to assure it is balanced: See section pair formation |

| Pair dissolution | \( \gamma_{ji} \) | Dissolution rate | Fixed | 0 |
|---|---|---|---|---|

| Number of acts in a pair (pw) | \( n_j^r \) | Fixed | 2 |
|---|---|---|---|

| Condom use in pairs | \( u_j^r \) | Proportions of acts protected by condoms. Only unprotected acts modeled in this analysis. | Fixed | 0 |

\( pw: \) per week; \( py: \) per year; \( IQR: \) interquartile range

*) We chose to fix the fraction of the population defined as high risk at a constant 10%, but to accommodate uncertainty in levels of risk behavior by varying the partner change rates by relationship stats and age, in each of the risk groups. Defining a set proportion of the population to belong to a risk group and varying partner change rates is a modeling convention. Varying both the partner change rate and proportion of high risk population overparameterize the same source of uncertainty.
Web Table 6. Posterior estimates for the parameters in the four calibration scenarios. Presenting the median and 95% credibility interval in brackets. Rates are shown per week.

| Parameter/Variable | Symbol | Description | i) More Constrained Priors on Reporting and Screening | ii) Less Constrained Prior on Reporting, More Constrained Priors on Screening | iii) More Constrained Priors on Reporting, Less Constrained Priors on Screening | iv) Less Constrained Priors on Reporting and Screening |
|-------------------|-------|-------------|-----------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------|
| Testing symptomatic individuals (pw) |       |             |                                                     |                                                                 |                                                                 |                                                     |
| Women             | $\sigma_{\text{f}}$ | Testing of symptomatic women | 0.182 (0.179-0.185) | 0.181 (0.178-0.185) | 0.189 (0.186-0.192) | 0.188 (0.18-0.192) |
| Men               | $\sigma_{\text{m}}$ | Testing of symptomatic men | 0.171 (0.168-0.174) | 0.17 (0.164-0.175) | 0.173 (0.17-0.178) | 0.173 (0.165-0.176) |
| Testing asymptomatic 15-18 years old women (pw) | $\sigma_{\text{f}}$ | Time-varying parameter, see section screening for further detail. | 0 (0-0) | 0 (0-0.001) | 0 (0-0) | 0 (0-0) |
|                   | $\sigma_{\text{m}}$ | Time-varying parameter, see section screening for further detail. | 0.013 (0.013-0.014) | 0.013 (0.011-0.014) | 0.007 (0.006-0.007) | 0.006 (0.006-0.007) |
| Testing asymptomatic 19-24 women (pw) | $\sigma_{\text{f}}$ | Time-varying parameter, see section screening for further detail. | 0.001 (0.001-0.001) | 0 (0-0.002) | 0.005 (0.005-0.005) | 0.005 (0.005-0.005) |
|                   | $\sigma_{\text{m}}$ | Time-varying parameter, see section screening for further detail. | 0.013 (0.012-0.013) | 0.013 (0.012-0.014) | 0.014 (0.013-0.015) | 0.014 (0.013-0.014) |
| Testing asymptomatic 25-39 women (pw) | $\sigma_{\text{f}}$ | Time-varying parameter, see section screening for further detail. | 0 (0-0) | 0 (0-0) | 0 (0-0) | 0 (0-0) |
|                   | $\sigma_{\text{m}}$ | Time-varying parameter, see section screening for further detail. | 0.003 (0.002-0.003) | 0.003 (0.003-0.003) | 0.002 (0.002-0.002) | 0.002 (0.002-0.002) |
| Screening in men |       |             |                                                     |                                                                 |                                                                 |                                                     |
| Men 15-18, 19-24 |       | Scaler vs the same age group of women | 0.149 (0.141-0.159) | 0.108 (0.09-0.127) | 0.177 (0.162-0.185) | 0.133 (0.111-0.145) |
| Men 25-39         |       | Scaler vs W, aged 25-39 | 0.02 (0.015-0.026) | 0.021 (0.017-0.024) | 0.021 (0.019-0.023) | 0.021 (0.017-0.024) |
| Partner notification | $g_{\text{f}}$ | Proportion of partners of index case that get correctly notified and correctly tested (among those in a long-term pair) |                                                     |                                                                 |                                                                 |                                                     |
| Women             |       | PN, index case F 15-18 | 0.549 (0.485-0.572) | 0.528 (0.283-0.588) | 0.574 (0.55-0.628) | 0.511 (0.478-0.554) |
|                   |       | PN, index case F 19-24 | 0.701 (0.665-0.722) | 0.715 (0.688-0.804) | 0.668 (0.645-0.698) | 0.663 (0.612-0.691) |
|                   |       | PN, index case F 25-39 | 0.527 (0.503-0.569) | 0.53 (0.47-0.575) | 0.539 (0.522-0.57) | 0.544 (0.51-0.599) |
|                   |       | PN, index case F 40-54 | 0.502 (0.468-0.529) | 0.514 (0.481-0.54) | 0.502 (0.481-0.549) | 0.503 (0.471-0.536) |
| Men               | $g_{\text{m}}$ | PN, index case M 15-18 | 0.646 (0.601-0.673) | 0.663 (0.604-0.685) | 0.689 (0.662-0.741) | 0.683 (0.625-0.731) |
|                   |       | PN, index case M 19-24 | 0.651 (0.583-0.685) | 0.622 (0.548-0.649) | 0.683 (0.659-0.704) | 0.678 (0.623-0.724) |
|                   |       | PN, index case M 25-39 | 0.752 (0.717-0.787) | 0.767 (0.712-0.802) | 0.77 (0.738-0.792) | 0.78 (0.736-0.817) |
|                   |       | PN, index case M 40-54 | 0.713 (0.665-0.75) | 0.724 (0.632-0.762) | 0.709 (0.663-0.751) | 0.737 (0.696-0.771) |
| Test sensitivity | y | Sensitivity of NAAT | 0.995 (0.99-1) | 0.998 (0.993-1) | 0.997 (0.993-1) | 0.998 (0.993-1) |
|------------------|---|---------------------|----------------|----------------|----------------|----------------|
| z                | Sensitivity of non NAAT | 0.972 (0.947-0.986) | 0.982 (0.961-0.994) | 0.956 (0.925-0.983) | 0.982 (0.961-0.994) |
| Treatment success | r_i | Index case | 0.955 (0.951-0.959) | 0.956 (0.953-0.96) | 0.949 (0.947-0.951) | 0.951 (0.947-0.958) |
|                  | r_p | Partner of index case | 0.96 (0.956-0.964) | 0.958 (0.954-0.962) | 0.959 (0.955-0.962) | 0.96 (0.955-0.963) |
| Reporting | Proportion of diagnosed cases reported per year. |
| Women | rep | Proportion of diagnosed cases reported in 2000 | 0.563 (0.549-0.603) | 0.276 (0.254-0.313) | 0.588 (0.576-0.607) | 0.336 (0.302-0.394) |
| Men | rep | Relative to women | 0.708 (0.676-0.742) | 0.771 (0.706-0.807) | 0.721 (0.7-0.74) | 0.757 (0.735-0.804) |
| Natural recovery (pw) |
| Women | v_f |  | 0.015 (0.015-0.016) | 0.015 (0.015-0.016) | 0.016 (0.015-0.016) | 0.015 (0.015-0.016) |
| Men | v_m |  | 0.016 (0.015-0.016) | 0.016 (0.016-0.016) | 0.016 (0.016-0.016) | 0.016 (0.016-0.016) |
| Transmission probability | b | Per act probability | 0.02 (0.019-0.022) | 0.023 (0.02-0.028) | 0.021 (0.019-0.023) | 0.024 (0.022-0.026) |
| Proportion with symptoms |
| Women | f_f | Proportion symptomatic | 0.285 (0.28-0.287) | 0.286 (0.279-0.289) | 0.293 (0.287-0.295) | 0.293 (0.289-0.299) |
| Men | f_m |  | 0.261 (0.257-0.266) | 0.266 (0.261-0.278) | 0.254 (0.25-0.257) | 0.268 (0.265-0.273) |
| Sexual debut |
| Women | p_f | Had sex before age 15 | 0.312 (0.303-0.324) | 0.322 (0.292-0.339) | 0.311 (0.304-0.322) | 0.313 (0.3-0.338) |
| | ω_f | Rate of sexual initiation, calculated from: |
| | proportion sexually active by 18 (of those not yet active) used to derived a rate | 0.352 (0.338-0.39) | 0.351 (0.302-0.383) | 0.337 (0.306-0.349) | 0.344 (0.325-0.367) |
| | R_f | Relative change in sexual debut | 0.985 (0.962-1.077) | 0.937 (0.897-1.3) | 1.079 (1.055-1.145) | 1.048 (1.018-1.092) |
| | ω_2 | Rate of sexual initiation, calculated from the |
| | proportion sexually active by 25 (of those not yet active) used to derived a rate | 0.92 (0.91-0.927) | 0.92 (0.908-0.932) | 0.92 (0.913-0.928) | 0.922 (0.913-0.928) |
| Men | p_m | Had sex before age 15 | 0.284 (0.264-0.327) | 0.29 (0.265-0.308) | 0.282 (0.273-0.3) | 0.295 (0.276-0.312) |
| | ω_m | Rate of sexual initiation, calculated from: |
| | proportion sexually active by 18 (of those not yet active) used to derived a rate | 0.298 (0.285-0.314) | 0.314 (0.277-0.327) | 0.282 (0.245-0.316) | 0.299 (0.271-0.336) |
| | R_m | Relative change in sexual debut | 0.983 (0.956-1.012) | 0.826 (0.805-1.101) | 1.019 (0.994-1.034) | 0.891 (0.851-0.952) |
| | ω_m | Rate of sexual initiation, calculated from: |
| | proportion sexually active by 25 used to derived a rate | 0.928 (0.92-0.935) | 0.933 (0.926-0.94) | 0.928 (0.923-0.93) | 0.935 (0.93-0.945) |
| Casual partners (pw) | c_f | |  |  |  |  |
| High-risk (HR) | Single, 15-18 HR | 0.045 (0.037-0.068) | 0.047 (0.041-0.389) | 0.034 (0.03-0.041) | 0.029 (0.023-0.043) |
| | Single, 19-24 HR | 0.246 (0.234-0.252) | 0.223 (0.058-0.248) | 0.239 (0.225-0.25) | 0.222 (0.206-0.233) |
|                       | Single, 25-39 HR | Single, 40-54 HR | Low-risk (LR) Single, 15-18 LR | Single, 19-24 LR | Single, 25-39 LR | Single, 40-54 LR |
|-----------------------|------------------|------------------|--------------------------------|------------------|------------------|------------------|
|                       | 0.042 (0.031-0.048) | 0.04 (0.028-0.071) | 0.043 (0.04-0.047) | 0.024 (0.019-0.028) |                   |                   |
|                       | 0.002 (0.002-0.003) | 0.002 (0.002-0.004) | 0.002 (0.001-0.003) | 0.001 (0-0.003)   |                   |                   |
| Low-risk (LR)         |                  |                  |                                |                  |                  |                   |
|                       | 0.009 (0.008-0.015) | 0.011 (0-0.013)  | 0.012 (0.01-0.016) | 0.012 (0.009-0.017) |
|                       | 0.001 (0-0.003)   | 0.001 (0-0.021)  | 0.001 (0-0.005)   | 0.002 (0-0.006)   |
|                       | 0 (0-0.002)       | 0.001 (0-0.002)  | 0 (0-0.002)       | 0.002 (0.001-0.003) |
|                       | 0 (0)             | 0 (0)            | 0 (0)             | 0 (0)             |

*Among paired (concurrent) $c_f^*$ Relative rate compared to the single group*

|                       | High-risk (HR) Paired, 15-54 HR | Low-risk (LR) Paired, 15-54 LR |
|-----------------------|--------------------------------|--------------------------------|
|                       | 0.095 (0.09-0.1)               | 0.088 (0.071-0.111)            |
|                       | 0.098 (0.082-0.114)            | 0.089 (0.082-0.1)              |
|                       | 0.097 (0.09-0.1)               | 0.083 (0.07-0.089)             |
|                       | 0.122 (0.115-0.129)            | 0.089 (0.083-0.1)              |
Web Figure 8. Pearson correlation matrix for the calibration scenario: More constrained priors

on reporting and screening

Scalor for reporting (reporting among men)
Scalor on PCR for concurrency among low-risk people in pairs
Scalor on PCR for concurrency among high-risk people in pairs

Successfully treating the partner in a pair following partner notification
Successfully treating the index case
Transmission probability per act from women to men
Partner notification among paired men 40–54 yrs
Partner notification among paired men 25–39 yrs
Partner notification among paired men 19–24 yrs
Partner notification among paired men 15–18 yrs
Partner notification among paired women 40–54 yrs
Partner notification among paired women 25–39 yrs
Partner notification among paired women 19–24 yrs
Partner notification among paired women 15–18 yrs
Casual partner rate for low-risk single people 40–54 yrs
Casual partner rate for low-risk single people 25–39 yrs
Casual partner rate for low-risk single people 19–24 yrs
Casual partner rate for low-risk single people 15–18 yrs
Casual partner rate for high-risk single people 40–54 yrs
Casual partner rate for high-risk single people 25–39 yrs
Casual partner rate for high-risk single people 19–24 yrs
Casual partner rate for high-risk single people 15–18 yrs
Sexually active women by 15
Proportion of CT infected men who become symptomatic
Proportion of CT infected women who become symptomatic
RR change in sexual activity initiation among men
RR change in sexual activity initiation among women
Sexually active men by 25
Sexually active men by 20
Sexually active men by 18
Sexually active women by 25
Sexually active women by 20
Sexually active women by 18
Natural recovery rate for men
Natural recovery rate for women
Reporting (2000)
Rep & Sens growth rate

b_2
c_2
b_3
c_3
25–39 screening start (2000)
15–18 screening start (2000)

Test sensitivity of NAAT
Test sensitivity of non-NAAT

b
c

d

19–24 screening start (2000)
Screening scaler for men <24 yrs compared to women > 24 yrs
Screening scaler for men <25 yrs compared to women <25 yrs
Test&treat symptomatic men 15–24 yrs
Test&treat symptomatic women 15–24 yrs

Footnote for Web Figure 8: Parameters b, c, d, b_2, c_2, d_2, and b_3, c_3, d_3 refer to the last three control points in the Bezier curve defining screening trends for the 19-24, 15-18 and 25-39 years old women, respectively.
Web Figure 9. Pearson correlation matrix for the calibration scenario: Less constrained prior on reporting, more constrained priors on screening

Footnote for Web Figure 9: Parameters b, c, d, b_2, c_2, d_2, and b_3, c_3, d_3 refer to the last three control points in the Bezier curve defining screening trends for the 19-24, 15-18 and 25-39 years old women, respectively.
Web Figure 10. Pearson correlation matrix for the calibration scenario: More constrained priors on reporting, less constrained priors on screening

Scaler for reporting (reporting among men)
Scaler on PCR for concurrency among low-risk people in pairs
Scaler on PCR for concurrency among high-risk people in pairs

d_3
c_3
b_3

25–39 screening start (2000)
Successfully treating the partner in a pair following notification
Successfully treating the index case
Transmission probability per act from women to men
Partner notification among paired men 40–54 yrs
Partner notification among paired men 15–24 yrs
Partner notification among paired women 15–24 yrs
Partner notification among paired women 40–54 yrs
Partner notification among paired women 25–39 yrs
Casual partner rate for high-risk single people 25–39 yrs
Casual partner rate for high-risk single people 15–18 yrs
Casual partner rate for low-risk single people 25–39 yrs
Casual partner rate for low-risk single people 15–18 yrs
Casual partner rate for low-risk single people 40–54 yrs
Casual partner rate for high-risk single people 19–24 yrs

Sexually active women by 15
Sexually active men by 15
Propotion of CT infected men who become symptomatic
Propotion of CT infected women who become symptomatic

RR change in sexual activity initiation among men
RR change in sexual activity initiation among women
Sexually active men by 25
Sexually active women by 25
Sexually active men by 18
Sexually active women by 18
Natural recovery rate for men
Natural recovery rate for women

Rep & Sera growth rate
d_2
c_2
b_2

15–18 screening start (2000)
Test sensitivity of NAAT
Test sensitivity of non-NAAT
d
c

b

10–24 screening start (2000)
Screening scaler for men <24 yrs compared to women >24 yrs
Screening scaler for men <25 yrs compared to women <25 yrs

Test/Ident symptomatic men 15–54yrs
Test/Ident symptomatic women 15–54yrs

Footnote for Web Figure 10: Parameters b, c, d, b_2, c_2, d_2, and b_3, c_3, d_3 refer to the last three control points in the Bezier curve defining screening trends for the 19-24, 15-18 and 25-39 years old women, respectively.
Web Figure 11. Pearson correlation matrix for the calibration scenario: Less constrained priors on reporting and screening

Footnote for Web Figure 11: Parameters b, c, d; b_2, c_2, d_2, and b_3, c_3, d_3 refer to the last three control points in the Bezier curve defining screening trends for the 19-24, 15-18 and 25-39 years old women, respectively.
Web Figure 12. Calibration results for the four calibration scenarios varying prior assumptions for reporting and screening. For each scenario the mean and 95% credible interval of the calibrated model is shown along with the data (black circles) used in the calibration (and respective confidence interval, where applicable). Note the varying y-axis between the subgroups.

Footnote for Web Figure 12: 95% confidence intervals around the data estimates reflect variance in NHANES and YRBS data for prevalence and ever had sex, respectively. NHANES prevalence estimates for 15–17 years old women and men are restricted variables, these data were accessed through the Research Data Center. Case report data presents reported chlamydia cases per 100,000 persons. Confidence intervals are not presented for case report data.
Web Figure 13. Priors and posteriors for the calibration scenario: More constrained priors on reporting and screening.

**Prior assumptions**
- Reporting restricted to >50% since 2000: Prior parameter for (Beta(7,3)/2+0.5) with a median reporting 86% (IQR 80-90%) in 2000. Reporting is modeled as a logistic function only allowing for increase in reporting over time.
- Time-varying screening parameter constrained so screening may have increased or remained stable between 2000-2015.

13 A) Time-varying screening, reporting and sensitivity
13 B) Treatment and recovery parameters
13 C) Behavioral parameters
**Web Figure 14.** Priors and posteriors for the calibration scenario: Less constrained priors on reporting, more constrained priors on screening.

**Prior assumptions**

- Reporting in 2000 estimated as Beta(7,3) with a median of 71% (IQR 61-80%) in 2000. Reporting is modeled as a logistic function only allowing for increase in reporting over time.
- Time-varying screening parameter constrained so screening may have increased or remained stable between 2000-2015 for 15-24 years old.

14 A) Time-varying screening, reporting and sensitivity
14 B) Treatment and recovery parameters

Legend
- Prior
- Posterior
14 C) Behavioral parameters
Web Figure 15. Priors and posteriors for the calibration scenario: More constrained prior on reporting, less constrained priors on screening.

Prior assumptions
- Reporting restricted to >50% since 2000. Prior parameter for (Beta(7,3)/2+0.5).
- The starting (2000) and end (2015) priors for the screening for 15-24 years old remain unchanged but time-varying shape of the screening parameter is allowed to vary over time.

15 A) Time-varying screening, reporting and sensitivity
15 B) Treatment and recovery parameters

- Transmission probability per act from women to men
- Proportion of CT infected women who become symptomatic
- Natural recovery rate for women
- Twiddemat symptomatic women 15-54 yrs
- Twiddemat symptomatic men 15-54 yrs
- Transmission probability per act from men to women
- Proportion of CT infected men who become symptomatic
- Natural recovery rate for men
- Partner notification among paired women 15-18 yrs
- Partner notification among paired women 19-24 yrs
- Partner notification among paired women 25-39 yrs
- Partner notification among paired women 40-54 yrs
- Partner notification among paired men 15-18 yrs
- Partner notification among paired men 19-24 yrs
- Partner notification among paired men 25-39 yrs
- Partner notification among paired men 40-54 yrs
- Successfully treating the index case
- Successfully treating the partner in a pair following notification

Legend
- Prior
- Posterior
15 C) Behavioral parameters
Web Figure 16. Priors and posteriors for the calibration scenario: Less constrained priors on reporting and screening

**Prior assumptions**

- Reporting in 2000 estimated as Beta(7,3) with a median of 71% (IQR 61-80%) in 2000. Reporting is modeled as a logistic function only allowing for increase in reporting over time.
- The starting (2000) and end (2015) priors for the screening for 15-24 years old remain unchanged but time-varying shape of the screening parameter is allowed to vary over time

16 A) Time-varying screening, reporting and sensitivity
16 B) Treatment and recovery parameters
16 C) Behavioral parameters
**Web Figure 17.** Mid-year model prevalence estimates per 100 among women for 2000-2015 in the calibrated model (current policy) contrasted to the counterfactual scenarios.

Footnote for Web Figure 17.

- **Current policy:** model estimated prevention efforts for 2000-2015.
- **Services at 2000 level:** Screening kept at the model estimated coverage in 2000.
- **No PN (partner notification):** Partner notification set to 0 for 2000-2015.
- **No screening:** Screening set to 0 for 2000-2015.
- **No PN or screening:** Both PN and screening set to 0 for 2000-2015.
Web Figure 18. Mid-year model prevalence estimates per 100 among men for 2000-2015 in the calibrated model (current policy) contrasted to the counterfactual scenarios.

Current policy: model estimated prevention efforts for 2000-2015
Services at 2000 level: Screening kept at the model estimated coverage in 2000
No PN (partner notification): Partner notification set to 0 for 2000-2015
No screening: Screening set to 0 for 2000-2015
No PN or screening: Both PN and screening set to 0 for 2000-2015
Web Figure 19. Model estimated chlamydia case report rate (CRR) in 2015 in the calibrated model for (estimating the impact under current policy), and across counterfactual scenarios using the mean and 95% credible intervals. Note the varying y-axis between the subgroups.

Footnote for Web Figure 19.
Current policy: model estimated prevention efforts for 2000-2015
Services at 2000 level: Screening kept at the model estimated coverage in 2000
No PN (partner notification): Partner notification set to 0 for 2000-2015
No screening: Screening set to 0 for 2000-2015
No PN or screening: Both PN and screening set to 0 for 2000-2015
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