

THE LANCET HIV

Supplementary appendix

This appendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

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Potential population-level impacts of HIV self-test distribution among key populations in Côte d’Ivoire, Mali, and Senegal: a mathematical modelling analysis. Supplement material.

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Methods: model description

This model description was adapted from Maheu-Giroux et al. ¹

Overview

The deterministic compartmental model used for this analysis was adapted from a previously published model of HIV transmission in Côte d’Ivoire¹⁻³ and coded in C++. Our model was fitted to country-specific demographic, behavioural, HIV epidemiological and intervention data in Côte d’Ivoire, Mali and Senegal over 1980-2020.

The sexually active modelled population is noted $X_{i,u,s}^{r,a}(t)$, where

- The subscript “ r ” corresponds to gender-risk groups combinations: low-risk females ($r=0$), intermediate-risk females ($r=1$), female sex worker (FSW, $r=2$), low-risk males ($r=3$), intermediate-risk males ($r=4$), clients of FSW ($r=5$), men who have sex with men and women (MSMW) ($r=6$), and men who have sex with men exclusively (MSME) ($r=7$). See **Figure S1a**.
- The subscript “ a ” corresponds to age group: 15-19 years olds ($a=0$), 20-24 years olds ($a=1$), 25-49 years olds ($a=2$), and 50-59 years olds ($a=3$). See **Figure S1b**.
- The subscript “ i ” corresponds to HIV infection status: susceptible ($i=0$), acute infection ($i=1$), chronic infection with CD4 > 500 cells/ μ L ($i=2$), with CD4 between 350 and 500 cells/ μ L ($i=3$), with CD4 between 200 and 350 cells/ μ L ($i=4$), and with CD4 < 200 cells/ μ L ($i=5$). See **Figure S1c**.
- The subscript “ u ” corresponds to HIV testing/diagnosis/treatment status: never tested ($u=0$), ever tested and undiagnosed if PLHIV ($u=1$), had a reactive self-test but is not diagnosed ($u=2$), diagnosed by conventional test and without having had a reactive self-test ($u=3$), diagnosed via a confirmatory test following a reactive self-test ($u=4$), treated ($u=5$), ever treated but dropped-out from treatment ($u=6$). See **Figure S1d**.
- The subscript “ s ” corresponds to the population history of HIV self-testing: have never used self-test ($s=0$), have ever used self-tests ($s=1$). See **Figure S1d**.
- Our equations also use the subscript “ g ”, which corresponds to the population sex, with females ($g=0$), and males ($g=1$).

The sexually naïve population is noted $V_r(t)$, with everyone being assumed to be aged 15-19 year old, HIV uninfected, and never having tested for HIV.

Model equations

The model can be expressed as a set of ordinary differential equation reflecting changes in modelled number of sexually naïve (V_r) and sexually active individuals ($X_{i,u,s}^{r,a}$).

$$\frac{dV_r}{dt} = L_r(t) - G'_r(t) - Y'_r(t)$$

$$\begin{aligned} \frac{dX_{i,u,s}^{r,a}}{dt} = & E_{i,u,s}^{r,a}(t) + J_{i,u,s}^{r,a}(t) + Y_{i,u,s}^{r,a}(t) + G_{i,u,s}^{r,a}(t) + D_{i,u,s}^{r,a}(t) + Q_{i,u,s}^{r,a}(t) + T_{i,u,s}^{r,a}(t) + U_{i,u,s}^{r,a}(t) \\ & + S_{i,u,s}^{r,a}(t) \end{aligned}$$

Where

- L_r represents recruitment of sexually naïve populations into the model
- $E_{i,u,s}^{r,a}$ represents the recruitment of sexually active population through sexual debut of sexually naïve populations or migration of 25-49 years old adults
- $J_{i,u,s}^{r,a}$ represents the turnover in sex-work between female sex workers and intermediate-risk females
- $Y_{i,u,s}^{r,a}$ represents non-HIV mortality among sexually active, and Y'_r among sexually naïve
- $G_{i,u,s}^{r,a}$ represents ageing among sexually active, and G'_r among sexually naïve
- $D_{i,u,s}^{r,a}$ represents HIV acquisition
- $Q_{i,u,s}^{r,a}$ represents HIV infection progression and mortality
- $T_{i,u,s}^{r,a}$ represents HIV conventional testing and diagnosis
- $U_{i,u,s}^{r,a}$ represents HIV treatment (ART) initiation and drop-out
- $S_{i,u,s}^{r,a}$ represents HIV self-testing

Each of the components of the two equations above is described in the section that follows the characterization of the population at model initiation

Model initiation (1970)

The model starts in 1970 with a population of size N_0 (estimated by the United Nations Population Division (UNPD))⁴, and using the age-distribution for the year 1970. The initial population is assumed to be HIV uninfected ($i=0$) and having never tested for HIV ($u=0, s=0$).

The relative sizes of the KPs are constant over time from simulation start, and reflect estimates from country-specific surveys spanning over 1995-2020. As in¹, the risk-distribution of the sexually naïve population mirrors the one of the sexually active populations to keep the size of KP constant over time.

$$X_{i,u,s}^{r,a}(1970) = 0 \text{ if } i=0 \text{ or } u=0 \text{ or } s=0$$

In 1970, the female population is distributed as follows:

- 1) Lower-risk females ($r=0$) of age a (sexually active and naïve):

$$\left\{ \begin{array}{l} X_{0,0,0}^{0,a}(1970) = N_0 PR_{Fem} PR_{A_a} (1 - PR_{FSW})(1 - PR_{IRF})(1 - Vir_0(1970)) \\ V_0(1970) = N_0 PR_{Fem} PR_{A_a} (1 - PR_{FSW})(1 - PR_{IRF})Vir_0(1970) \end{array} \right\} \text{ if } a=0$$

$$X_{0,0,0}^{0,a} = N_0 PR_{Fem} PR_{A_a} (1 - PR_{FSW})(1 - PR_{IRF}) \text{ if } a>0$$

2) Intermediate-risk females ($r=1$) of age a (sexually active and naïve):

$$\left\{ \begin{array}{l} X_{0,0,0}^{1,a}(1970) = N_0 PR_{Fem} PR_{A_a} (1 - PR_{FSW})PR_{IRF}(1 - Vir_0(1970)) \\ V_1(1970) = N_0 PR_{Fem} PR_{A_a} (1 - PR_{FSW})PR_{IRF}Vir_0(1970) \end{array} \right\} \text{ if } a=0$$

$$X_{0,0,0}^{1,a} = N_0 PR_{Fem} PR_{A_a} (1 - PR_{FSW})PR_{IRF} \text{ if } a>0$$

3) Female sex workers ($r=2$) of age a (sexually active and naïve):

$$\left\{ \begin{array}{l} X_{0,0,0}^{2,a}(1970) = N_0 PR_{Fem} PR_{A_a} PR_{FSW}(1 - Vir_0(1970)) \\ V_2(1970) = N_0 PR_{Fem} PR_{A_a} PR_{FSW}Vir_0(1970) \end{array} \right\} \text{ if } a=0$$

$$X_{0,0,0}^{2,a}(1970) = N_0 PR_{Fem} PR_{A_a} PR_{FSW} \text{ if } a>0$$

Where PR_{Fem} is the proportion of females in the model, PR_{A_a} is the relative size of the age group a at model start, $Vir_0(1970)$ the fraction of females aged 15-19 years old that are sexually naïve in 1970 (this fraction being assumed to be equal to the fraction in the first data point), PR_{FSW} the fraction of FSW among all females, PR_{IRF} the fraction of intermediate-risk females among all non-KP females. Empirical studies suggested slightly higher proportions of FSW among adult females in Côte d'Ivoire, (e.g. > 1% in ^{5,6}) compared to Mali and Senegal.

In 1970, the male population is distributed as follows:

4) Lower-risk males ($r=3$) of age a (sexually active and naïve):

$$\left\{ \begin{array}{l} X_{0,0,0}^{3,a}(1970) = N_0 (1 - PR_{Fem})PR_{A_a} (1 - PR_{Cii})(1 - PR_{MSM})(1 - PR_{IRM})(1 - Vir_1(1970)) \\ V_3(1970) = N_0 (1 - PR_{Fem})PR_{A_a} (1 - PR_{Cii})(1 - PR_{MSM})(1 - PR_{IRM})Vir_1(1970) \end{array} \right\} \text{ if } a=0$$

$$X_{0,0,0}^{3,a}(1970) = N_0 (1 - PR_{Fem})PR_{A_a} (1 - PR_{Cii})(1 - PR_{MSM})(1 - PR_{IRM}) \text{ if } a>0$$

5) Intermediate-risk males ($r=4$) of age a (sexually active and naïve):

$$\left\{ \begin{array}{l} X_{0,0,0}^{4,a}(1970) = N_0 (1 - PR_{Fem})PR_{A_a} (1 - PR_{Cii})(1 - PR_{MSM})PR_{IRM}(1 - Vir_1(1970)) \\ V_4(1970) = N_0 (1 - PR_{Fem})PR_{A_a} (1 - PR_{Cii})(1 - PR_{MSM})PR_{IRM}Vir_1(1970) \end{array} \right\} \text{ if } a=0$$

$$X_{0,0,0}^{4,a}(1970) = N_0 (1 - PR_{Fem})PR_{A_a} (1 - PR_{Cii})(1 - PR_{MSM})PR_{IRM} \text{ if } a>0$$

6) Clients of FSW ($r=5$) of age a (sexually active and naïve):

$$\left\{ \begin{array}{l} X_{0,0,0}^{5,a}(1970) = N_0 (1 - PR_{Fem}) PR_{A_a} PR_{Cli} (1 - Vir_1(1970)) \\ V_5(1970) = N_0 (1 - PR_{Fem}) PR_{A_a} PR_{Cli} Vir_1(1970) \end{array} \right\} \text{ if } a=0$$

$$X_{0,0,0}^{5,a}(1970) = N_0 (1 - PR_{Fem}) PR_{A_a} PR_{Cli} \text{ if } a>0$$

7) Men who have sex with men and women (MSMW, $r=6$) of age a (sexually active and naïve):

$$\left\{ \begin{array}{l} X_{0,0,0}^{6,a}(1970) = N_0 (1 - PR_{Fem}) PR_{A_a} PR_{MSM} PR_{Bi} (1 - Vir_1(1970)) \\ V_6(1970) = N_0 (1 - PR_{Fem}) PR_{A_a} PR_{MSM} PR_{Bi} Vir_1(1970) \end{array} \right\} \text{ if } a=0$$

$$X_{0,0,0}^{6,a}(1970) = N_0 (1 - PR_{Fem}) PR_{A_a} PR_{MSM} PR_{Bi} \text{ if } a>0$$

7) Men who have sex with men exclusively (MSME, $r=7$) of age a (sexually active and naïve):

$$\left\{ \begin{array}{l} X_{0,0,0}^{7,a}(1970) = N_0 (1 - PR_{Fem}) PR_{A_a} PR_{MSM} (1 - PR_{Bi}) (1 - Vir_1(1970)) \\ V_7(1970) = N_0 (1 - PR_{Fem}) PR_{A_a} PR_{MSM} (1 - PR_{Bi}) Vir_1(1970) \end{array} \right\} \text{ if } a=0$$

$$X_{0,0,0}^{7,a}(1970) = N_0 (1 - PR_{Fem}) PR_{A_a} PR_{MSM} (1 - PR_{Bi}) \text{ if } a>0$$

Where $(1 - PR_{Fem})$ is the proportion of males in the model, PR_{A_a} is the relative size of the age group a at model start, $Vir_1(1970)$ the fraction of males aged 15-19 years old that are sexually naïve in 1970 (again, this fraction being assumed to be equal to the estimate from each country first data point), PR_{IRM} the fraction of intermediate-risk males among all non-KP and non-client males, PR_{Cli} the fraction of FSW clients among all males, PR_{MSM} the fraction of MSM among all males, PR_{Bi} the fraction of MSM that ever had a female partner.

The fraction PR_{Cli} is calculated using the multiplier method^{7,8}, accounting for partner change rates reported by FSW and their clients, as well as the size of the FSW population¹. As in^{1,3}, simulations were discarded when the estimated fraction PR_{Cli} was over 20%.

Seeding of HIV in the population

HIV is assumed to start spreading into a very small fraction of the modelled population between 1975 and 1979 (using a parameter HIV_{Start}). At that particular time point, fractions $Prev_{FSW}$, $Prev_{Cli}$, and $Prev_{MSM}$ of FSW, clients and MSM respectively are assumed to become infected by HIV (and all with a $CD4 > 500$ cells/ μ L) (see **Table S1a**).

Population recruitment of sexually naïve populations L_r

Recruitment of sexually naïve populations of each risk group (L_r) is determined at each time step using the following formula:

$$L_r(t) = \left(Y'_r(t) + \sum_{a,i,u,s} \mu_a X_{i,u,s}^{r,a}(t) + \sum_{a,i>0,u\neq 5,s} \gamma_4 X_{i,u,s}^{r,a}(t) + \sum_{a,i>0,s} \frac{\gamma_4}{RR_\omega} X_{i,5,s}^{r,a}(t) \right. \\ \left. + \varepsilon' \left(\sum_{a,i,u,s} X_{i,u,s}^{r,a}(t) + V_r(t) \right) + \sum_{i,u,s} G_{i,u,s}^{r,3}(t) \right) Vir_g(t)$$

Where $Y'_r (= \mu_0 V_r)$ and $\mu_a X_{i,u,s}^{r,a}$ are the number of sexually naïve and sexually active individuals exiting the model due to non-HIV mortality at each time step, γ_4 the rate at which PLHIV in the last stage of infection (<200 CD4 cells/ μ L) die from AIDS. The parameter RR_ω reflects the increase in survival among PLHIV on ART compared to PLHIV not on ART⁹. The term ε' is the population growth due to fertility and is calculated as $\varepsilon' = \varepsilon - (\chi PR_{A_2})$, where ε is the total population growth rate, χ the migration rate and PR_{A_2} the fraction of people aged 25-49 years old in the model. As suggested by census data for Côte d'Ivoire, the large majority of immigrants are aged between 25 and 49 years¹⁰. The term $G_{i,u,s}^{r,3}$ is the number of people leaving the model having reached the age of 60 years old. Finally, the time-dependant parameter $Vir_g(t)$ is the fraction of female or male entering the 15-19 years old age group as sexually naïve and was informed using data from the countries successive DHS's.

Recruitment of sexually active population $E_{i,u,s}^{r,a}$

Sexually active individuals of each risk group are recruited at each time step through ageing of sexually naïve 15-19 years old or migration of sexually active 25-49 years old (which are assumed to have the same HIV prevalence as adults in Côte d'Ivoire but are assumed to have never tested for HIV).

$$E_{i=0,u=0,s=0}^{r,a=0} = \left(Y'_r(t) + \sum_{a,i,u,s} \mu_a X_{i,u,s}^{r,a}(t) + \sum_{a,i>0,u\neq 5,s} \gamma_4 X_{i,u,s}^{r,a}(t) + \sum_{a,i>0,s} \frac{\gamma_4}{RR_\omega} X_{i,5,s}^{r,a}(t) + \varepsilon' \left(\sum_{a,i,u,s} X_{i,u,s}^{r,a}(t) + V_r(t) \right) + \sum_{i,u,s} G_{i,u,s}^{r,3}(t) \right) (1 - Vir_g(t))$$

$$E_{i=0,u=0,s=0}^{r,a=1} = Age_0 V_r(t)$$

$$E_{i,u=0,s=0}^{r,a=2} = \chi PR_{A_2} \sum_{a,u,s} X_{i,u,s}^{r,a}(t)$$

Where χ is the migration rate and PR_{A_2} the fraction of people aged 25-49 years old in the model

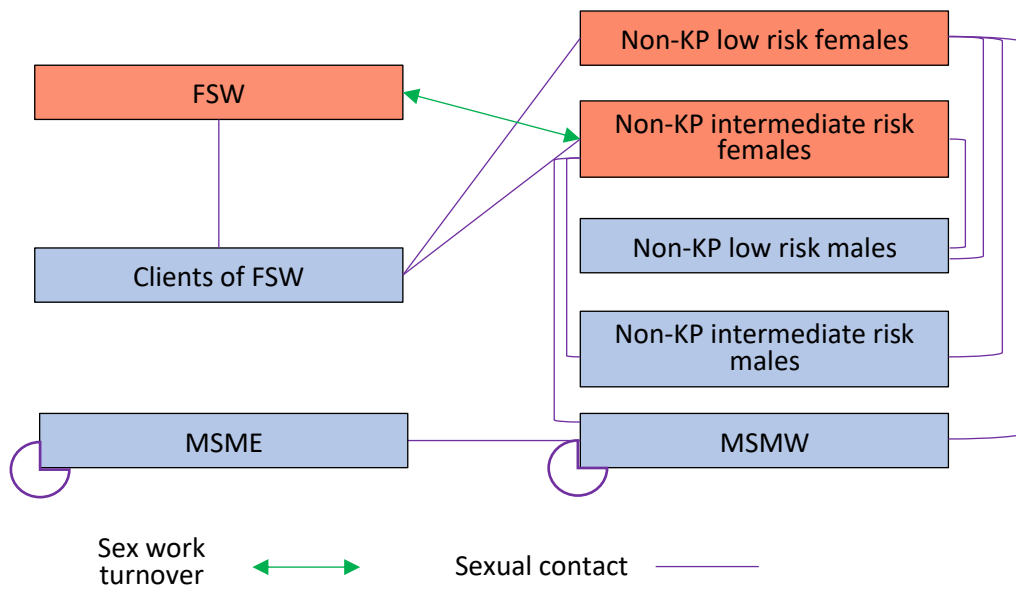


Figure S1a: modelled risk populations and their sexual contacts in the model, adapted from Maheu-Giroux et al. ¹. Female sex workers (FSW) only have sexual contacts with clients but can retire from sex work and move into the compartment of non-KP women with intermediate risk of infection. Clients of FSW have sexual contacts with all women risk groups. Non-KP women (low- and intermediate-risk women) have sexual contacts with all male risk groups, except MSME. The latter are assumed to form partnerships with other male exclusively, whereas MSMW form partnerships with both men and women.

Table S1a: Model parameters related to demography and population structure					
Population	Symbol	Value/ Prior distribution			References
		Côte d'Ivoire	Mali	Senegal	
Demography					
Total population aged 15-59 years in 1970	N_0	2,583,135	3,152,660	2,176,151	⁴
Population growth rate (year ⁻¹)	ε	3.40%	2.30%	2.85%	⁴
Immigration rate of 25-49 years old (year ⁻¹)	χ	U(0.0, 0.025)	U(0.0, 0.025)	U(0.0, 0.025)	⁴ . Widened range around country estimates. This parameter was fitted to population age distributions in 2020.
Mortality rate (year ⁻¹)	$\mu_{0:1}$ μ_2 μ_3	U(0.0201, 0.0207) U(0.0240, 0.0252) U(0.0455, 0.0475)	U(0.0186, 0.0198) U(0.0220, 0.0240) U(0.0425, 0.0440)	U(0.0172, 0.0183) U(0.0205, 0.0218) U(0.0398, 0.0406)	(1/life expectancy at 15, 25, and 50 years)
Proportion of females in population	PR_{Fem}	47.3%	51.1%	51.8%	⁴ (for the year 2000)
Age distribution (15-19, 20-24, 25-49, 50-59 years old) in 1970	PR_{A_0} PR_{A_1} PR_{A_2} PR_{A_3}	18.2% 14.7% 56.5% 13.2%	19.7% 15.7% 51.4% 13.2%	19.9% 15.8% 53.4% 10.9%	⁴ (for the year 1970)
Rate of ageing in an older risk group or exiting the model at age 60	Age_0 Age_1 Age_2 Age_3	$Age_0 = \frac{1}{5}; Age_1 = \frac{1}{5}; Age_2 = \frac{1}{25}; Age_3 = \frac{1}{10}$			Based on the pre-defined modelled age groups (15-19, 20-24, 25-49, 50-59 years old)
Population risk-structure					

Proportion of sexually naïve among 15-19 years old females	$Vir_{g=0}(t)$	Start = 27.4% 1994 = 27.4% 1999 = 35.9% 2004.5 = 34.2% 2012 = 35.3% End = 35.3%	Start = 27.4% 1995.5 = 27.4% 2001 = 36.5% 2006 = 45.2% 2012.5 = 35.3% 2018 = 32.2% End = 32.2%	Start = 64.8% 1992.5 = 64.8% 1997 = 66.0% 2005 = 71.2% 2011 = 72.1% 2013 = 74.8% 2014 = 72.9% 2015 = 74.8% 2016 = 74.4% 2017 = 74.1% 2018 = 75.8% 2019 = 77.2% End = 77.2%	DHS surveys in Côte d'Ivoire ¹¹⁻¹⁴ , Mali ¹⁵⁻¹⁹ , and Senegal ²⁰⁻²⁹ . Proportion is assumed to be constant from the last data point.
Proportion of sexually naïve among 15-19 years old males	$Vir_{g=1}(t)$	Start = 44.3% 1994 = 44.3% 1999 = 44.3% 2004.5 = 48.9% 2012 = 57.3% End = 57.3%	Start = 63.3% 1995.5 = 63.3% 2001 = 66.1% 2006 = 75.8% 2012.5 = 81.3% 2018 = 77.5% End = 77.5%	Start = 69.0% 1992.5 = 69.0% 1997 = 69.0% 2005 = 69.0% 2011 = 80.9% 2013 = 89.0% 2014 = 89.0% 2015 = 86.5% 2016 = 87.8% 2017 = 84.6% 2018 = 89.3% 2019 = 92.4% End = 92.4%	As above
Fraction of FSW among females (assumed constant over time)	PR_{FSW}	U(0.8, 2.1%)	U(0.4, 1.1%)	U(0.5, 0.9%)	Ranges selected using minimum and maximum study point estimates. Côte d'Ivoire: ^{5,6,30-32} Mali: ^{6,33} Senegal: ^{6,34,35}
Fraction of MSM among males (assumed constant over time)	PR_{MSM}	U(0.8, 1.7%)	U(0.2, 0.5%)	U(0.3, 1.2%)	Ranges selected using minimum and maximum study point estimates. Côte d'Ivoire: ³⁶⁻³⁹ Mali: ^{6,33} Senegal: ^{6,40}

Fraction of MSMW among all MSM (assumed constant over time)	PR_{Bi}	U(54.0, 75.5%)	U(53.5, 86.0%)	U(62.0, 85.0%)	Range for Mali selected using minimum and maximum study point estimates. Ranges for Côte d'Ivoire and Senegal were obtained from the pooled estimate of country-specific estimates. Côte d'Ivoire: ^{39,41-47} Mali: ^{46,48-50} Senegal: ⁵¹⁻⁵⁷ Assumed as in ^{1,3}
Turnover of sex work (year ⁻¹)	tur	U(0.067, 0.2)	U(0.067, 0.2)	U(0.067, 0.2)	
Fraction of intermediate-risk females (>1 partner/yr) among all non-KP females	PR_{IRF}	U(5, 10%)	U(1, 5%)	U(1, 5%)	Based on estimates from population surveys. Côte d'Ivoire: ^{11-13,32,58} Mali: ^{16-18,59} Senegal: ^{22,23,25-28,60}
Fraction of intermediate-risk males (>2 partner/yr) among all non-KP males	PR_{IRM}	U(5, 10%)	U(1, 5%)	U(1, 5%)	As above
HIV epidemic seeding					
Year of epidemic start	HIV_{Start}	U(1975, 1979)	U(1975, 1979)	U(1975, 1979)	Wide range used due to estimates not being available. This parameter was fitted to HIV prevalence data.
HIV prevalence among FSW at epidemic start	$Prev_{FSW}$	U(0.1, 2%)	U(0.1, 2%)	U(0.1, 2%)	As above
HIV prevalence among FSW clients at epidemic start	$Prev_{Cli}$	U(0.1, 1%)	U(0.1, 1%)	U(0.1, 1%)	As above
HIV prevalence among MSM clients at epidemic start	$Prev_{MSM}$	U(0.1, 2%)	U(0.1, 2%)	U(0.1, 2%)	As above

FSW: female sex workers; MSM: men who have sex with men; MSMW: men who have sex with men and women; U: uniform distribution (min, max)

Turnover in sex-work $J_{i,u,s}^{r,a}$

Female sex-workers ($r=2$) are assumed to start and cease sex work over their life course (see **Figure S1a** and **Table S1a**).

$$J_{i,u,s}^{r,a}(t) = 0 \text{ if } r \neq 1 \text{ and } r \neq 2$$

$$J_{i,u,s}^{r=1,a}(t) = tur X_{i,u,s}^{r=2,a}(t) - tur'(t) X_{i,u,s}^{r=1,a}(t)$$

$$J_{i,u,s}^{r=2,a}(t) = tur'(t) X_{i,u,s}^{r=1,a}(t) - tur X_{i,u,s}^{r=2,a}(t)$$

Where tur is the rate at which FSW ($r=2$) cease forming commercial partnership and transition to the risk group of intermediate-risk females ($r=1$). This parameter varies across simulations but is fixed over time. Conversely, the parameter $tur'(t)$ represent the rate at which intermediate-risk females initiate sex work and transit into the compartment of FSW. This parameter is calculated at each time step so that the number of women initiating sex work is always equal to the number of women ceasing sex work.

$$tur'(t) = \frac{tur \sum_{r=2,a,i,u,s} X_{i,u,s}^{r,a}(t)}{\sum_{r=1,a,i,u,s} X_{i,u,s}^{r,a}(t)}$$

Non-HIV mortality $Y_{i,u,s}^{r,a}$

The rates of non-HIV mortality (μ_a) vary by age group a and are sourced from the United Nations Population Division (2019 revision of World Population Prospects) ⁴.

$$Y_{i,u,s}^{r,a}(t) = -\mu_a X_{i,u,s}^{r,a}(t)$$

Non-HIV mortality rates also apply to the sexually naïve population, with $Y'_r(t) = -\mu_0 V_r(t)$

Population ageing $G_{i,u,s}^{r,a}$

The rates of ageing of sexually active populations into older age groups (or to exit the model when reaching 60 years old) ($G_{i,u,s}^{r,a}$), are obtained as the inverse of the number of years covered by the age groups: $Age_0 = \frac{1}{5}$; $Age_1 = \frac{1}{5}$; $Age_2 = \frac{1}{25}$; $Age_3 = \frac{1}{10}$.

The term G'_r correspond to the ageing of sexually naïve populations (all assumed to be 15-19 years old) age into a compartment of 20-24 years of sexually active.

$$G'_r(t) = Age_0 V_r(t)$$

Whereas,

$$G_{i,u,s}^{r,0}(t) = -Age_0 X_{i,u,s}^{r,0}(t)$$

$$G_{i,u,s}^{r,1}(t) = Age_0 X_{i,u,s}^{r,0}(t) - Age_1 X_{i,u,s}^{r,0} + Age_0 V_r(t) \text{ if } (i+u+s)=0, \text{ and } G_{i,u,s}^{r,1}(t) = Age_0 X_{i,u,s}^{r,0}(t) - Age_1 X_{i,u,s}^{r,0}(t) \text{ otherwise}$$

$$G_{i,u,s}^{r,2}(t) = Age_1 X_{i,u,s}^{r,1}(t) - Age_2 X_{i,u,s}^{r,2}(t)$$

$$G_{i,u,s}^{r,3}(t) = Age_2 X_{i,u,s}^{r,2}(t) - Age_3 X_{i,u,s}^{r,3}(t)$$

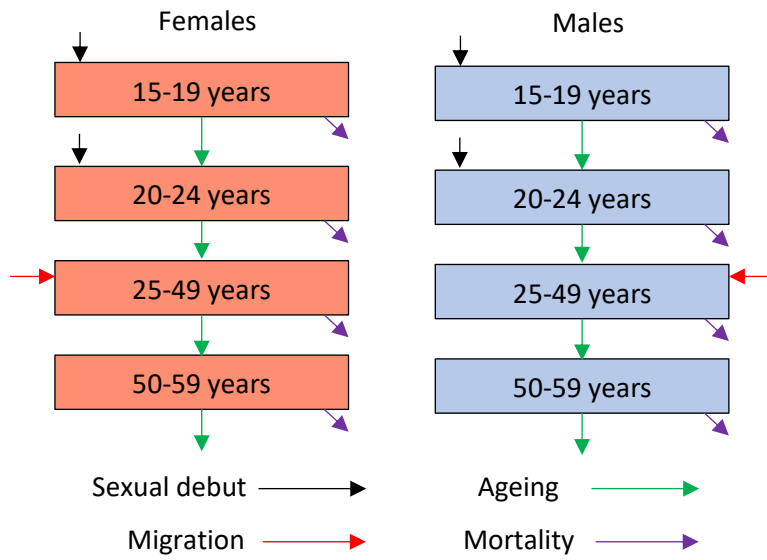


Figure S1b: modelled population age structure, migration, ageing and mortality, adapted from Maheu-Giroux et al. ¹.

HIV infection $D_{i,u,s}^{r,a}$

The force of HIV infection, or rate at which people acquire HIV, vary over time and depend on individual and partner risk factors. We first describe how sexual mixing is represented in the model, then how the force of infection is derived.

Overall sexual mixing

As in ¹, sexual mixing was modelled as a function of the gender, age, and risk group of individuals, and informed with data whenever possible. We define $p_{rariar'}$ as the probability of a sexual contact between someone of risk group r and age i with someone of risk group r' and age i' , and estimated this quantity using the following equation:

$$p_{riri'} = WMW_{rr'}(M_{rr'})\Lambda_{raa'}$$

$$WMW_{rr'} = \begin{pmatrix} & F_{LR} & F_{IR} & F_{FSW} & M_{LR} & M_{IR} & M_{Cli} & M_{MSMW} & M_{MSME} \\ F_{LR} & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 \\ F_{IR} & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 \\ F_{FSW} & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ M_{LR} & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ M_{IR} & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ M_{Cli} & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ M_{MSMW} & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 \\ M_{MSME} & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \end{pmatrix}$$

The binary matrix $WMW_{rr'}$ represent the types of partnerships allowed in the model for the risk groups of lower-risk females (F_{LR}), intermediate-risk female (F_{IR}), and female sex worker (F_{FSW}), as well as lower-risk males (M_{LR}), intermediate-risk males (M_{IR}), clients of female sex workers (M_{Cli}), men who have sex with men and women (M_{MSMW}), and men who have sex with men exclusively (M_{MSME}).

As in ¹, the sizes of the low- and intermediate-risk groups were based on the number of sexual partners during the last 12 months in the countries DHS surveys (F_{IR} defined as >1 partner per year; M_{IR} defined as >2 partners per year; excluding those that reported selling or buying sex).

Risk-mixing

Sexual mixing by risk group was calculated using sexual behaviour data for low and intermediate-risk individuals. Due to data limitation, mixing by risk group was only available for couples living in the same household who both agreed to be interviewed and reported complete data on their sexual partners in Côte d'Ivoire, and was analysed from the female perspective. A DHS-reported matrix M was expanded to include the other risk groups and their associated parameters: Bi_{Pref} being the fraction of partnerships that are with females for men having sex with men and women (MSMW), Pr_{MSMW} the fraction of MSM also having sex with women (assuming proportional mixing between MSMW and MSME), and Cli_{Mix} the fraction of partnerships that are with FSW for clients of FSW $Cli_{Mix} = \frac{c_5}{c_5 + c_{5b}}$, where c_5 and c_{5b} are the clients reported number of commercial partners and non-commercial partners, respectively.

$$M_{rr'} = \begin{pmatrix} F_{LR} & F_{IR} & F_{FSW} & M_{LR} & M_{IR} & M_{Cti} & M_{MSMW} & M_{MSME} \\ F_{LR} & 0 & 0 & 0 & 0.91 & \frac{0.09 \cdot M_{IR}}{M_{IR} + M_{Cti} + M_{MSMW}} & \frac{0.09 \cdot M_{Cti}}{M_{IR} + M_{Cti} + M_{MSMW}} & \frac{0.09 \cdot M_{MSMW}}{M_{IR} + M_{Cti} + M_{MSMW}} & 0 \\ F_{IR} & 0 & 0 & 0 & 0.88 & \frac{0.12 \cdot M_{IR}}{M_{IR} + M_{Cti} + M_{MSMW}} & \frac{0.12 \cdot M_{Cti}}{M_{IR} + M_{Cti} + M_{MSMW}} & \frac{0.12 \cdot M_{MSMW}}{M_{IR} + M_{Cti} + M_{MSMW}} & 0 \\ F_{FSW} & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ M_{LR} & 0.91 & 0.09 & 0 & 0 & 0 & 0 & 0 & 0 \\ M_{IR} & 0.88 & 0.12 & 1 & 0 & 0 & 0 & 0 & 0 \\ M_{Cti} & 0.88(1 - Cli_{Mix}) & 0.12(1 - Cli_{Mix}) & Cli_{Mix} & 0 & 0 & 0 & 0 & 0 \\ M_{MSMW} & 0.88(Bi_{Pref}) & 0.12(Bi_{Pref}) & 0 & 0 & 0 & 0 & Pr_{MSMW}(1 - Bi_{Pref}) & (1 - Pr_{MSMW})(1 - Bi_{Pref}) \\ M_{MSME} & 0 & 0 & 0 & 0 & 0 & 0 & Pr_{MSMW} & 1 - Pr_{MSMW} \end{pmatrix}$$

Mixing between risk groups was calculated using data from the 2011-2012 DHS in Côte d'Ivoire. See ¹ for further details.

Age-mixing

Mixing patterns by age (A) were informed using data from the latest DHS surveys available for each country. This survey data reports the age of the most recent sexual partner among the population that was sexually active in the 12 months preceding the survey interview. The age-mixing matrices differ for males and females. As in ¹, we assumed that age-mixing between FSW and their clients would correspond to that reported by males in the DHSs. For MSM, it was assumed that age mixing could range between completely assortative and proportional using the tuning parameter MSM_{AgeMix} , which was given a uniform distribution between 0 and 1.

For Côte d'Ivoire:

$$\Lambda_{raar} = \begin{pmatrix} 0.130 & 0.130 & 0.719 & 0.021 \\ 0.130 & 0.130 & 0.719 & 0.021 \\ 0.003 & 0.003 & 0.753 & 0.241 \\ 0 & 0 & 0.187 & 0.813 \end{pmatrix} \text{ for } r=0,1$$

$$\Lambda_{raar} = \begin{pmatrix} 0.483 & 0.483 & 0.035 & 0 \\ 0.483 & 0.483 & 0.035 & 0 \\ 0.194 & 0.194 & 0.609 & 0.004 \\ 0.125 & 0.125 & 0.187 & 0.167 \end{pmatrix} \text{ for } r=2:6$$

$$\Lambda_{raar} = (1 - MSM_{AgeMix}) \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} + MSM_{AgeMix} \begin{pmatrix} 0.182 & 0.147 & 0.565 & 0.106 \\ 0.182 & 0.147 & 0.565 & 0.106 \\ 0.182 & 0.147 & 0.565 & 0.106 \\ 0.182 & 0.147 & 0.565 & 0.106 \end{pmatrix} \text{ for } r=7:8$$

For Mali:

$$\Lambda_{raar} = \begin{pmatrix} 0.076 & 0.076 & 0.820 & 0.028 \\ 0.076 & 0.076 & 0.820 & 0.028 \\ 0.001 & 0.001 & 0.674 & 0.324 \\ 0 & 0 & 0.112 & 0.888 \end{pmatrix} \text{ for } r=0,1$$

$$\Lambda_{rar'} = \begin{pmatrix} 0.496 & 0.496 & 0.008 & 0 \\ 0.496 & 0.496 & 0.008 & 0 \\ 0.175 & 0.175 & 0.645 & 0.004 \\ 0.024 & 0.024 & 0.876 & 0.077 \end{pmatrix} \text{ for } r=2:6$$

$$\Lambda_{rar'} = (1 - MSM_{AgeMix}) \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} + MSM_{AgeMix} \begin{pmatrix} 0.197 & 0.157 & 0.514 & 0.132 \\ 0.197 & 0.157 & 0.514 & 0.132 \\ 0.197 & 0.157 & 0.514 & 0.132 \\ 0.197 & 0.157 & 0.514 & 0.132 \end{pmatrix} \text{ for } r=7:8$$

For Senegal:

$$\Lambda_{rar'} = \begin{pmatrix} 0.043 & 0.043 & 0.886 & 0.028 \\ 0.043 & 0.043 & 0.886 & 0.028 \\ 0.001 & 0.001 & 0.638 & 0.361 \\ 0 & 0 & 0.088 & 0.912 \end{pmatrix} \text{ for } r=0,1$$

$$\Lambda_{rar'} = \begin{pmatrix} 0.494 & 0.494 & 0.012 & 0 \\ 0.494 & 0.494 & 0.012 & 0 \\ 0.182 & 0.182 & 0.632 & 0.003 \\ 0.026 & 0.026 & 0.865 & 0.103 \end{pmatrix} \text{ for } r=2:6$$

$$\Lambda_{rar'} = (1 - MSM_{AgeMix}) \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} + MSM_{AgeMix} \begin{pmatrix} 0.199 & 0.158 & 0.534 & 0.109 \\ 0.199 & 0.158 & 0.534 & 0.109 \\ 0.199 & 0.158 & 0.534 & 0.109 \\ 0.199 & 0.158 & 0.534 & 0.109 \end{pmatrix} \text{ for } r=7:8$$

As in ¹, probabilities of sexual contacts are calculated separately for each partnership type ($rar'a'$). Imbalances between sexual partnerships demand and offer of the groups are likely (e.g. males typically reporting higher number of partners than females). The balance between supply of and demand for sexual partnership was obtained using a modified partner change rate ($c_{rar'a'}^*$) using the method described by Garnett and Anderson ⁶¹, and below:

$$\Delta_{rar'a'} = \frac{c_{r'a'} p_{r'a'} N_{r'a'}}{c_{ra} p_{rar'a'} N_{ra}}$$

$$c_{rar'a'}^* = c_{ra} \Delta_{rar'a'}^{\eta_k}$$

$$c_{r'a'ra}^* = c_{r'a'} \Delta_{rar'a'}^{-(1-\eta_k)}$$

Here, the parameter $\Delta_{rar'a'}$ measures the degree of imbalance between supply and demand for sexual partnerships of type $rar'a'$, while η_k is the balance parameter which determines the degree to which partners alter their demand/offer of sexual partnerships. We assumed that clients of FSW would drive demand, whereas the balance parameter was assumed to be equal to 0.5 for MSM.

HIV force of infection

As in ¹, we defined the force of infection (i.e. annual probability of HIV transmission) from an individual of risk group r' and age class a' to an individual of risk group r and age class a ⁶². This probability partly depends on a “base” per-sex-act probability of transmission β which has different

values depending on the sex of both partners, with 1) female-to-male transmission probabilities ($= \beta_{fm}$) being lower than 2) male-to-female ($= \beta_{fm}RR_{\beta_{mf}}$) and 3) male-to-male ($= \beta_{fm}RR_{\beta_{mm}}$) transmission probabilities. Per-act transmission probabilities are further altered by a term of cofactors $Cof_{gg'a'}^{iu}$ (see next page and **Table S1c**). Since male circumcision is nearly ubiquitous in Western Africa, its protective effect was implicitly taken into account in the per-sex act transmission probabilities⁶³.

The matrix $\lambda_{rar'a'}(t)$ reflects the transmission probabilities for each partnership combination of category r/r' and age a/a' , where the susceptible partner is the one indexed by ra . The terms g' and g refers to the susceptible partner and infectious partner sex ($=0$ if female, $=1$ if male)

$$\lambda_{rar'a'}(t) = c_{rar'a'}^* p_{rar'a'} \left[\sum_{i,t} \left(\left(\frac{I_{r'a'}^{iu}(t)}{\sum_{i,t} I_{r'a'}^{iu}(t) + S_{r'a'}(t)} \right) \left(1 - \left((1 - \beta Cof_{gg'a'}^{iu}(t))^{\alpha_{rar'a'}(1-v_{ra}(t))} \left(1 - \beta Cof_{gg'a'}^{iu}(t)(1-\zeta) \right)^{\alpha_{rar'a'}(v_{ra}(t))} \right) \right) \right) \right]$$

Where $Cof_{gg'a'}^{iu}(t)$ represent a combination of cofactors for HIV acquisition (related to the susceptible individual gender g' and age a') and transmissions (related to the infectious individual disease stage i and treatment status u). Here, the model accounts for the elevated risk of acquisition among young women ($RR_{\beta_{YF}}$) (compared to older women)^{64,65}, the elevated risk of HIV transmission of individuals in the acute stage of HIV infection ($RR_{\beta_{Acute}}$)⁶⁶. We also assume that an increasing fraction of PLHIV on ART ($VLS_g(t)$) have a suppressed viral load and can't transmit HIV⁶⁷. Estimates of this fraction are available over time and by sex from UNAIDS⁶⁸. PLHIV on ART that don't have a suppressed viral load ($1 - (VLS_g(t) VLS_{Ptl})$) are assumed to transmit HIV at the same rate as those not on ART.

The cofactor term $Cof_{gg'a'}^{iu}(t)$ is described below under three specific cases:

1) when both susceptible and infected partners don't have any specific risk factor for HIV acquisition/transmission (if ($g' = 1$ or $a' > 1$) and $i > 1$ and $u \neq 5$):

$$1.1.: Cof_{gg'a'}^{iu}(t) = 1$$

2) when the susceptible individual is not a young woman (i.e. if $g' = 1$ or $a' > 1$) and the infected partner has a modified risk of HIV transmission because he/she is in the acute stage of infection or in on ART (i.e. if $i = 1$ or $u = 5$):

$$2.1.: Cof_{gg'a'}^{iu}(t) = RR_{\beta_{Acute}} \text{ if } i = 1 \text{ and } u \neq 5$$

$$2.2.: Cof_{gg'a'}^{iu}(t) = \left(1 - (VLS_g(t) VLS_{Ptl}) \right) \text{ if } i \neq 1 \text{ and } u = 5$$

$$2.3.: Cof_{gg'a'}^{iu}(t) = RR_{\beta_{Acute}} \left(1 - (VLS_g(t) VLS_{Ptl}) \right) \text{ if } i = 1 \text{ and } u = 5$$

3) when the susceptible individual is a young woman (i.e. if $g' = 0$ and $a' \leq 1$) and the infected partner has a modified risk of HIV transmission because it is in the acute stage of infection or in on ART (if $i = 1$ or $u = 5$):

$$2.1.: Cof_{gg'a'}^{iu}(t) = RR_{\beta_{Acute}}RR_{\beta_{YF}} \text{ if } i = 1 \text{ and } u \neq 5$$

$$2.2.: Cof_{gg'a'}^{iu}(t) = \left(1 - (VLS_g(t) VLS_{Ptl})\right) RR_{\beta_{YF}} \text{ if } i \neq 1 \text{ and } u = 5$$

$$2.3.: Cof_{gg'a'}^{iu}(t) = RR_{\beta_{Acute}} \left(1 - (VLS_g(t) VLS_{Ptl})\right) RR_{\beta_{YF}} \text{ if } i = 1 \text{ and } u = 5$$

Table S1b: Model parameters related to sexual behaviours					
Parameter	Symbol	Prior distribution			References
		Côte d'Ivoire	Mali	Senegal	
Number of sexual partners of sexually active risk groups					
Lower-risk females	c_0	U(0.8, 0.9)	U(0.79, 0.84)	U(0.63, 0.66)	Range selected as minimum and maximum values across DHS surveys in Côte d'Ivoire ¹¹⁻¹⁴ , Mali ¹⁵⁻¹⁹ , and Senegal ²⁰⁻²⁹
Intermediate-risk females	c_1	U(2.4, 9.4)	U(2.0, 2.8)	U(2.0, 2.2)	As above
Lower-risk males	c_3	U(1.0, 1.2)	U(0.86, 0.92)	U(0.61, 0.73)	As above
Intermediate-risk males	c_4	U(4.7, 6.8)	U(4.2, 8.2)	U(3.2, 7.0)	As above
FSW	c_2	U(216.0, 360.0)	U(200.0, 1007.0)	U(182.0, 273.0)	Range selected as minimum and maximum estimates from studies among FSW in Côte d'Ivoire ⁶⁹⁻⁷² , Mali ⁷³ , and Senegal ⁷⁴⁻⁷⁷
Clients of FSW with FSW	c_5	U(23.0, 37.0)	U(23.0, 37.0)	U(23.0, 42.0)	Surveys in Côte d'Ivoire ⁷⁸ and Senegal (personal communication of estimated from an unpublished IBBS client survey ⁷⁹). No data for Mali (used Côte d'Ivoire data)
Clients of FSW with non-KP females	c_{5b}	U(1.0, 6.8)	U(1.0, 6.8)	U(2.5, 4.5)	Surveys in Côte d'Ivoire ⁶⁹⁻⁷² and Senegal ⁷⁹ . No data for Mali (used Côte d'Ivoire data)
MSMW	c_6	U(1.0, 10.0)	U(1.0, 10.0)	U(1.0, 10.0)	Conservative assumption
MSME	c_7	U(1.0, 10.0)	U(1.0, 10.0)	U(1.0, 10.0)	Conservative assumption
Number of sex acts per partner-year					
Lower-risk partners (r=0,3)	α_{ririir}	U(40.0, 48.0)	U(40.0, 48.0)	U(40.0, 48.0)	¹¹
Intermediate-risk partners (r=1,4)	α_{ririir}	U(33.0, 66.0)	U(33.0, 66.0)	U(33.0, 66.0)	¹¹
Clients-FSW partners (r=3,5)	α_{ririir}	U(1.0, 4.0)	U(1.0, 4.0)	U(1.0, 4.0)	¹¹
MSM partners (r=6,7)	α_{ririir}	U(33.0, 66.0)	U(33.0, 66.0)	U(26.4, 39.6)	Data from MSM survey in Senegal ⁸⁰ . Conservative assumption for Côte d'Ivoire and Mali
Increase in numbers of sex acts of MSM from 2016 compared to before 2007	$RR\alpha_{MSM2016}$	No increase assumed	No increase assumed	U(1.5, 2.0)	Assuming a linear trend between 2007 ⁵³ and 2016 ⁵⁶

Sexual balance parameter as per Garnett et al. 1994 ⁶¹	η	U(0, 1)	U(0, 1)	U(0, 1)	Assumption
Proportion of partnerships that are with females for MSMW	Bi_{Pref}	U(32.0, 44.3%)	U(30.0, 45.0%)	U(34.7, 42.0%)	Surveys among MSM in Côte d'Ivoire ³⁷ and Senegal ⁸⁰ . Range for Mali expanded from Côte d'Ivoire and Senegal estimates (as no Mali data available)
Tuning parameter between assortative and proportional mixing by age among MSM	MSM_{AgeMix}	U(0, 1)	U(0, 1)	U(0, 1)	Assumption

FSW: female sex workers; MSM: men who have sex with men; MSMW: men who have sex with men and women; MSME: men who have sex with men exclusively; U: uniform distribution (min, max)

Table S1c: Model parameters related to HIV infection and transmission (prior ranges assumed similar across countries)			
Parameter	Symbol	Prior distribution	References
Natural history progression (PLHIV not on ART)			
Average duration of acute infection (years)	$1/\gamma_0$	U(0.11, 0.18)	Uncertainty around the point estimate of 1.7 month from ⁶⁶ .
Average time from seroconversion to 350 CD4 cells/ μ L	$1/\gamma_0 + 1/\gamma_1 + 1/\gamma_2$	U(2.2, 4.6)	Ranges selected from the 50% UI of estimates of ⁸¹ , as in ¹
Average time from 350 CD4 to 200 CD4 cells/ μ L	$1/\gamma_3$	U(3.9, 5.0)	As above
Average time from 200 CD4 cells/ μ L to death	$1/\gamma_4$	U(1.9, 3.9)	As above
HIV transmission			
Female-to-male transmission probability per sex act	β_{fm}	U(0.001, 0.017)	Range around study point estimates from ^{82,83}
RR of HIV transmission from male to female compared to from female to male	$RR_{\beta mf}$	U(1, 3)	Range around study point estimates from ^{82,84}
RR of HIV transmission between males compared to from female to male	$RR_{\beta mm}$	U(2, 6)	Range around study point estimates from ^{84,85}
RR of HIV acquisition of females aged <25 years compared to females aged ≥ 25 years	$RR_{\beta YF}$	U(1.25, 2.5)	Range around study point estimates from ^{64,65}
Excess hazard-months of HIV transmission attributable to the acute stage	$EHM_{\beta Acute}$	U(4.2, 16.8)	Conservative range over the point estimate of ⁶⁶ . This parameter is used to calculate the RR of HIV transmission during acute HIV infection $RR_{\beta Acute}$ using the formula $RR_{\beta Acute} = \left(\frac{EHM_{\beta Acute}}{12/\gamma_0} \right) + 1$
RR of HIV transmission among when a condom is used during a sex act (vs during a condomless sex act)	ζ	U(0.75, 0.942)	Assumption based on ⁸⁶
ART and viral suppression			
ART initiation rate in the AIDS stage (<200 CD4 cells/ μ L)	ρ_4	U(0.5, 4.0)	Conservative assumption taken from ¹
Slope cofactor shaping linear relation between CD4 stages and ART initiation	ϖ	U(0, 1.0)	As above
RR of ART initiation among diagnosed PLHIV in 2000 compared to 2020	$RR_{\rho 2000}$	U(0, 1.0)	As above
RR of ART initiation among KP compared to non-KP	$RR_{\rho KP}$	U(0.2, 5.0)	As above
RR survival extension cofactor by HIV diagnosis/treatment status	$RR\omega_u$	U(2.2, 6.3) if $u=5$, and 0 otherwise (only PLHIV on ART experience a reduced HIV mortality)	Range selected from minimum and maximum effects across ALPHA study sites in ⁹
ART drop-out rate prior to 2015	φ	U(0.15, 0.27)	As in ¹ , the lower bound selected as median of national estimates for Cote d'Ivoire over 2008-2013 ⁸⁷⁻⁹³ , whereas the upper bound is taken from a collaboration of 11 cohorts of HIV-infected adult patients in Western Africa ⁹⁴ .

RR of ART drop-out for FSW and MSM (vs non-KP or clients)	$RR_{\phi KP}$	U(1.25, 1.75)	Uncertainty around estimate from ⁹⁵ (FSW data)
RR of ART drop-out after 2015 compared to before 2015	$RR_{\phi 2015p}$	U(0.75, 1.00)	Assumption

FSW: female sex workers; MSM: men who have sex with men; MSMW: men who have sex with men and women;
MSME: men who have sex with men exclusively; RR: relative risk; U: uniform distribution (min, max)

Table S1d: Model parameters related to condom use					
Parameter	Symbol	Prior distribution			References
		Côte d'Ivoire	Mali	Senegal	
During sex acts between non-KP groups					
Among 15-24 years old	$Condom_{0:1}(t)$	Start = (0-5%) $YrCond_{NonKP} = (3-5\%)$ 1995 = (9.9-47.2%) 1999 = (11.5-55.7%) 2006 = (20.9-53.5%) 2012 = (20.7-59.5%) End = (20.7-59.5%)	Start = (0-1%) $YrCond_{NonKP} = (1-2\%)$ 2001 = (2.8-20.5%) 2006 = (20.6-30.5%) 2012 = (4.1-26.4%) 2018 = (2.5-20.7%) End = (2.5-20.7%)	Start = (0-1%) $YrCond_{NonKP} = (1-2\%)$ 2005 = (1.2-5.6%) 2011 = (0.0-1.8%) 2014 = (2.8-4.8%) 2016 = (1.7-3.8%) 2018 = (1.3-2.4%) End = (1.3-2.4%)	^{96,97} For estimates in the early 1980's. Range from DHS surveys in Côte d'Ivoire ¹¹⁻¹⁴ , Mali ¹⁵⁻¹⁹ , and Senegal ²⁰⁻²⁹ , using levels reported by females as minimum, and reported by males as maximum
Among 25-49 years old	$Condom_2(t)$	Start = (0-2.5%) $YrCond_{NonKP} = (1-2.5\%)$ 1995 = (2.5-21.7%) 1999 = (3.1-21.8%) 2006 = (4.7-23.8%) 2012 = (7.3-24.2%) End = (7.3-24.2%)	Start = (0-1%) $YrCond_{NonKP} = (0.5-1\%)$ 2001 = (0.1-4.1%) 2006 = (1.0-4.4%) 2012 = (1.4-4.5%) 2018 = (0.9-5.4%) End = (0.9-5.4%)	Start = (0-1%) $YrCond_{NonKP} = (0.5-1\%)$ 2005 = (1.2-4.6%) 2011 = (1.6-3.3%) 2014 = (1.5-2.0%) 2016 = (1.8-2.8%) 2018 = (0.5-1.5%) End = (0.5-1.5%)	As above
Among 50-59 years old	$Condom_3(t)$	Start = (0-2%) $YrCond_{NonKP} = (0.2-2\%)$ 1995 = (0.2-9.7%) 1999 = (0.6-9.7%) 2006 = (0.6-10.0%) 2012 = (1.8-11.5%) End = (1.8-11.5%)	Start = (0-1%) $YrCond_{NonKP} = (0.5-1\%)$ 2001 = (0.1-4.1%) 2006 = (1.0-4.4%) 2012 = (1.4-4.5%) 2018 = (0.9-5.4%) End = (0.9-5.4%)	Start = (0-1%) $YrCond_{NonKP} = (0.5-1\%)$ 2005 = (1.2-4.6%) 2011 = (1.6-3.3%) 2014 = (1.5-2.0%) 2016 = (1.8-2.8%) 2018 = (0.5-1.5%) End = (0.5-1.5%)	As above
During sex acts of KP					

All FSW with clients	$Condom_{SW}(t)$	Start = (0-5%) $YrCond_{SW} = (5-15\%)$ 1991 = (57-68%) 1993 = (74-81%) 1995 = (73-88%) 1997 = (88-93%) 1998 = (88-98%) 2002 = (91-99%) 2007 = (90-99%) 2012 = (90-95%) 2014 = (85-93%) End = (85-93%)	Start = (0-5%) $YrCond_{SW} = (5-15\%)$ 1997 = (74-83%) 2000 = (90-98%) 2003 = (94-98%) 2009 = (94-98%) 2018 = (95-98%) End = (95-98%)	Start = (0-5%) $YrCond_{SW} = (5-15\%)$ 1990 = (79-89%) 2006 = (93-99%) 2010 = (90-98%) 2015 = (95-99%) 2019 = (88-96%) End = (88-96%)	Surveys among FSW in Côte d'Ivoire ^{69,70,72,98} , Mali ^{73,99-104} and Senegal ^{74-77,105}
All MSM	$Condom_{MSM}(t)$	Start = (0-0%) $YrCond_{MSM} = (5-15\%)$ 2004 = (35-50%) 2012 = (57-69%) 2015 = (63-81%) 2017 = (68-82%) End = (68-82%)	Start = (0-0%) $YrCond_{MSM} = (5-15\%)$ 2014 = (70-82%) 2018 = (70-82%) End = (70-82%)	Start = (0-0%) $YrCond_{MSM} = (5-15\%)$ 2005 = (76-77%) 2014 = (73-76%) 2016 = (70-84%) End = (70-84%)	Surveys among MSM in Côte d'Ivoire ^{37,41,51} , Mali ^{33,106} and Senegal ^{53,56,79,107} . Estimates in Côte d'Ivoire and Senegal similar to levels of condom use reported by CohMSM participants (~75%) ⁴⁶ .
Year of increase in condom use in the 1980's					
Non-KP groups (r=0,1,3,4)	$YrCond_{NonKP}$	U(1981, 1990)	U(1981, 1990)	U(1981, 1990)	Assumption
FSW with clients (r=2,5)	$YrCond_{SW}$	U(1981, 1990)	U(1981, 1990)	U(1981, 1990)	Assumption
MSM (r=6,7)	$YrCond_{MSM}$	U(1981, 1990)	U(1981, 1990)	U(1981, 1990)	Assumption
Scaling factors for the proportion of sex acts protected by condoms					
Among non-KP aged 15-24 years	$CondPtl_{0:1}$	U(0, 1)	U(0, 1)	U(0, 1)	Assumption
Among non-KP aged 25-49 years	$CondPtl_2$	U(0, 1)	U(0, 1)	U(0, 1)	Assumption
Among non-KP aged 50-59 years	$CondPtl_3$	U(0, 1)	U(0, 1)	U(0, 1)	Assumption
All FSW with clients	$Cond_{SW}Ptl$	U(0, 1)	U(0, 1)	U(0, 1)	Assumption
All MSM	$Cond_{MSM}Ptl$	U(0, 1)	U(0, 1)	U(0, 1)	Assumption
RR actual condom use during sex work (vs reported)	RR_{CondsW}	U(0.7,1.0)	U(0.7,1.0)	U(0.7,1.0)	Conservative assumption based on studies among clients of FSW, or using biomarkers, pooling booth surveys or list randomisation ¹⁰⁸⁻¹¹⁰

FSW: female sex workers; MSM: men who have sex with men; MSMW: men who have sex with men and women; MSME: men who have sex with men exclusively;
RR: relative risk; U: uniform distribution (min, max)

HIV disease progression and mortality $Q_{i,u,s}^{r,a}$

At each time step, newly infected PLHIV progress through different stages of infections according to their CD4 cell counts, expressed by the superscript “ i ”, (with $i=0$ corresponding to HIV-uninfected people, **Figure S1c**). The first stage of HIV infection ($i=1$) corresponds to acute infection, the second ($i=2$) to $CD4 > 500$ cells/ μ L, the third ($i=3$) for $CD4$ between 350 and 500 cells/ μ L, the fourth ($i=4$) for $CD4$ between 200 and 350 cells/ μ L, and the last one ($i=5$) for $CD4 < 200$ cells/ μ L, the latter stage being associated with HIV-related mortality. Transitions rates between infection stages (γ_i) were sourced from the literature and shown in **Table S1c**. As in ¹, the reduced HIV-mortality among PLHIV on ART was obtained by reducing the transition rates γ_3 and γ_4 by a factor $RR\omega_u$ (informed by mortality data) which is > 1 only when $u=5$.

For HIV-uninfected people: $Q_{i=0,u,s}^{r,a}(t) = 0$

For PLHIV:

$$Q_{i=1,u,s}^{r,a}(t) = -\gamma_0 X_{i=1,u,s}^{r,a}(t), \text{ if in the acute infection stage}$$

$$Q_{i=2,u,s}^{r,a}(t) = \gamma_0 X_{i=1,u,s}^{r,a}(t) - \gamma_1 X_{i=2,u,s}^{r,a}(t), \text{ if } CD4 > 500 \text{ cells}/\mu L$$

$$Q_{i=3,u,s}^{r,a}(t) = \gamma_1 X_{i=2,u,s}^{r,a}(t) - \gamma_2 X_{i=3,u,s}^{r,a}(t), \text{ if } CD4 \text{ between } 350 \text{ and } 500 \text{ cells}/\mu L$$

$$Q_{i=4,u,s}^{r,a}(t) = \gamma_2 X_{i=3,u,s}^{r,a}(t) - \left(\frac{\gamma_3}{RR\omega_u}\right) X_{i=4,u,s}^{r,a}(t), \text{ if } CD4 \text{ between } 200 \text{ and } 350 \text{ cells}/\mu L$$

$$Q_{i=5,u,s}^{r,a}(t) = \left(\frac{\gamma_3}{RR\omega_u}\right) X_{i=4,u,s}^{r,a}(t) - \left(\frac{\gamma_4}{RR\omega_u}\right) X_{i=5,u,s}^{r,a}(t), \text{ if } CD4 < 200 \text{ cells}/\mu L$$

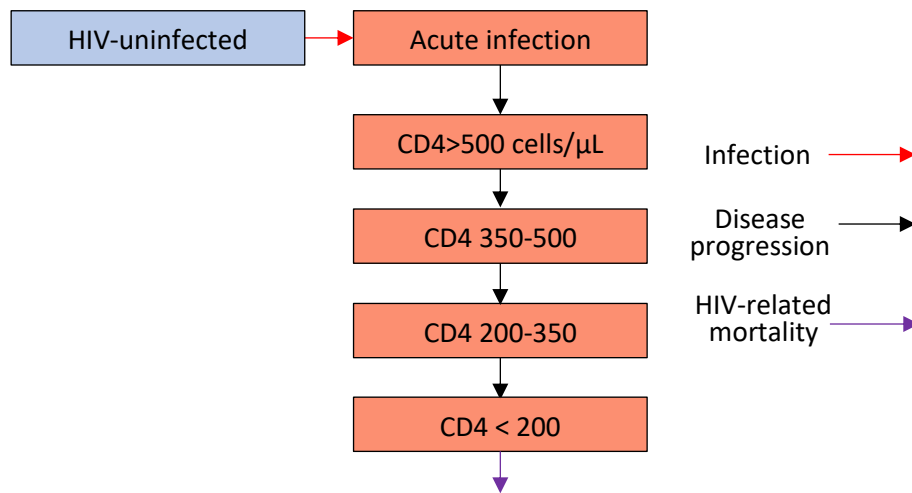


Figure S1c: modelled HIV infection stages among people not on ART.

HIV conventional testing, and diagnosis $T_{i,u,s}^{r,a}$

The rates of conventional HIV testing and diagnosis in the modelled populations vary over time and are informed by the trends in proportions of people having tested for HIV in the last year (parameter $\tau^{g,a}(t)$) (see **Table S2e**). This data was available by sex and age group from countries successive DHS surveys. As in¹, in order to replicate the trends in testing rates and maintain temporal consistency despite uncertainties in exact levels of testing, the parameter $TestPtl$ is used to represent the percentile of each data uncertainty range, and is sampled between 0 and 1 within each simulation. The variable $Year_{\tau}$ is the time where people start testing for HIV in each country, and is sampled in each simulation.

$$T_{i,u,s}^{r,a}(t) = 0 \text{ if time } \leq Year_{\tau}$$

When time $> Year_{\tau}$, population flows will depend on population HIV and diagnosis/treatment status.

Among HIV-uninfected populations ($i=0$):

$$T_{i,u=0,s}^{r,a}(t) = -X_{i,u=0,s}^{r,a}(t) \tau^{g,a}(t) RRTest_{i,u=0}^r(t) K_g$$

$T_{i,u=1,s=0}^{r,a}(t) = 0$ (conventional HIV tests by this population are accounted for, but do not correspond to a flow into another population group)

$T_{i,u=1,s=1}^{r,a}(t) = X_{i,u=2,s=1}^{r,a}(t) \tau^{g,a}(t) RRTest_{i,u=2}^r(t) K_g$ (conventional HIV tests following false-reactive self-tests)

$T_{i,u=2,s=1}^{r,a}(t) = -X_{i,u=2,s=1}^{r,a}(t) \tau^{g,a}(t) RRTest_{i,u=2}^r(t) K_g$ (as above)

Among PLHIV ($i > 0$):

$$T_{i,u=0,s}^{r,a}(t) = -X_{i,u=0,s}^{r,a}(t) \tau^{g,a}(t) RRTest_{i,u=0}^r(t) K_g$$

$$T_{i,u=1,s=0}^{r,a}(t) = -X_{i,u=1,s=0}^{r,a}(t) \tau^{g,a}(t) RRTest_{i,u=1}^r(t) K_g$$

$$T_{i,u=1,s=1}^{r,a}(t) = -X_{i,u=1,s=1}^{r,a}(t) \tau^{g,a}(t) RRTest_{i,u=1}^r(t) K_g$$

$$T_{i,u=2,s=1}^{r,a}(t) = -X_{i,u,s}^{r,a}(t) \tau_{ST} \text{ (confirmation of reactive HIV self-tests)}$$

$$T_{i,u=3,s=0}^{r,a}(t) = \left(\left(X_{i,u=0,s}^{r,a}(t) \tau^{g,a}(t) RRTest_{i,u=0}^r(t) \right) + \left(X_{i,u=1,s=0}^{r,a}(t) \tau^{g,a}(t) RRTest_{i,u=1}^r(t) \right) \right) K_g$$

$$T_{i,u=3,s=1}^{r,a}(t) = X_{i,u=1,s=1}^{r,a}(t) \tau^{g,a}(t) RRTest_{i,u=1}^r(t) K_g$$

$$T_{i,u=4,s}^{r,a}(t) = X_{i,u=2,s=1}^{r,a}(t) \tau^{g,a}(t) RRTest_{i,u=2}^r(t) K_g$$

$T_{i,u \geq 5,s}^{r,a}(t) = 0$ (conventional HIV tests by PLHIV on ART or that have dropped-out from ART are accounted for, but do not correspond to a flow into another population group)

Where the parameter $RR_{Test_{i,u}^r}(t)$ is a product of cofactors (relative risks) defined using wide uncertainty ranges which aimed at reproducing empirical heterogeneities in HIV testing coverage by risk group, HIV status and HIV testing history status (see **Table S1e**):

- The parameter $RR_{\tau AIDS}$ reflects the increase in HIV conventional testing among PLHIV in the AIDS stage of infection (compared to PLHIV not in the AIDS stage).
- The parameters $RR_{\tau FSWstart}$ and $RR_{\tau FSW2020}$ represent the elevated HIV conventional testing rates among FSW compared to non-FSW females at the time points $Year_{\tau}$ and 2020, with the RR for a specific time being calculated assuming a linear trend between $RR_{\tau FSWstart}$ and $RR_{\tau FSW2020}$ over the period $[Year_{\tau} - 2020]$. A similar assumption is made for the HIV testing rates of MSM (compared to non-MSM males), using the parameters $RR_{\tau MSMstart}$ and $RR_{\tau MSM2020}$.
- Heterogeneities in HIV conventional testing rates among PLHIV vs HIV-uninfected populations are represented using one parameter for KPs ($RR_{\tau PLHIV_KP}$) and one for non-KPs ($RR_{\tau PLHIV_NKP}$), and similarly for populations never having tested for HIV (vs ever testing, including HIV self-tests) (using the parameters $RR_{\tau NTest_KP}$ and $RR_{\tau NTest_NKP}$).
- Possible heterogeneities in HIV conventional testing among diagnosed PLHIV (compared to undiagnosed PLHIV) are captured using the parameter $RR_{\tau Diagn}$.

An overall K_g parameter is used as an overall fudge factor to fit the model to history of HIV testing (by risk group, and HIV status when available) as well as number of conventional HIV tests done in the countries.

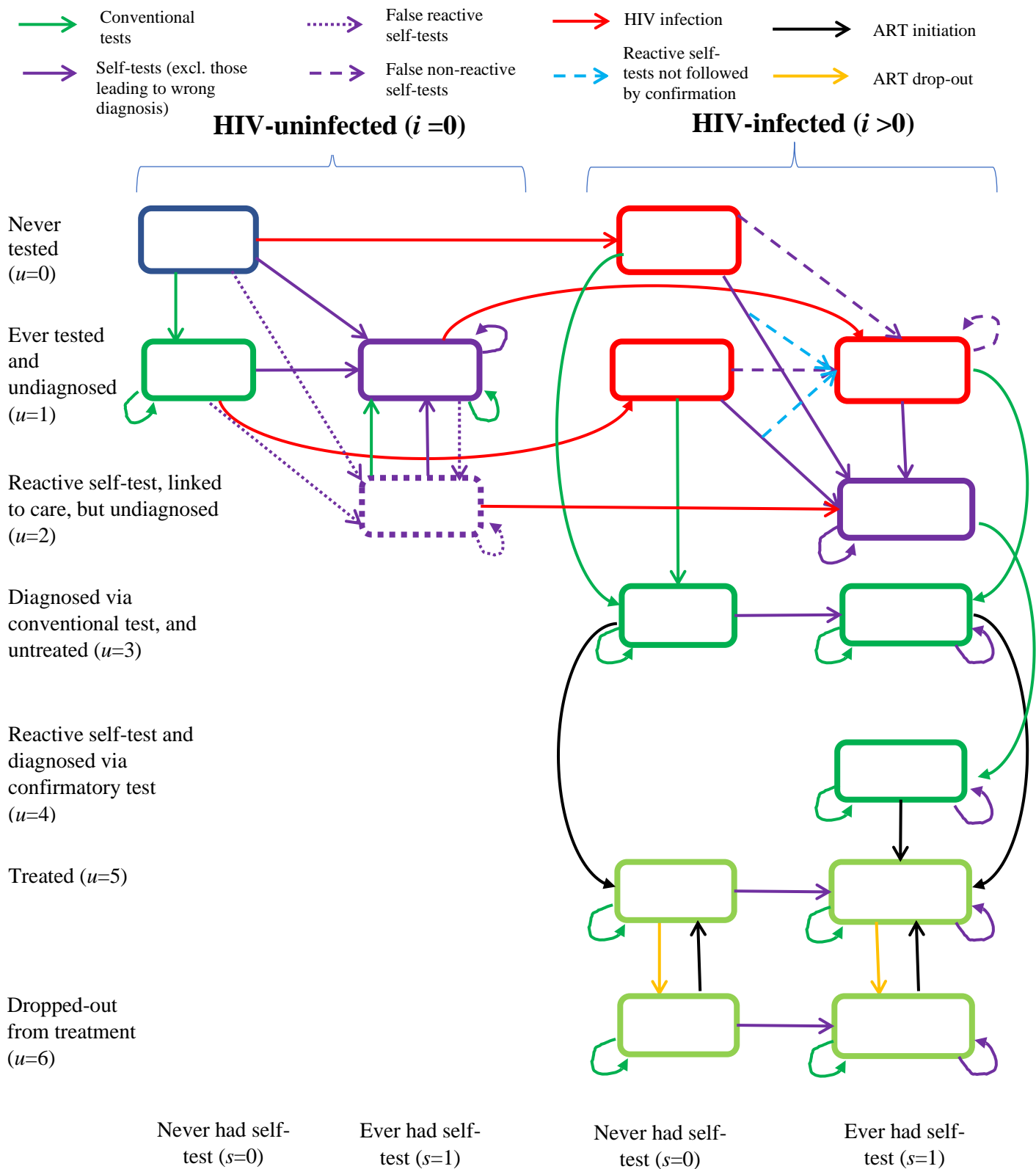


Figure S1d: Model compartments and flows between compartments of HIV testing history (including HIV self-testing), diagnosis, and treatment, among people not living with HIV (left columns) and

people living with HIV (right columns). Following WHO recommendation, reactive self-tests among PLHIV are not considered as a positive diagnostic test¹¹¹.

Table S1e: Model parameters related to HIV testing and treatment					
Parameter	Symbol	Prior distribution			References
		Côte d'Ivoire	Mali	Senegal	
HIV conventional testing probabilities (last 12 months) $\tau^{g,a}(t)$					
Start year of HIV testing	$Year_{\tau}$	U(1996, 1999)	U(1996, 1999)	U(1996, 1999)	Conservative assumption based on World Bank report on HIV response in Western Africa ¹¹²
Non-FSW females aged 15-24 years	$\tau^{0,0:1}(t)$	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (1, 6%) 2011 = (7, 26%) 2017 = (8, 33%) End = (8, 33%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2006 = (2, 7%) 2013 = (3, 12%) 2018 = (4, 15%) End = (4, 15%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (0, 2%) 2011 = (5, 25%) 2014 = (7, 28%) End = (7, 28%)	DHS surveys in Côte d'Ivoire ¹¹⁻¹⁴ , Mali ¹⁵⁻¹⁹ , and Senegal ^{20-23,29}
Non-FSW females aged 25-49 years	$\tau^{0,2}(t)$	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (2, 9%) 2011 = (7, 26%) 2017 = (11, 45%) End = (11, 45%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2006 = (1, 5%) 2013 = (3, 12%) 2018 = (5, 18%) End = (5, 18%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (0, 1%) 2011 = (7, 28%) 2014 = (8, 33%) End = (8, 33%)	As above
Non-FSW females aged 50-59 years	$\tau^{0,3}(t)$	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (2, 9%) 2011 = (7, 26%) 2017 = (11, 45%) End = (11, 45%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2006 = (1, 3%) 2013 = (2, 4%) 2018 = (3, 12%) End = (3, 12%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (0, 2%) 2011 = (4, 17%) 2014 = (6, 25%) End = (6, 25%)	As above
Non-MSM males aged 15-24 years	$\tau^{1,0:1}(t)$	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (1, 4%) 2011 = (4, 15%) 2017 = (3, 11%) End = (3, 11%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2006 = (1, 4%) 2013 = (2, 7%) 2018 = (1, 4%) End = (1, 4%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (0, 2%) 2011 = (3, 15%) 2014 = (3, 15%) End = (3, 15%)	As above
Non-MSM males aged 25-49 years	$\tau^{1,2}(t)$	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (2, 8%) 2011 = (5, 22%) 2017 = (7, 28%) End = (7, 28%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2006 = (2, 10%) 2013 = (4, 15%) 2018 = (3, 12%) End = (3, 12%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (1, 4%) 2011 = (5, 20%) 2014 = (5, 20%) End = (5, 20%)	As above

Non-MSM males aged 50-59 years	$\tau^{1,3}(t)$	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (1, 3%) 2011 = (5, 22%) 2017 = (4, 16%) End = (4, 16%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2006 = (2, 10%) 2013 = (4, 15%) 2018 = (3, 12%) End = (3, 12%)	Start = (0, 0%) $Year_{\tau} = (0, 0\%)$ 2005 = (1, 4%) 2011 = (4, 17%) 2014 = (3, 15%) End = (3, 15%)	As above
Scaling factor for HIV testing among non-FSW and non-MSM	$TestPtl$	U(0, 1)	U(0, 1)	U(0, 1)	Assumed
Overall HIV testing scaling factor (by gender)	K_g	U(0.2, 5)	U(0.2, 5)	U(0.2, 5)	Conservative assumption. This parameter is fitted to HIV diagnosis and treatment data, including programmatic data on the number of HIV tests done in each country over time.
Relative change in conventional testing rate among populations					
RR HIV testing among PLHIV in AIDS stage (vs PLHIV not in the AIDS stage)	$RR_{\tau AIDS}$	U(1, 8)	U(1, 8)	U(1, 8)	Conservative assumption similar to ¹
RR HIV testing among FSW (vs non-KP females) at $Year_{\tau}$	$RR_{\tau FSWstart}$	U(1, 10)	U(1, 10)	U(1, 10)	Conservative assumption based on the higher reported history of testing among FSW compared to non-FSW women
RR HIV testing among FSW (vs non-KP females) from 2020	$RR_{\tau FSW2020}$	U(1, 10)	U(1, 10)	U(1, 10)	As above
RR HIV testing among MSM (vs non-MSM males) at $Year_{\tau}$	$RR_{\tau MSMstart}$	U(1, 10)	U(1, 10)	U(1, 10)	Conservative assumption based on the higher reported history of testing among MSM compared to non-MSM men
RR HIV testing among MSM (vs non-MSM males) from 2020	$RR_{\tau MSM2020}$	U(1, 10)	U(1, 10)	U(1, 10)	As above
RR HIV testing among KP PLHIV (vs HIV-uninfected KP)	$RR_{\tau PLHIV_KP}$	U(0.2, 5)	U(0.2, 5)	U(0.2, 5)	Assumed
RR HIV testing among non-KP PLHIV (vs HIV-uninfected non-KP)	$RR_{\tau PLHIV_NKP}$	U(0.2, 5)	U(0.2, 5)	U(0.2, 5)	Assumed
RR HIV testing among KP never having tested (vs KP ever tested)	$RR_{\tau NTest_KP}$	U(0.2, 5)	U(0.2, 5)	U(0.2, 5)	Assumed
RR HIV testing among non-KP never having tested (vs non-KP ever tested)	$RR_{\tau NTest_NKP}$	U(0.2, 5)	U(0.2, 5)	U(0.2, 5)	Assumed
RR HIV testing among diagnosed PLHIV (vs undiagnosed)	$RR_{\tau Diagn}$	U(0.2, 3)	U(0.2, 3)	U(0.2, 3)	Assumed

HIV self-testing					
Rate of HIV self-testing	$v_{i,u,s}^{r,a}(t)$				Calculated from the number of kits distributed and used, see specific section
Fraction of HIV self-tests replacing conventional tests	$Repl$	20%	30%	40%	From an analysis of ATLAS and subnational programmatic data in Côte d'Ivoire and Senegal ¹¹³ . Mali assumed as the average between the estimates for Côte d'Ivoire and Senegal (details in Table S5).
HIV self-test sensitivity and specificity	$STSe_i$ and $STSp$		$STSe_i = 0.92$ if $i > 1$ $STSe_i = 0$ if $i = 1$		Assumptions of the base-case scenario, based on manufacturer data ¹¹⁴ . We assumed that tests cannot detect HIV when the individual is in the acute stage of infection
Fraction of HIV self-tests which are followed by a confirmation test and linkage to care	$STLnk$		$STLnk = 0.5$		From ATLAS phone survey data (2 nd stage) ¹¹⁵
Rate of HIV confirmatory testing among having had a reactive test and linked to care	τ_{ST}		$\tau_{ST} = 6$		As above
Rate of ART initiation among those diagnosed via a confirmed reactive test	ρ_{ST}		$\rho_{ST} = 12$		As above
Viral suppression among PLHIV					
Fraction of female PLHIV on ART that have a suppressed viral load	$VLS_{g=0}(t)$	Start = (40-60%) 2000 = (40-60%) 2018 = (70-89%) 2020 = (73-93%) 2030 = (85-95%) End = (85-95%)	Start = (40-60%) 2000 = (40-60%) 2020 = (63-83%) 2030 = (85-95%) End = (85-95%)	Start = (40-60%) 2000 = (40-60%) 2016 = (73-91%) 2020 = (77-97%) 2030 = (85-97%) End = (85-97%)	From ⁶⁸ for 2016 and 2020, assumptions otherwise
Fraction of male PLHIV on ART that have a suppressed viral load	$VLS_{g=1}(t)$	Start = (40-60%) 2000 = (40-60%) 2018 = (69-91%) 2020 = (75-97%) 2030 = (85-97%) End = (85-97%)	Start = (40-60%) 2000 = (40-60%) 2020 = (65-87%) 2030 = (85-95%) End = (85-97%)	Start = (40-60%) 2000 = (40-60%) 2016 = (66-83%) 2020 = (76-96%) 2030 = (85-96%) End = (85-96%)	As above
Scaling factor for viral suppression among PLHIV on ART	$VLSptl$	U(0, 1)	U(0, 1)	U(0, 1)	Assumption

FSW: female sex workers; MSM: men who have sex with men; MSMW: men who have sex with men and women; MSME: men who have sex with men exclusively;
RR: Relative risk; U: uniform distribution (min, max)

HIV treatment initiation and drop-out $U_{i,u,s}^{r,a}$

Our model reused the approach from^{1,3} to represent ART initiation, which accounts for changes in ART eligibility, while reflecting the fact that CD4 cell counts may have been widely available in the region⁹². Our model assumes that individuals could only initiate ART after being diagnosed, hence no treatment was given until the period 1980- $Year_\tau$, with $Year_\tau$ being sampled over 1996-1999. PLHIV diagnosed through a confirmed reactive self-test initiate ART at a rate ρ_{ST} , informed by ATLAS survey data (see **Figure S1d**).

$$U_{i,u,s}^{r,a}(t) = 0 \text{ if } u \leq 2$$

$$U_{i,u=3,s}^{r,a}(t) = -UStart_i RRUStart_r(t) X_{i,u=3,s}^{r,a}(t)$$

$$U_{i,u=4,s}^{r,a}(t) = -\rho_{ST} X_{i,u=4,s}^{r,a}(t)$$

$$U_{i,u=5,s=0}^{r,a}(t) = UStart_i RRUStart_r(t) X_{i,u=3,s=0}^{r,a}(t) + \left((UStart_i RRUStart_r(t)) - (UStop RRUStop(t)) \right) X_{i,u=6,s=0}^{r,a}(t)$$

$$U_{i,u=5,s=1}^{r,a}(t) = UStart_i RRUStart_r(t) X_{i,u=3,s=1}^{r,a}(t) + \rho_{ST} X_{i,u=4,s}^{r,a}(t) + \left((UStart_i RRUStart_r(t)) - (UStop RRUStop(t)) \right) X_{i,u=6,s=1}^{r,a}(t)$$

$$U_{i,u=6,s}^{r,a}(t) = UStop RRUStop(t) X_{i,u=6,s}^{r,a}(t)$$

The parameter $UStart_i$ is the “base” rate of ART initiation and depend on PLHIV HIV stage of infection, whereas $UStop$ is the “base” rate of ceasing ART. As in^{1,3}, we assumed that PLHIV with a diagnosed infection and a CD4 count <200 cells/ μ L were more likely to show clinical symptoms and initiate ART. A linear relation was assumed between CD4 count stage and initiation rate using parameter ϖ . This parameter was given a uniform prior over [0-1] so that PLHIV with lower CD4 cell counts always had higher initiation rates. ART initiation rates were first sampled among PLHIV with a CD4 count <200 cells/ μ L ($UStart_4 = \rho_4$), and the rates among the other infection stages were calculated using the formula described in¹, where $m = ((0 - \rho_4)/9.25) \varpi$, $UStart_3 = \rho_3 = 3m - \rho_4$, $UStart_2 = \rho_2 = 6m - \rho_4$, and $UStart_1 = \rho_1 = 9m - \rho_4$.

The parameter $RRUStart_r(t)$ is a product of cofactors for initiating ART (see **Table S1c**): the parameter $RR_{\rho_{2000}}$ is the relative risk of ART initiation among PLHIV with a diagnosed infection at the time $Year_\tau$ compared to 2020, and we assumed that ART initiation rates would linearly increase between $Year_\tau$ and 2020, then stay constant at the 2020 levels after this period. Our model allowed the ART initiation rates to differ between KP and non-KP, using a wide prior range for a parameter $RR_{\rho_{KP}}$.

Similarly, the parameter $RRUStop_r(t)$ is a product of cofactors for ceasing ART: our model assumed that ART drop-out rates could slightly decrease over time and be different between FSW and MSM compared to non-KP and FSW clients.

Our model used a specific ART initiation rate among people that had confirmed a reactive HIV reactive self-test (ρ_{ST}), which could be directly informed by ATLAS data (see specific section).

A fraction of PLHIV on ART have a suppressed viral load and are assumed not to be able to transmit HIV. This fraction increases over time and vary by sex ($VLS_g(t)$), using estimates from UNAIDS⁶⁸. The scaling factor $VLSptl$ sampled between 0 and 1 was used to reflect uncertainties in estimates as well as overall time trends.

HIV self-testing $S_{i,u,s}^{r,a}$

We calculated the number of HIV self-test kits used by each modelled population at each timestep ($v_{i,u}^{r,a}$). For the period 2019-2021, this number was based on the ATLAS programmatic data (available for each quarter over 2019-2021) and survey data described in the “HIVST scenarios” of this supplement. From January 2022, the number of kits used was calculated by assuming that 95% of KP HIV-uninfected or living with HIV but not on ART should receive two HIV tests each year (see specific section on HIV self-testing). The parameters $STSe_i$ and $STSp$ represent the sensitivity and specificity of the self-tests, whereas $STLnk$ is the fraction of reactive self-tests which are followed by conventional tests (informed by ATLAS survey data). False-reactive self-tests among people not living with HIV were contradicted by subsequent non-reactive tests or negative conventional tests (see Figure S1d), whereas false non-reactive self-tests among PLHIV would prevent them to undertake confirmatory tests in facilities.

Transitions between model states $S_{i,u,s}^{r,a}$ are shown in **Figure S1d** and only apply to:

1) people who have never tested for HIV ($u=0$), or ever had a conventional test but never a self-test ($u=1, s=0$):

$$S_{i,u=0-1,s=0}^{r,a} = -v_{i,u=0-1,s=0}^{r,a}$$

2) people not living with HIV ($i=0$) who have ever had a conventional HIV test but never had a self-test ($u=1, s=0$), and that can have a first self-test that is a false reactive:

$$S_{i=0,u=1,s=0}^{r,a} = -v_{i=0,u=1,s=0}^{r,a}(1 - STSp)$$

3) people not living with HIV ($i=0$) who have ever had a conventional HIV test, ever had a self-test, and their last self-test was not reactive ($u=1, s=1$):

$$S_{i=0,u=1,s=1}^{r,a} = [(v_{i=0,u=0,s=0}^{r,a} + v_{i=0,u=1,s=0}^{r,a} + v_{i=0,u=2,s=1}^{r,a})STSp] - v_{i=0,u=1,s=1}^{r,a}(1 - STSp)$$

4) people not living with HIV ($i=0$) who have ever had a conventional HIV test and a self-test, but their last self-test was reactive and they haven't had a conventional test since ($u=2, s=1$):

$$S_{i=0,u=2,s=1}^{r,a} = [(v_{i=0,u=0,s=0}^{r,a} + v_{i=0,u=1,s=0}^{r,a} + v_{i=0,u=1,s=1}^{r,a})(1 - STSp)] - v_{i=0,u=2,s=1}^{r,a}STSp$$

5) PLHIV ($i > 0$) who are currently undiagnosed ($u=1$) and have never tested for HIV ($s=0$):

$$S_{i>0,u=1,s=0}^{r,a} = -v_{i>0,u=1,s=0}^{r,a}$$

6) PLHIV ($i > 0$) who are currently undiagnosed ($u=1$) and have ever tested for HIV ($s=1$), some of which may have had a reactive self-test, but not followed by a confirmation test (fraction $(1 - STLnk)$).

$$S_{i>0,u=1,s=1}^{r,a} = \sum_{u=0-1} v_{i>0,u,s=0}^{r,a} ((1 - STSe_i) + (STSe_i \times (1 - STLnk))) - v_{i>0,u=1,s=1}^{r,a} STSe_i$$

7) PLHIV who have had a reactive self-test, are undiagnosed but can do a confirmation test ($u=2$).

$$S_{i>0,u=2,s=1}^{r,a} = [v_{i>0,u=0,s=0}^{r,a} + v_{i>0,u=1,s=0}^{r,a} + v_{i>0,u=1,s=1}^{r,a}] STSe_i$$

8) PLHIV who have never used a self-test ($s=0$) but that have a diagnosed infection ($u=3,5,6$). Our base case scenario assumes that PLHIV in ART ($u=5$) do not receive self-tests.

$$S_{i>0,u>2,s=0}^{r,a} = -v_{i>0,u>2,s=0}^{r,a}$$

7) PLHIV who have ever used a self-test ($s=1$) but that have a diagnosed infection ($u=3,5,6$).

$$S_{i>0,u>2,s=1}^{r,a} = v_{i>0,u>2,s=0}^{r,a}$$

Model fitting overview

Each model was fitted under a Bayesian framework in three steps. In the first step, a Latin hypercube of model parameters was used to simulate 50M simulations from prior distributions of the parameters describe above. In the second step, we only retained the simulations which agreed with all the widened confidence intervals of the fitting outcomes (i.e., prior constraints) described in **Tables S2a-c** (between 579 and 1550 simulations were retained across models). In the third step, the 100 fitted simulations with the highest overall likelihood (calculated by summing the simulation likelihood across all outcomes using their original sample size, except on HIV incidence rate, number of conventional tests and fraction of positive tests, for which there were no sample size) were identified for each country. The resulting posterior parameter sets were used to simulate all our model scenarios.

Model fitting data

Fitting data (Côte d’Ivoire)

Table S2a: List of demographic, epidemiological, and intervention outcomes used for model fitting in Côte d’Ivoire					
Population or age group	Year	Point estimate (sample size used for simulation likelihood calculation)	Original 95%CI	Prior constraint	Reference
Population size					
Total number of 15-59 years-old	1970 1980 1990 2000 2010 2020	2.58 million 4.05 million 6.02 million 8.51 million 10.64 million 14.19 million	N.A.	Initial value for 1970 and direct calibration using growth rate between 1970 and 2020 estimates	From ⁴
Age distribution among 15–59-year-old females					
	1970	15-24 years: 33.5% 25-49 years: 55.5% 50-59 years: 10.9%	N.A.	Used for comparison	From ⁴ . This data was only used for comparison because we used UNPD estimates for the year 1970 combining female and males as model input (Table S1a), and fitted our model to sex-specific UNPD estimates for 2020.

1980	15-24 years: 37.1% 25-49 years: 52.7% 50-59 years: 10.4%	N.A.	Used for comparison	As above
1990	15-24 years: 38.1% 25-49 years: 51.7% 50-59 years: 10.2%	N.A.	Used for comparison	As above
2000	15-24 years: 40.0% 25-49 years: 51.1% 50-59 years: 9.0%	N.A.	Used for comparison	As above
2010	15-24 years: 39.6% 25-49 years: 51.0% 50-59 years: 9.3%	N.A.	Used for comparison	As above
2020	15-24 years: 38.7% 25-49 years: 52.3% 50-59 years: 9.0%	N.A.	35.2-42.6% 47.5-57.5% 6.9-11.7%	Fitted from ⁴
Age distribution among 15–59-year-old males				
1970	15-24 years: 32.2% 25-49 years: 57.5% 50-59 years: 10.3%	N.A.	Used for comparison	From ⁴ . This data was only used for comparison because we used UNPD estimates for the year 1970 combining female and males as model input (Table S1a), and fitted our model to sex-specific UNPD estimates for 2020.
1980	15-24 years: 33.4% 25-49 years: 56.1% 50-59 years: 10.5%	N.A.	Used for comparison	As above
1990	15-24 years: 33.9% 25-49 years: 54.9% 50-59 years: 11.3%	N.A.	Used for comparison	As above
2000	15-24 years: 36.6% 25-49 years: 52.7% 50-59 years: 10.7%	N.A.	Used for comparison	As above
2010	15-24 years: 37.6% 25-49 years: 51.7% 50-59 years: 10.7%	N.A.	Used for comparison	As above
2020	15-24 years: 38.0% 25-49 years: 52.1% 50-59 years: 9.9%	N.A.	34.5-41.8% 47.4-57.3% 7.6-12.9%	Fitted from ⁴
HIV prevalence among all adult females (except female sex workers)				
15-24	1989	2.5% (n=713)	(0.9-4.4%)	0.1-18.0% ¹¹⁶
15-24	2005	2.4% (n=1054)	(1.6-3.0%)	1.0-10.0% ¹²
15-24	2012	2.2% (n=1314)	(1.5-3.0%)	1.0-10.0% ¹¹
15-24	2017	0.9% (n=3186)	(0.5-1.4%)	0.2-6.0% ³²
15-24	2018	0.4%	(0.0-0.8%)	Only used for comparison ¹¹⁷ . This study was identified post model fitting but had a low sample size (5 women were living with HIV).
25-49	1989	2.5% (n=1020)	(1.0-4.3%)	0.8-20.0% ¹¹⁶ (estimate for the 25-54 year old age group, as estimate for the 25-49 year old age groups was not available)
25-49	2005	9.9% (n=1221)	(8.4-12.0%)	4.0-18.0% ¹²
25-49	2012	6.3% (n=1546)	(5.2-8.0%)	3.0-15.0% ¹¹
25-49	2017	5.5% (n=4840)	(4.5-6.8%)	3.0-8.0% ³²
50-59	1989	1.9% (n=192)	(0.4-4.4%)	0.1-10.0% ¹¹⁶ (estimate for the 50-64 year old age group, as estimate for the 50-59 year old age groups was not available)

50-59	2005	10.2% (n=139)	(6.2-16.0%)	4.0-20.0%	¹² (prevalence for the 45-49 years old age group)
50-59	2012	9.5% (n=146)	(5.7-15.0%)	4.0-20.0%	¹¹ (prevalence for the 45-49 Years old age group)
50-59	2017	8.2% (n=723)	(5.0-13.1%)	4.0-20.0%	³²
HIV prevalence among all adult males					
15-24	1989	2.4% (n=664)	(0.8-4.3%)	0.5-15.0%	¹¹⁶
15-24	2005	0.3% (n=1069)	(0.1-1.0%)	0.1-4.0%	¹²
15-24	2012	0.3% (n=1090)	(0.1-1.0%)	0.1-4.0%	¹¹
15-24	2017	0.3% (n=2750)	(0.1-0.9%)	0.1-4.0%	³²
15-24	2018	0.3%	(0.0-0.6%)	Only used for comparison	¹¹⁷ . This study was identified post model fitting but had a low sample size (2 men were living with HIV).
25-49	1989	7.7% (n=858)	(5.5-10.0%)	2.0-40.0%	¹¹⁶ (estimate for the 25-54 year old age group, as estimate for the 25-49 year old age groups was not available)
25-49	2005	4.8% (n=907)	(3.6-6.0%)	2.0-15.0%	¹²
25-49	2012	4.3% (n=1427)	(3.3-5.0%)	2.0-15.0%	¹¹
25-49	2017	2.1% (n=4923)	(1.4-2.9%)	1.0-4.0%	³²
50-59	1989	1.7% (n=283)	(0.4-3.9%)	1.0-25.0%	¹¹⁶
50-59	2005	4.9% (n=151)	(2.4-10.0%)	2.0-20.0%	¹²
50-59	2012	8.7% (n=184)	(5.4-14.0%)	4.0-30.0%	¹¹
50-59	2017	3.6% (n=907)	(1.7-7.4%)	2.0-15.0%	³²
HIV prevalence among all female sex workers					
15-59	1986	36.9% (n=101)	(27.6-46.7%)	10.0-85.0%	¹¹⁸
15-59	1987	36.9% (n=116)	(30.1-48.2%)	10.0-85.0%	¹¹⁸
15-59	1989	47.6% (n=120)	(38.4-56.7%)	10.0-85.0%	¹¹⁸
15-59	1990	68.4% (n=72)	(57.0-78.6%)	10.0-85.0%	¹¹⁸
15-59	1994	67.0% (n=607)	(63.2-70.8%)	10.0-85.0%	⁶⁹
15-59	1995	54.0% (n=832)	(50.5-57.4%)	10.0-85.0%	⁶⁹
15-59	1996	52.0% (n=916)	(48.7-55.2%)	10.0-85.0%	⁶⁹
15-59	1997	52.0% (n=876)	(48.7-55.4%)	10.0-85.0%	⁶⁹
15-59	1998	32.0% (n=876)	(28.9-35.3%)	10.0-65.0%	From ¹¹⁹ . As sample size was not available but data was from the same clinic as ⁶⁹ , we assumed the same sample size as the 1998 estimates.
15-59	1999	32.0% (n=876)	(28.7-35.5%)	10.0-65.0%	As above
15-59	2000	28.0% (n=876)	(24.8-31.4%)	10.0-55.0%	As above
15-59	2001	31.0% (n=876)	(27.7-34.4%)	10.0-55.0%	As above
15-59	2002	27.0% (n=876)	(23.8-30.3%)	10.0-55.0%	As above
15-59	2003	33.0% (n=876)	(28.0-38.0%)	10.0-55.0%	From ¹²⁰ . As sample size was not available but data was from the same clinic as ⁶⁹ , we assumed the same sample size as the 1998 estimates.
15-59	2004	27.0% (n=876)	(22.4-31.9%)	10.0-55.0%	¹²⁰
15-59	2005	18.0% (n=876)	(14.1-22.4%)	8.0-40.0%	¹²⁰
15-59	2006	19.0% (n=876)	(15.1-23.6%)	8.0-40.0%	¹²⁰
15-59	2007	21.0% (n=876)	(16.9-25.7%)	8.0-40.0%	¹²⁰
15-59	2007	22.9% (n=446)	(13.7-35.6%)	8.0-40.0%	¹²¹
15-59	2008	19.0% (n=876)	(15.1-23.6%)	8.0-40.0%	¹²⁰
15-59	2009	20.0% (n=876)	(15.9-22.5%)	8.0-40.0%	¹²⁰
15-59	2009	11.2% (n=446)	(6.4-18.9%)	8.0-40.0%	¹²¹
15-59	2010	21.0% (n=569)	(10.0-35.0%)	8.0-40.0%	¹²⁰
15-59	2014	11.0% (n=500)	(8.3-14.3%)	5.0-25.0%	⁹⁸ . Sample size not available and assumes n=500.
15-59	2016	11.4% (n=466)	(8.8-14.8%)	5.0-25.0%	⁷⁰

15-59	2020	4.9% (n=1177)	(3.8-6.3%)	2.0-15.0%	122
HIV prevalence among clients of sex workers					
15-59	1999	13.4% (n=423)	(10.5-17.0%)	5.0-30.0%	78
HIV Prevalence among MSM					
All 15-59	2015	11.2% (n=1301)	(9.6-13.1%)	5.0-25.0%	43
All 15-59	2016	19.6% (n=500)	N.A.	10.0-40.0%	123. Sample size not available and assumed n=500.
All 15-59	2017	12.3% (n=365)	(9.3-16.1%)	5.0-25.0%	124
All 15-59	2020	6.4% (n=1301)	(5.2-7.5%)	4.0-20.0%	47
All 15-24	2012	12.5% (n=355)	(6.8-18.2%)	3.0-35.0%	41
All 15-24	2015	11.4% (n=329)	(6.6-19.0%)	3.0-25.0%	43
All 15-24	2020	5.1% (n=633)	(3.4-6.8%)	2.0-15.0%	47. Sample size not available and assumed half of the study total sample size (n=1265)
All 25-49	2012	24.8% (n=246)	(16.7-34.9%)	10.0-60.0%	41
All 25-49	2015	16.3% (n=643)	(7.5-32.0%)	5.0-40.0%	43
All 25-49	2020	11.2% (n=633)	(7.3-14.9%)	3.0-22.0%	47. Sample size not available and assumed half of the study total sample size (n=1265)
All MSMW	2012	12.3% (n=327)	(9.2-16.3%)	5.0-25.0%	41
All MSMW	2020	6.2% (n=633)	(4.1-8.3%)	3.0-15.0%	47. Sample size not available and assumed half of the study total sample size (n=1265)
All MSME	2012	25.7% (n=264)	(20.8-31.3%)	10.0-45.0%	41
All MSME	2020	6.2% (n=633)	(4.0-8.2%)	3.0-15.0%	47. Sample size not available and assumed half of the study total sample size (n=1265)
HIV incidence rate (per 100 susceptible-year)					
15-59	2005	0.161	(0.069-0.304)	0.03-0.75	125. No sample size available.
15-59	2010	0.152	(0.065-0.286)	0.03-0.75	As above
15-59	2017	0.129	(0.055-0.243)	0.05-0.24	As above
Number of new HIV infections					
15-59	2005	18100	(7900-34000)	3000-65000	As above
15-59	2010	22000	(9700-41000)	4000-80000	As above
15-59	2017	26000	(11400-49000)	11400-49000	As above
Number of HIV-related deaths					
15-59	2005	48000	(29000-72000)	1000-100000	As above
15-59	2010	29000	(17500-45000)	5000-70000	As above
15-59	2017	21700	(12700-32000)	12700-32000	As above
Fraction of all females ever tested for HIV					
15-49	2000	7.2% (n=11475)	(6.7-7.7%)	1.0-25.0%	126
15-49	2005	10.9% (n=5177)	(8.2-14.5%)	5.0-35.0%	12
15-49	2011	35.4% (n=9937)	(33.1-37.8%)	20.0-50.0%	11
15-49	2016	56.0% (n=11780)	(53.9-58.0%)	35.0-75.0%	127
15-24	2009	25.3% (n=2325)	(23.6-27.1.)	10.0-50.0%	128
Fraction of all females not living with HIV ever tested for HIV					
15-49	2005	10.0% (n=4274)	(7.2-13.7%)	4.0-25.0%	12
15-49	2011	34.5% (n=4385)	(31.8-37.2%)	15.0-55.0%	11
15-49	2017	56.3% (n=5000)	(54.3-58.2%)	35.0-75.0%	32. Sample size not available and assumed n=5000.
Fraction of all females living with HIV ever tested for HIV					
15-49	2005	13.6% (n=255)	(7.9-22.5%)	5.0-40.0%	12
15-49	2011	42.0% (n=208)	(34.2-50.2%)	20.0-70.0%	11
15-49	2017	74.7% (n=300)	(67.5-82.0%)	50.0-95.0%	32. Sample size not available.
Fraction of all males ever tested for HIV					
15-49	2005	7.9% (n=4500)	(6.2-9.9%)	3.0-25.0%	12

15-49	2011	23.1% (n=4677)	(20.7-25.7%)	10.0-40.0%	11
15-49	2016	34.6% (n=5405)	(32.1-37.1%)	20.0-55.0%	127
15-24 males	2009	18.1% (n=2537)	(16.7-19.6%)	5.0-40.0%	128
Fraction of all males not living with HIV ever tested for HIV					
15-49	2005	7.4% (n=3791)	(6.2-9.9%)	3.0-20.0%	12
15-49	2011	23.0% (n=3851)	(20.7-25.7%)	10.0-40.0%	11
15-49	2017	32.2% (n=5000)	(30.1-34.4%)	20.0-45.0%	32. Sample size not available and assumed n=5000.
Fraction of all males living with HIV ever tested for HIV					
15-49	2005	23.7% (n=97)	(10.9-44.1%)	8.0-50.0%	12
15-49	2011	39.0% (n=107)	(28.4-50.7%)	25.0-65.0%	11
15-49	2017	53.4% (n=300)	(39.1-67.6%)	30.0-75.0%	32. Sample size not available and assumed n=300.
Fraction of FSW ever tested for HIV					
15-59	2007	54.0% (n=2461)	(52.0-56.0%)	30.0-85.0%	129
15-59	2020	82.0% (n=1177)	(79.0-83.0%)	65.0-92.0%	122
15-24	2014	75.3% (n=178)	(68.5-81.0%)	50.0-95.0%	98
25-49	2014	85.7% (n=245)	(81.1-89.3%)	65.0-99.0%	98
Fraction of MSM ever tested for HIV					
15-59	2011	62.6% (n=601)	(56.5-68.2%)	40.0-95.0%	41
15-59	2015	92.4% (n=105)	(85.7-96.1%)	70.0-99.0%	130
15-59	2020	70.0% (n=1265)	(67.0-72.0%)	60.0-90.0%	47
Fraction of all females living with HIV which are diagnosed					
15-59	2000	4.2% (n=500)	(3.5-5.0%)	1.0-15.0%	131. No sample size available but was assumed n=500.
15-59	2005	14.7% (n=500)	(12.2-17.6%)	5.0-30.0%	As above
15-59	2010	42.0% (n=500)	(35.0-50.3%)	20.0-60.0%	As above
15-59	2015	69.0% (n=500)	(58.3-84.0%)	50.0-95.0%	As above
15-59	2020	84.7% (n=500)	(70.5-99.0%)	70.0-99.0%	As above
Fraction of all males living with HIV which are diagnosed					
15-59	2000	3.2% (n=500)	(2.7-3.8%)	1.0-15.0%	As above
15-59	2005	10.9% (n=500)	(9.0-13.1%)	5.0-25.0%	As above
15-59	2010	29.1% (n=500)	(24.3-34.9%)	15.0-50.0%	As above
15-59	2015	49.9% (n=500)	(41.6-59.9%)	30.0-70.0%	As above
15-59	2020	68.1% (n=500)	(56.7-81.7%)	50.0-90.0%	As above
Fraction of all FSW living with HIV with a diagnosed infection					
15-59	2014	26.7% (n=45)	(15.9-41.0%)	5.0-70.0%	98
15-59	2020	81.0% (n=57)	(69.0-89.0%)	50.0-95.0%	122
Fraction of all MSM living with HIV with a diagnosed infection					
15-59	2011	15.9% (n=113)	(10.3-23.8%)	30.0-50.0%	41
15-59	2015	37.0% (n=146)	(29.6-45.1%)	15.0-65.0%	37
15-59	2017	26.7% (n=45)	(16.0-41.0%)	10.0-60.0%	45
15-59	2020	32.7% (n=98)	(34.1-42.4%)	15.0-60.0%	47
Fraction of all females living with HIV with a treated infection					
15-59	2015	44.0%	(40.0-50.0%)	25.0-60.0%	68. No sample size available.
15-59	2020	83.0%	(74.0-94.0%)	69.0-99.0%	As above
Fraction of all males living with HIV with a treated infection					
15-59	2015	29.0%	(25.0-34.0%)	15.0-50.0%	As above
15-59	2020	61.0%	(55.0-71.0%)	49.0-78.0%	As above
Fraction of all FSW living with HIV with a treated infection					
15-59	2012	45.6% (n=163)	(42.2-49.1%)	20.0-70.0%	120
15-59	2020	65.0% (n=32)	(52.0-76.0%)	52.0-76.0%	122
Fraction of PLHIV with a suppressed viral load					
15-49 females	2017	38.4% (n=240)	(29.2-47.7%)	20.0-55.0%	32
15-49 males	2017	20.1% (n=97)	(11.9-28.3%)	5.0-40.0%	32
15-49 MSM	2017	19.4% (n=36)	(9.8-35.2%)	10.0-45.0%	45
Number of conventional HIV tests done by females each year					

15-59	2015	1,601,691	N.A.	(800,846-3,203,382)	Programmatic data reported by countries to UNAIDS's Shiny90 ¹³¹ . No sample size available.
15-59	2016	1,826,826	N.A.	(913,413-3,653,652)	As above
15-59	2017	1,631,236	N.A.	(815,718-3,262,672)	As above
15-59	2018	1,809,731	N.A.	(904,866-3,619,462)	As above
Number of conventional HIV tests done by males each year					
15-59	2015	492,691	N.A.	(246,346-985,382)	As above
15-59	2016	553,680	N.A.	(276,840-1,107,360)	As above
15-59	2017	437,692	N.A.	(218,846-975,384)	As above
15-59	2018	902,838	N.A.	(451,419-1,805,676)	As above
Fraction of conventional HIV tests done by females which are positive					
15-59	2015	3.2%	N.A.	(1.6-6.5%)	As above
15-59	2016	2.6%	N.A.	(1.3-5.2%)	As above
15-59	2017	2.2%	N.A.	(1.1-4.4%)	As above
15-59	2018	1.8%	N.A.	(0.9-3.5%)	As above
Fraction of conventional HIV tests done by males which are positive					
15-59	2015	3.6%	N.A.	(1.8-7.1%)	As above
15-59	2016	3.0%	N.A.	(1.5-6.0%)	As above
15-59	2017	3.0%	N.A.	(1.5-6.0%)	As above
15-59	2018	3.5%	N.A.	(1.8-7.0%)	As above

MSMW: men who have sex with men as well as female partners; MSME: men who have sex with men exclusively.
N.A.: Not available

Fitting data (Mali)

Table S2b: List of demographic, epidemiological, and intervention outcomes used for model fitting in Mali					
Population or age group	Year	Point estimate (sample size used for simulation likelihood calculation)	Original 95% CI	Prior constraint	Reference
Population size					
Total number of 15-59 years-old	1970 1980 1990 2000 2010 2020	3.15 million 3.57 million 4.00 million 5.30 million 7.27 million 9.95 million	N.A.	Initial value for 1970 and direct calibration using growth rate between 1970 and 2020 estimates	From ⁴
Age distribution among 15–59-year-old females					
	1970	15-24 years: 35.0% 25-49 years: 51.6% 50-59 years: 13.4%	N.A.	Used for comparison	From ⁴ . This data was only used for comparison because we used UNPD estimates for the year 1970 combining female and males as model input (Table S1a), and fitted our model to sex-specific UNPD estimates for 2020.
	1980	15-24 years: 36.3% 25-49 years: 51.5% 50-59 years: 12.2%	N.A.	Used for comparison	As above
	1990	15-24 years: 39.0% 25-49 years: 49.8% 50-59 years: 11.2%	N.A.	Used for comparison	As above
	2000	15-24 years: 40.5% 25-49 years: 49.3% 50-59 years: 10.2%	N.A.	Used for comparison	As above
	2010	15-24 years: 39.0% 25-49 years: 51.7% 50-59 years: 9.3%	N.A.	Used for comparison	As above
	2020	15-24 years: 39.9% 25-49 years: 51.1% 50-59 years: 9.0%	N.A.	30.7-51.9% 39.3-66.4% 6.0-13.5%	Fitted from ⁴
Age distribution among 15–59-year-old males					
	1970	15-24 years: 35.8% 25-49 years: 51.2% 50-59 years: 13.0%	N.A.	Used for comparison	From ⁴ . This data was only used for comparison because we used UNPD estimates for the year 1970 combining female and males as model input (Table S1a), and fitted our model to sex-specific UNPD estimates for 2020.
	1980	15-24 years: 38.0% 25-49 years: 50.2% 50-59 years: 11.8%	N.A.	Used for comparison	As above
	1990	15-24 years: 42.0% 25-49 years: 47.9% 50-59 years: 10.1%	N.A.	Used for comparison	As above

	2000	15-24 years: 43.3% 25-49 years: 48.1% 50-59 years: 8.6%	N.A.	Used for comparison	As above
	2010	15-24 years: 40.5% 25-49 years: 51.5% 50-59 years: 8.0%	N.A.	Used for comparison	As above
	2020	15-24 years: 41.1% 25-49 years: 50.9% 50-59 years: 8.0%	N.A.	31.6-53.4% 39.2-66.2% 5.3-12.0%	Fitted from ⁴
HIV prevalence among all adult females (except female sex workers)					
15-24	2001	1.3% (n=1546)	(0.7-2.0%)	0.1-5.0%	18
15-24	2006	0.9% (n=1850)	(0.4-1.5%)	0.1-4.0%	17
15-24	2013	1.1% (n=1713)	(0.6-1.7%)	0.3-2.3%	16
25-49	2001	2.6% (n=2289)	(1.0-4.3%)	0.5-10.0%	18
25-49	2006	1.7% (n=2677)	(1.0-2.4%)	0.2-7.0%	17
25-49	2013	1.5% (n=3093)	(1.0-1.9%)	0.4-2.9%	16
HIV prevalence among all adult males					
15-24	2001	0.3% (n=994)	(0.0-0.7%)	0.0-3.0%	18
15-24	2006	0.5% (n=1492)	(0.0-0.9%)	0.0-4.0%	17
15-24	2013	0.3% (n=1210)	(0.0-0.7%)	0.0-1.0%	16
25-49	2001	2.0% (n=1602)	(1.0-4.3%)	0.5-8.0%	18
25-49	2006	1.1% (n=2121)	(0.5-1.8%)	0.2-5.0%	17
25-49	2013	1.1% (n=2293)	(0.6-1.6%)	0.2-2.5%	16
50-59	2006	1.2% (n=488)	(0.0-2.4%)	0.0-7.0%	17
50-59	2013	1.2% (n=551)	(0.0-2.3%)	0.0-3.5%	16
HIV prevalence among all female sex workers					
15-59	1987	36.0% (n=103)	N.A.	5.0-85.0%	99
15-59	1995	46.0% (n=176)	(38.8-53.4%)	20.0-85.0%	132
15-59	1997	30.4% (n=191)	(24.3-37.2%)	15.0-80.0%	100
15-59	2000	28.9% (n=200)	N.A.	13.0-70.0%	⁷³ . Sample size not available and assumed n=200.
15-59	2003	31.9% (n=200)	N.A.	15.0-60.0%	As above
15-59	2006	35.3% (n=200)	N.A.	15.0-70.0%	As above
15-59	2009	24.2% (n=433)	(21.4-27.2%)	12.0-60.0%	⁷³
15-59	2013	18.3% (n=388)	(14.8-22.5%)	10.0-50.0%	¹⁰³
15-59	2017	20.8% (n=303)	(16.6-25.7%)	10.0-40.0%	¹³³
15-59	2018	20.4% (n=353)	(16.3-25.0%)	10.0-40.0%	¹⁰⁴
15-59	2019	8.7% (n=1253)	(7.3-10.4%)	4.0-30.0%	¹⁵
HIV prevalence among clients of sex workers					
15-59	2009	2.7% (n=731)	(1.8-4.2%)	Only used for comparison	⁷³ . This study was among truck drivers, which do not well represent FSW clients.
15-59	2019	1.9% (n=1104)	(1.2-2.9%)	Only used for comparison	¹⁵ . This study was among truck drivers, which do not well represent FSW clients.
HIV Prevalence among MSM					
All 15-59	2011	20.1% (n=200)	N.A.	5.0-70.0%	⁶ (original source not found, sample size not available and assumed n=200)
All 15-59	2015	18.1% (n=552)	(15.1-21.5%)	3.0-32.0%	⁵⁰
All 15-59	2015	9.5% (n=613)	(5.6-13.5%)	3.0-32.0%	⁴⁸
All 15-24	2020	8.5% (n=613)	(6.5-11.0%)	4.0-15.0%	³³
All 25-49	2020	19.1% (n=418)	(15.6-23.1%)	10.0-28.0%	³³
HIV incidence rate (per 100 susceptible-year)					
15-59	1990	0.255	(0.128-0.398)	0.03-1.40	⁶⁸
15-59	1995	0.232	(0.179-0.310)	0.06-0.36	As above
15-59	2000	0.133	(0.105-0.167)	0.05-0.30	As above
15-59	2005	0.092	(0.071-0.115)	0.03-0.21	As above
15-59	2010	0.066	(0.049-0.086)	0.03-0.19	As above

15-59	2015	0.048	(0.032-0.067)	0.01-0.17	As above
15-59	2020	0.030	(0.018-0.052)	0.01-0.06	As above
Number of new HIV infections					
15-59	1990	11000	(5600-17000)	2600-37000	⁶⁸
15-59	1995	11000	(8700-15000)	2700-35000	As above
15-59	2000	7400	(5800-9300)	1800-25300	As above
15-59	2005	5900	(4500-7400)	1200-14000	As above
15-59	2010	4900	(3600-6400)	1000-9000	As above
15-59	2015	4100	(2800-5800)	800-8000	As above
15-59	2020	3100	(1800-5200)	1800-7000	As above
Number of HIV-related deaths					
15-59	1990	1100	(0-3200)	0-8200	⁶⁸
15-59	1995	3400	(1600-6700)	500-12300	As above
15-59	2000	6000	(4100-8500)	2100-15500	As above
15-59	2005	6400	(5100-8000)	2100-16000	As above
15-59	2010	4200	(3300-5400)	1300-9400	As above
15-59	2015	4300	(3400-5400)	1400-9400	As above
15-59	2020	3100	(2200-4300)	1500-5500	As above
Fraction of all females ever tested for HIV					
15-49	2001	4.2% (n=12837)	(3.5-5.0%)	1.0-20.0%	¹⁸
15-49	2009	14.4% (n=26717)	(13.3-15.6%)	5.0-50.0%	¹³⁴
15-49	2015	19.9% (n=18409)	(18.0-21.9%)	8.0-50.0%	¹³⁵
15-49	2018	17.9% (n=10519)	(15.8-20.1%)	10.0-50.0%	⁵⁹
Fraction of all females not living with HIV ever tested for HIV					
15-49	2006	6.2% (n=4644)	(5.2-7.5%)	2.0-25.0%	¹⁷
15-49	2013	12.4% (n=5044)	(10.6-14.3%)	5.0-45.0%	¹⁶
Fraction of all females living with HIV ever tested for HIV					
15-49	2006	16.9% (n=69)	N.A.	5.0-50.0%	¹³¹
15-49	2013	36.5% (n=66)	N.A.	20.0-60.0%	As above
15-49	2020	54.7% (n=100)	N.A.	40.0-70.0%	As above
Fraction of all males ever tested for HIV					
15-49	2001	9.0% (n=3053)	(7.3-10.9%)	1.0-40.0%	¹⁸
15-49	2015	17.3% (n=7428)	(15.7-19.0%)	5.0-45.0%	¹³⁵
15-49	2018	14.7% (n=4618)	(32.1-37.1%)	8.0-30.0%	⁵⁹
Fraction of all males not living with HIV ever tested for HIV					
15-49	2006	6.4% (n=3449)	(5.3-7.8%)	2.0-30.0%	¹⁷
15-49	2013	10.7% (n=3304)	(9.1-12.6%)	4.0-30.0%	¹⁶
Fraction of all males living with HIV ever tested for HIV					
15-49	2006	16.4% (n=34)	N.A.	8.0-45.0%	¹³¹
15-49	2013	33.7% (n=25)	N.A.	15.0-60.0%	As above
15-49	2020	49.8% (n=100)	N.A.	35.0-65.0%	As above
Fraction of FSW ever tested for HIV					
15-59	2000	35.9% (n=131)	N.A.	2.0-70.0%	¹⁰¹
15-59	2003	30.5% (n=133)	N.A.	10.0-60.0%	As above
15-59	2006	50.8% (n=200)	N.A.	25.0-80.0%	As above
15-59	2009	67.3% (n=409)	N.A.	30.0-90.0%	As above
15-59	2018	45.8% (n=72)	(34.8-57.3%)	20.0-85.0%	¹⁰⁴ (Sample of FSW living with HIV)
Fraction of MSM ever tested for HIV					
15-59	2015	71.6% (n=522)	N.A.	50.0-95.0%	⁵⁰
15-59	2019	83.2% (n=1031)	(80.8-85.4%)	60.0-90.0%	³³
Fraction of all females living with HIV which are diagnosed					
15-59	2000	5.5% (n=500)	(4.6-6.6%)	1.0-15.0%	¹³¹ . No sample size available but was assumed n=500.
15-59	2005	11.6% (n=500)	(9.7-14.0%)	5.0-25.0%	As above
15-59	2010	30.4% (n=500)	(25.3-36.5%)	15.0-50.0%	As above
15-59	2015	37.8% (n=500)	(31.5-45.4%)	20.0-60.0%	As above
15-59	2020	51.3% (n=500)	(42.8-61.6%)	30.0-70.0%	As above
Fraction of all males living with HIV which are diagnosed					

15-59	2000	5.3% (n=500)	(4.4-6.4%)	1.0-15.0%	As above
15-59	2005	11.2% (n=500)	(9.3-13.5%)	5.0-25.0%	As above
15-59	2010	28.8% (n=500)	(24.0-34.6%)	15.0-50.0%	As above
15-59	2015	34.9% (n=500)	(29.1-41.9%)	20.0-60.0%	As above
15-59	2020	45.5% (n=500)	(37.9-54.6%)	30.0-70.0%	As above
Fraction of all FSW living with HIV with a diagnosed infection					
15-59	2018	45.8% (n=72)	(34.8-57.3%)	28.0-70.0%	¹⁰⁴
Fraction of all MSM living with HIV with a diagnosed infection					
15-59	2014	34.1% (n=79)	(15.6-52.5%)	15.0-65.0%	⁴⁸
Fraction of all females living with HIV with a treated infection					
15-49	2015	39.0%	(33.0-47.0%)	20.0-60.0%	⁶⁸ . No sample size available.
15-49	2020	62.0%	(51.0-76.0%)	45.0-82.0%	As above
Fraction of all males living with HIV with a treated infection					
15-49	2015	25.0%	(21.0-30.0%)	10.0-50.0%	As above
15-49	2020	44.0%	(35.0-53.0%)	30.0-60.0%	As above
Fraction of all MSM living with HIV with a treated infection					
15-59	2014	30.0% (n=79)	(18.3-45.0%)	10.0-60.0%	⁴⁸
Fraction of FSW living with HIV with a suppressed viral load					
15-49	2019	51.6% (n=93)	(41.3-61.7%)	30.0-70.0%	¹⁵
Fraction of MSM living with HIV with a suppressed viral load					
15-49	2014	30.0% (n=79)	(18.3-45.0%)	10.0-60.0%	⁴⁸
15-24	2020	40.0% (n=52)	(27.5-44.8%)	20.0-65.0%	³³
25-49	2020	48.1% (n=79)	(37.0-59.2%)	30.0-70.0%	³³
Number of conventional HIV tests done each year (females and males combined)					
15-59	2015	393,007	N.A.	(196,504-786,014)	Programmatic data reported by countries to UNAIDS's Shiny90 ¹³¹
15-59	2016	400,005	N.A.	(200,003-800,010)	As above
15-59	2017	476,098	N.A.	(238,049-952,196)	As above
15-59	2018	565,838	N.A.	(282,919-1,131,676)	As above
15-59	2019	504,414	N.A.	(252,207-1,008,828)	As above
Fraction of conventional HIV tests done which are positive (females and males combined)					
15-59	2015	2.3%	N.A.	(1.2-4.6%)	As above
15-59	2016	1.7%	N.A.	(0.9-3.5%)	As above
15-59	2017	2.6%	N.A.	(1.3-5.1%)	As above
15-59	2018	2.3%	N.A.	(1.2-4.6%)	As above
15-59	2019	2.5%	N.A.	(1.2-5.0%)	As above

MSMW: men who have sex with men as well as female partners; MSME: men who have sex with men exclusively.
N.A.: Not available

Fitting data (Senegal)

Table S2c: List of demographic, epidemiological, and intervention outcomes used for model fitting in Senegal					
Population or age group	Year	Point estimate (sample size used for simulation likelihood calculation)	Original 95%CI	Prior constraint	Reference
Population size					
Total number of 15-59years-old	1970 1980 1990 2000 2010 2020	2.18 million 2.74 million 3.64 million 4.92 million 6.56 million 8.81 million	N.A.	Initial value for 1970 and direct calibration using growth rate between 1970 and 2020 estimates	From ⁴
Age distribution among 15–59-year-old females					
	1970	15-24 years: 35.7% 25-49 years: 53.0% 50-59 years: 11.3%	N.A.	Used for comparison	From ⁴ . This data was only used for comparison because we used UNPD estimates for the year 1970 combining female and males as model input (Table S1a), and fitted our model to sex-specific UNPD estimates for 2020.
	1980	15-24 years: 37.2% 25-49 years: 51.4% 50-59 years: 11.4%	N.A.	Used for comparison	As above
	1990	15-24 years: 39.3% 25-49 years: 49.8% 50-59 years: 10.9%	N.A.	Used for comparison	As above
	2000	15-24 years: 40.4% 25-49 years: 50.1% 50-59 years: 9.5%	N.A.	Used for comparison	As above
	2010	15-24 years: 37.8% 25-49 years: 52.5% 50-59 years: 9.7%	N.A.	Used for comparison	As above
	2020	15-24 years: 35.6% 25-49 years: 54.2% 50-59 years: 10.2%	N.A.	27.4-46.3% 41.6-70.5% 6.8-15.3%	Fitted from ⁴
Age distribution among 15–59-year-old males					
	1970	15-24 years: 35.7% 25-49 years: 53.8% 50-59 years: 10.5%	N.A.	Used for comparison	From ⁴ . This data was only used for comparison because we used UNPD estimates for the year 1970 combining female and males as model input (Table S1a), and fitted our model to sex-specific UNPD estimates for 2020.
	1980	15-24 years: 37.3% 25-49 years: 51.6% 50-59 years: 11.1%	N.A.	Used for comparison	As above
	1990	15-24 years: 40.4% 25-49 years: 48.8% 50-59 years: 10.8%	N.A.	Used for comparison	As above

2000	15-24 years: 42.8% 25-49 years: 48.2% 50-59 years: 9.0%	N.A.	Used for comparison	As above	
2010	15-24 years: 41.4% 25-49 years: 50.0% 50-59 years: 8.6%	N.A.	Used for comparison	As above	
2020	15-24 years: 39.1% 25-49 years: 52.3% 50-59 years: 8.6%	N.A.	30.1-50.8% 40.2-68.0% 5.7-12.9%	Fitted from ⁴	
HIV prevalence among all adult females (except female sex workers)					
15-24	2005	0.5% (n=1991)	(0.1-0.8%)	0.1-3.0%	22
15-24	2011	0.3% (n=2432)	(0.1-0.5%)	0.1-3.0%	23
15-24	2017	0.2% (n=3353)	(0.0-0.5%)	0.0-1.0%	25
25-49	2005	0.8% (n=2475)	(0.4-1.3%)	0.4-6.0%	22
25-49	2011	0.8% (n=3158)	(0.4-1.1%)	0.4-5.0%	23
25-49	2017	0.7% (n=4612)	(0.5-1.3%)	0.5-1.5%	25
HIV prevalence among all adult males					
15-24	2005	0.1% (n=1482)	(0.0-0.2%)	0.0-1.5%	22
15-24	2011	0.1% (n=1916)	(0.0-0.1%)	0.0-1.5%	23
15-24	2017	0.1% (n=2736)	(0.0-0.2%)	0.0-1.0%	25
25-49	2005	0.7% (n=1466)	(0.1-1.2%)	0.1-5.0%	22
25-49	2011	0.7% (n=1956)	(0.3-1.2%)	0.1-5.0%	23
25-49	2017	0.6% (n=2994)	(0.3-1.0%)	0.1-2.0%	25
50-59	2011	0.8% (n=455)	(0.1-1.4%)	0.0-5.0%	23
50-59	2017	1.2% (n=615)	(0.3-2.1%)	0.0-3.0%	25
HIV prevalence among all female sex workers					
15-59	1988	16.1% (n=1710)	(14.5-18.0%)	5.0-60.0%	136
15-59	1989	3.1% (n=200)	N.A.	1.0-60.0%	137
15-59	1994	10.1% (n=200)	N.A.	2.0-60.0%	As above
15-59	2000	20.1% (n=1296)	(18.0-22.4%)	5.0-60.0%	138
15-59	2006	19.8% (n=618)	(16.8-23.1%)	5.0-60.0%	77
15-59	2010	18.5% (n=672)	N.A.	5.0-50.0%	76
15-59	2015	6.6% (n=694)	(5.4-8.7%)	2.0-30.0%	75
15-59	2015	3.3% (n=758)	(1.5-5.2%)	2.0-30.0%	79
15-59	2017	8.1% (n=173)	N.A.	3.0-40.0%	110
15-59	2019	5.8% (n=1749)	(4.0-7.0%)	10.0-40.0%	74
HIV prevalence among clients of sex workers					
15-59	1999	4.4% (n=1071)	(3.3-5.8%)	1.0-30.0%	139
15-59	2015	1.2% (n=600)	(0.2-2.5%)	0.5-10.0%	IBBS surveys ⁷⁹ (personal communication of estimated from the unpublished client survey)
HIV Prevalence among MSM					
All 15-59	2012	38.6% (n=114)	(30.2-47.8%)	15.0-60.0%	140
All 15-59	2016	23.5% (n=724)	(18.6-28.4%)	10.0-40.0%	79 (RDS-adjusted estimates)
All 15-24	2014	17.7% (n=645)	(14.9-20.8%)	5.0-30.0%	55
All 15-24	2017	19.4% (n=690)	(16.6-22.5%)	5.0-35.0%	56 (data fitted among MSMW/MSME separately)
All 25-49	2014	18.1% (n=365)	(14.5-22.4%)	5.0-50.0%	55
All 25-49	2017	39.5% (n=441)	(35.0-44.1%)	16.0-60.0%	56
All MSMW	2004	20.2% (n=401)	(16.6-24.4%)	5.0-60.0%	51
All MSMW	2007	19.3% (n=357)	(15.5-23.7%)	5.0-50.0%	80
All MSMW	2017	24.1% (n=882)	(21.4-27.0%)	15.0-35.0%	56
All MSME	2004	34.1% (n=41)	(21.5-49.4%)	5.0-70.0%	51
All MSME	2007	29.0% (n=131)	(21.9-37.3%)	13.0-70.0%	80
All MSME	2017	37.7% (n=266)	(32.0-43.7%)	25.0-50.0%	56
HIV incidence rate (per 100 susceptible-year)					
15-59	1990	0.036	(0.028-0.046)	0.010-0.12	68
15-59	1995	0.072	(0.058-0.088)	0.018-0.160	As above
15-59	2000	0.094	(0.080-0.112)	0.030-0.192	As above

15-59	2005	0.064	(0.052-0.076)	0.022-0.146	As above
15-59	2010	0.018	(0.014-0.022)	0.007-0.052	As above
15-59	2015	0.010	(0.008-0.013)	0.004-0.045	As above
15-59	2020	0.010	(0.088-0.014)	0.004-0.030	As above
Number of new HIV infections					
15-59	1990	1400	(1100-1800)	300-4500	68
15-59	1995	3300	(2600-3900)	1600-7000	As above
15-59	2000	4900	(4100-5800)	2100-9800	As above
15-59	2005	3800	(3100-4500)	2100-8500	As above
15-59	2010	1200	(0-1500)	0-3500	As above
15-59	2015	500	(0-1000)	0-3000	As above
15-59	2020	700	(0-1300)	0-2600	As above
Number of HIV-related deaths					
15-59	1990	100	(0-500)	0-2000	68
15-59	1995	500	(0-1000)	0-3000	As above
15-59	2000	1300	(1100-1700)	500-3700	As above
15-59	2005	2400	(2000-2900)	1000-3900	As above
15-59	2010	1200	(0-1600)	0-3000	As above
15-59	2015	1600	(1200-2000)	600-4000	As above
15-59	2020	800	(0-1000)	0-1500	As above
Fraction of all females ever tested for HIV					
15-49	2000	3.0% (n=11793)	(2.4-3.8%)	0.0-20.0%	141
15-49	2014	42.6% (n=8488)	(40.0-45.2%)	25.0-80.0%	28
15-49	2015	42.6% (n=8851)	(40.1-45.1%)	25.0-80.0%	27
15-49	2016	39.8% (n=8865)	(36.8-42.8%)	10.0-50.0%	26
Fraction of all females not living with HIV ever tested for HIV					
15-49	2005	2.8% (n=4408)	(2.2-3.6%)	0.5-20.0%	22
15-49	2010	27.3% (n=5529)	(25.3-29.4%)	15.0-70.0%	142
15-49	2017	46.1% (n=7909)	(44.1-48.1%)	32.0-80.0%	25
Fraction of all females living with HIV ever tested for HIV					
15-49	2005	6.7% (n=48)	N.A.	2.0-40.0%	131
15-49	2010	50.0% (n=61)	N.A.	25.0-80.0%	As above
15-49	2017	82.2% (n=56)	N.A.	70.0-99.0%	As above
Fraction of all males ever tested for HIV					
15-49	2014	20.0% (n=3067)	(17.5-22.7%)	12.0-70.0%	28
15-49	2015	21.8% (n=3445)	(19.2-24.7%)	12.0-70.0%	27
15-49	2016	19.8% (n=3236)	(17.3-22.4%)	10.0-70.0%	26
15-49	2018	17.9% (n=3134)	(15.8-20.1%)	10.0-60.0%	24
Fraction of all males not living with HIV ever tested for HIV					
15-49	2005	3.7% (n=2977)	(2.8-4.9%)	1.0-20.0%	22
15-49	2010	16.7% (n=3919)	(15.1-18.6%)	5.0-60.0%	142
15-49	2017	19.0% (n=5790)	(17.3-20.8%)	15.0-70.0%	25
Fraction of all males living with HIV ever tested for HIV					
15-49	2005	4.9% (n=14)	N.A.	1.0-40.0%	131
15-49	2010	30.0% (n=24)	N.A.	10.0-80.0%	As above
15-49	2017	55.7% (n=27)	N.A.	35.0-90.0%	As above
Fraction of FSW ever tested for HIV					
15-59	2006	63.2% (n=618)	N.A.	10.0-90.0%	77
15-59	2010	73.6% (n=694)	N.A.	20.0-95.0%	76
15-59	2013	58.0% (n=500)	N.A.	25.0-90.0%	40. Sample size not available and assumed n=500.
15-59	2015	72.4% (n=550)	(68.5-76.0%)	30.0-95.0%	79
15-59	2018	79.4% (n=155)	(72.3-85.0%)	40.0-95.0%	143
Fraction of MSM ever tested for HIV					
15-59	2003	13.3% (n=158)	(8.9-19.5%)	3.0-60.0%	107
15-59	2004	10.8% (n=463)	(8.1-14.0%)	3.0-50.0%	51
15-59	2007	34.1% (n=501)	(30.1-38.4%)	10.0-70.0%	75,80
15-59	2012	86.6% (n=119)	(79.3-91.6%)	55.0-99.0%	140
15-59	2014	72.6% (n=3649)	N.A.	30.0-90.0%	144

15-59	2014	69.1% (n=1012)	N.A.	50.0-90.0%	75
15-59	2015	70.2% (n=727)	(66.7-74.4%)	50.0-95.0%	79
15-59	2017	82.6% (n=1148)	(80.2-84.7%)	60.0-95.0%	56
15-59	2018	54.0% (n=174)	(46.6-61.3%)	40.0-90.0%	143
Fraction of all females living with HIV which are diagnosed					
15-59	2000	2.0% (n=500)	(1.6-2.4%)	1.0-10.0%	¹³¹ . No sample size available but was assumed n=500.
15-59	2005	4.7% (n=500)	(4.0-5.7%)	1.0-20.0%	As above
15-59	2010	47.5% (n=500)	(39.6-57.0%)	30.0-70.0%	As above
15-59	2015	69.9% (n=500)	(58.3-83.9%)	50.0-95.0%	As above
15-59	2020	92.0% (n=500)	(76.7-99.0%)	75.0-99.0%	As above
Fraction of all males living with HIV which are diagnosed					
15-59	2000	1.3%	(1.1-1.6%)	1.0-10.0%	As above
15-59	2005	3.3% (n=500)	(2.8-4.0%)	1.0-15.0%	As above
15-59	2010	27.4% (n=500)	(22.0-32.9%)	10.0-50.0%	As above
15-59	2015	45.7% (n=500)	(38.1-54.8%)	30.0-70.0%	As above
15-59	2020	65.5% (n=500)	(54.6-78.6%)	50.0-90.0%	As above
Fraction of all FSW living with HIV with a diagnosed infection					
15-59	2000	5.1% (n=39)	(1.4-16.9%)	0.0-40.0%	145
15-59	2002	29.3% (n=208)	(23.6-35.8%)	5.0-70.0%	146
15-59	2010	12.5% (n=128)	(7.8-19.3%)	5.0-80.0%	76
15-59	2015	53.8% (n=39)	(37.4-69.6%)	20.0-90.0%	143
15-59	2015	67.5% (n=40)	(52.0-79.9%)	20.0-90.0%	147
15-59	2016	55.0% (n=40)	(39.8-69.3%)	30.0-80.0%	79
Fraction of all MSM living with HIV with a diagnosed infection					
15-59	2014	48.8% (n=41)	(34.2-63.5%)	20.0-85.0%	140
15-59	2016	13.2% (n=219)	(9.4-18.4%)	5.0-80.0%	79
15-59	2018	63.4% (n=100)	N.A.	40.0-90.0%	⁶ . No sample size available.
Fraction of all females living with HIV with a treated infection					
15-49	2015	56.0%	(50.0-63.0%)	20.0-90.0%	⁶⁸ . No sample size available.
15-49	2020	95.0%	(85.0-99.0%)	85.0-99.0%	As above
Fraction of all males living with HIV with a treated infection					
15-49	2015	35.0%	(31.0-39.0%)	10.0-80.0%	As above
15-49	2020	61.0%	(54.0-69.0%)	45.0-75.0%	As above
Fraction of all FSW living with HIV with a treated infection					
15-59	2016	37.5% (n=40)	(24.2-53.0%)	20.0-53.0%	79
Fraction of all MSM living with HIV with a treated infection					
15-59	2016	10.0% (n=219)	(24.2-53.0%)	20.0-53.0%	79
15-59	2019	38.0% (n=200)	N.A.	10.0-60.0%	⁶ , No sample size available.
Fraction of FSW living with HIV with a suppressed viral load					
15-49	2019	48.0% (n=100)	(38.5-57.7%)	35.0-60.0%	74
Number of conventional HIV tests done each year (females and males combined)					
15-59	2016	611,175	N.A.	(305,588-1,222,350)	Programmatic data reported by countries to UNAIDS's Shiny90 ¹³¹
15-59	2017	550,386	N.A.	(275,193-1,100,772)	As above
15-59	2018	669,438	N.A.	(334,719-1,338,876)	As above
15-59	2019	684,635	N.A.	(342,318-1,369,270)	As above
Fraction of conventional HIV tests done which are positive (females and males combined)					
15-59	2016	1.5%	N.A.	(0.7-2.9%)	As above
15-59	2017	1.6%	N.A.	(0.8-3.3%)	As above
15-59	2018	1.1%	N.A.	(0.5-2.1%)	As above
15-59	2019	1.2%	N.A.	(0.6-2.4%)	As above

MSMW: men who have sex with men as well as female partners; MSME: men who have sex with men exclusively.
N.A.: Not available

Methods: simulated HIVST scenarios

Number of HIVST distributed by ATLAS over 2019-2021

A total of 187,914 HIVST were distributed by ATLAS in Côte d’Ivoire over 2019-2021, including 105,904 tests (56%) through FSW channels, 53,864 (29%) through MSM channels, and 28,146 (15%) through other channels (48% of them within STI clinics, 48% to partners of PLHIV, and 3% to people who use drugs (PwUD)). Individuals reached by ATLAS received an average of two test kits, and it was expected that they would distribute some or sometimes all (e.g., PLHIV already aware of their status) their tests to their sexual partners or friends.

This analysis only used programmatic data on number of HIVST distributed through the FSW and MSM channels. We used the channel-specific age-distribution of individuals receiving the tests from the ATLAS programmatic data. The age distribution of HIVST distributed over 2019-2021 through the FSW and MSM channels of the three ATLAS countries, under our assumptions, is shown in **Table S3** and **Figure S2**.

Table S3: Number of HIV self-test (HIVST) kits distributed over 2019-2021 in each ATLAS country by distribution channel and age (% by group for each country)						
Age (years)	Female sex workers (FSW) channel			Men who have sex with men (MSM) channel		
	15-24	25-49	50+	15-24	25-49	50+
Côte d’Ivoire	46 300 (29%)	58 900 (37%)	800 (1%)	26 200 (16%)	27 400 (17%)	200 (<1%)
Mali	48 200 (37%)	58 900 (45%)	3100 (2%)	8800 (7%)	11 900 (9%)	200 (<1%)
Senegal	8100 (18%)	20 500 (45%)	1300 (3%)	5900 (13%)	9800 (21%)	200 (<1%)

Primary and secondary distribution

The first stage of an ATLAS phone survey, carried out between March and June 2021, administered sociodemographic questionnaires by telephone to individuals reporting having received ATLAS HIVST kits¹⁴⁸. In the survey, the HIVST distribution channel corresponding to the test used by a participant was identified using a survey serial number printed on survey flyers distributed with HIVST kits. The proportion of tests being received by individuals from the different modelled risk groups was calculated using two scenarios that reflect uncertainties related to the characteristics of individuals receiving the tests. This uncertainty was partly due to the poor reporting of specific behaviours such as paying or receiving money for sex, or sex between men in the region.

Both scenarios assumed that the age group of the individual (directly or indirectly) receiving a test is the same age group as the individual that directly received the test in the programmatic data (groups are 15-24, 25-49, 50+ years old). A specific sensitivity analysis is looking at the predicted impact of HIVST scale-up when using the age distribution from the phone survey and not the programmatic

data (see Figure S2). The model assumes that the fraction of HIVST used among those received is the same across risk groups (80% in most scenarios, see specific section), thus the age/risk distribution of people who received the tests is the same as the one who used the tests.

HIVST distribution under the base-case scenarios

All our base case scenarios used the sex distribution of the phone survey (1st stage) participants by HIVST distribution channel and reflected the distribution of HIVST within the different risk groups (through primary and secondary distribution) accounting for reporting biases described in qualitative studies. The **Table S4a** reports the fraction of HIVST distributed within each channel by risk group under the base case scenario.

In the phone survey, 52% of respondents receiving HIVST from a FSW channel reported being females, and 48% being males. Our base case scenarios assumed that 90% of females receiving the test through the FSW channels were female sex workers, with the remaining 10% being non-FSW females having multiple sexual partners in the model (“intermediate-risk females”). For the tests received by male participants through an FSW channel, we assumed that the 67% (2/3) were received by clients of FSW (as these males are likely to have received the tests from a FSW through secondary distribution), and the remaining 33% non-client males that have 3+ partners per year in the model to (“intermediate risk males”).

In the phone survey data, 91% of respondents using a test delivered through an MSM channel reported being males. We further assumed that all males receiving HIVST through the MSM channels were MSM and that 66% of them (60% of the total) also had female partners (MSMW). This assumption was based on country-level data on the fraction of MSMW among MSM, as well as the fraction (68%, 334/494) of male phone survey participants from the MSM channel reporting having both male and female partners among those reporting male partners. Out of the 9% of females receiving HIVST from the MSM channel, we assumed that 60% were lower-risk females, 40% were intermediate-risk females, and none were FSW. This was based on the likeliness of MSM having monogamous female partners, whilst in the phone survey, ~55% of females having received HIVST through an MSM channel reported 1 or 2 partners, and 30% reported having 3+ partners.

Table S4a: Fraction of tests distributed through the ATLAS FSW and MSM channels across risk groups in the base-case scenarios, based on the ATLAS phone survey (1st stage) data (all ATLAS countries combined)

FSW channel	All females (52%)			All males (48%)				
	Lower-risk females	Intermediate-risk females	FSW	Lower-risk males	Intermediate-risk males	Clients of FSW	MSMW	MSME
	0%	5%	47%	0%	16%	32%	0%	0%
MSM channel	All females (9%)			All males (91%)				
	Lower-risk females	Intermediate-risk females	FSW	Lower-risk males	Intermediate-risk males	Clients of FSW	MSMW	MSME
	5%	4%	0%	0%	0%	0%	61%	30%

FSW: female sex workers; MSMW: men who have sex with men as well as female partners; MSME: men who have sex with men exclusively.

HIVST distribution under the sensitivity scenario

A sensitivity scenario reflected the empirical outcomes of the ATLAS phone survey (1st stage) more accurately without accounting for likely reporting biases more self-tests distributed to non-KP. The **Table S4b** reports the fraction of HIVST distributed within each channel by risk group under the sensitivity scenario.

For the FSW channel, only 40% (250/620) of female phone survey respondents reported having received money in exchange for sex in the past year and were considered as FSW (only 25% of females reported having 3 or more partners). The fraction of tests distributed through the FSW ultimately received by lower risk females was assumed to be 28% as it is the fraction of phone survey female participants (FSW channel) reporting not having partners. Regarding the tests received by males through an FSW channel, only 24% of males reported having paid for sex in the last year, and were considered to be FSW clients in the model. Around 6% of males reported only having male partners, and 6% both male and female partners, proportions which were used to quantify the fraction of tests from FSW channels given to MSME and MSMW. Around 16% of males survey participants reported having no partners and were considered to correspond to lower-risk populations in the model. The fraction of HIVST from the FSW channel which ended up being received by intermediate risk females and males were calculated from the total number of tests distributed to each gender, and the fraction received by the other groups.

The sensitivity scenario assumed that 91% of individuals receiving HIVST from the MSM channels were males, still based on the phone survey (1st stage). Around 16% (160/997) and 34% (334/997) of men respondents reported having only male partners, and both male and female partners, respectively. The fraction of HIVST received by clients of FSW (12%) was assumed to be half the fraction of men reporting having paid for sex in the past 12 months (236/947/2), as reporting exchanging sex for money between two male partners is not uncommon in the region. The fraction of tests distributed through the MSM channels that were received by lower-risk (heterosexual) male was calculated as the fraction of men reporting no sexual partners (14%, 139/997). Around 24% (22/92) of female participants having received a test through the MSM channel reported having received money for sex in the past year and were considered FSW, whereas 15% reported not having any partner and were considered as low-risk females.

Table S4b: Fraction of tests distributed through the ATLAS FSW and MSM channels across risk groups in the sensitivity scenario (presented in the sensitivity analysis), based on the ATLAS phone survey data (all ATLAS countries combined)

FSW channel	All females (52%)			All males (48%)				
	Lower-risk females	Intermediate-risk females	FSW	Lower-risk males	Intermediate-risk males	Clients of FSW	MSMW	MSME
	15%	17%	20%	8%	23%	12%	3%	3%
MSM channel	All females (9%)			All males (91%)				
	Lower-risk females	Intermediate-risk females	FSW	Lower-risk males	Intermediate-risk males	Clients of FSW	MSMW	MSME
	2%	5%	2%	13%	22%	11%	30%	15%

FSW: female sex workers; MSMW: men who have sex with men as well as female partners; MSME: men who have sex with men exclusively.

Within each HIVST distribution scenario, we modelled the scale-up of the WHO objectives of 95% of KP testing twice a year for HIV¹⁴⁹, but only considering HIVST. We calculated the number of HIVST needed to be distributed each year through FSW and MSM channels so that 95% of FSW and 95% of MSM not living with HIV or living with HIV but not on ART (=“eligible” population) receive 2 HIVST each year from 2025. Our analysis assumed a linear scale-up from January 2022 and a plateau from 2025 onward, with kits being initially distributed at same rate as during the best quarter (i.e., 3 months of distribution) of the ATLAS distribution period (2019-2021) in each country. The size of the target population and number of HIVST to distribute each year were calculated in January 2022 and varied across simulations because sizes of KPs and coverage of ART vary from one simulation to another. Population growth was not accounted for when calculating the size of the target population in future years (but this assumption was tested in our sensitivity analysis), nor was the potential increase in ART coverage over time. The actual coverages in the model are different from the coverages as estimated in January 2022 because 1) large fractions of self-tests distributed through a KP channel were not kept by the target population (e.g. half of HIVST distributed to FSW end up in the hands of males), and 2) the size of the target population may change over time, partly due to the intervention.

As an example, if 50,000 FSW are not living with HIV or living with HIV but not on ART in January 2022, the model will represent a scale-up of HIVST over time so that 95% of 55,000 FSW (size of target population assuming population growth) receive two tests in 2025 through a FSW HIVST distribution channel ($0.95 \times 55,000 \times 2 = 104,500$ HIVST to distribute into the FSW channel).

All model scenarios assumed the same number of tests distributed into each channel each year, except in a specific sensitivity analysis scenario where it increases over time, according to population growth.

Other HIVST assumptions

Assumptions regarding HIVST uptake and linkage to care are described in **Figure 1** and **Table S5**. The independent influence of several assumptions on the estimated HIVST scale-up impacts were tested within specific sensitivity analyses.

Our main scenarios assumed that:

- 80% of distributed HIVST were used, based on the experience of STAR¹⁵⁰, although an higher fraction was estimated during a study among FSW in Senegal¹⁴³. This fraction was the same across all population strata.
- 20% (Côte d’Ivoire), 30% (Mali), and 40% (Senegal) of HIVST were “substitute” tests, which were discounted from the number of conventional tests (see specific section on HIVST assumptions) performed during the year by the same population strata. This was based on analysis of subnational-level programmatic data during ATLAS¹¹³, although these reductions were not statistically significant in the analysis. The fraction in Mali was conservatively calculated as the average between the fractions in Côte d’Ivoire and Senegal, because the larger fraction in Senegal is believed to be due to conventional tests using blood from veins in the country (in a region where fear of needles is highly prevalent), compared to prick tests in Côte d’Ivoire and Mali.
- Uptake of HIVST within a specific risk/age group combination did not depend on the history of testing nor HIV status, except that PLHIV on ART did not receive HIVST. A sensitivity analysis assumed that people that have never tested were twice more likely to receive a self-test compared to people with the same characteristics who ever had an HIV test.
- Only half of people had a confirmation test following a reactive test, with an average time of two months between the tests, whereas those subsequently receiving a positive confirmation test initiated ART after a month. These assumptions were derived from ATLAS phone survey (2nd

stage), which aimed at measuring linkage to care among people experiencing a reactive self-test¹¹⁵. A sensitivity analysis looked at the change in estimated impact if the fraction of confirmed reactive tests was increased from 50% to 80%.

- The sensitivity and specificity of the “OraQuick HIV Self-Tests” used during ATLAS were assumed to be 92% and 99%, according to manufacturer data¹¹⁴. Real-world studies have estimated lower sensitivity^{151,152} when the tests are performed by the intended users, due to variable literacy levels and limited exposure to HIVST. Since we assumed that only 50% of reactive HIVST would be followed by a confirmation test, further reducing the sensitivity had a minimal impact.

Table S5: Main assumptions of HIV self-testing scenarios.

Parameter	Assumptions		Comment
	Base-case scenario	Sensitivity analysis scenario)	
Number of HIVST kits distributed over 2019-2021	“Counterfactual”: No HIVST distributed “ATLAS-only” and “HIVST scale-up”: HIVST distribution		The number of kits distributed each year matches ATLAS programmatic data for FSW and MSM outreach channels (shown in Table S3)
Number of HIVST kits distributed over 2022-2038	“Counterfactual” and “ATLAS-only”: No HIVST distributed “HIVST scale-up”: linear increase up to 2025, then plateau		“HIVST scale-up”: target in 2025 defined as two self-tests to 95% of “eligible” HIVST users (i.e. people without HIV or untreated PLHIV, regardless of their awareness of HIV status)
Numbers of kits distributed to KP every year from 2025 account for growth of population size	No i.e. annual number of kits distributed constant over time	Yes, the annual number of kits distributed from 2025 increases by ~3% annually	Based on country-specific UNPD estimates of population growth ⁴
Fraction of kits distributed through the FSW and MSM channels received by each risk group	Shown in Table S4a: assumption accounting for biases in reported high risk behaviours in the ATLAS phone survey ¹⁴⁸ , where < 20% of distributed kits end up	Shown in Table S4b: assumption not accounting for biases in the ATLAS phone survey (1 st stage) ¹⁴⁸ , where around 50% of distributed kits end up in the hands of non-KP	Assumption reflecting most plausible secondary distribution of self-tests among ATLAS participants. See Tables S4a,b

	in the hands of non-KP		
Age distribution of people receiving self-tests kits	Matches programmatic data shown in Table S3	Shown in Figure S2: Matches ATLAS phone survey data among HIVST users ¹⁴⁸	Age distributions are comparable in the two datasets overall, but MSM participating to the phone survey are slightly younger than in the programmatic data, see Figure S2.
Fraction of all tests used	80% (constant across population strata)	100%	Based on STAR Malawi (80%) ¹⁵⁰ . Sensitivity assumption based on a survey among FSW in Senegal (~94% HIVST used) ¹⁴³ .
HIVST distributed to PLHIV on ART	No	No	Assumed
HIVST uptake (likelihood of receiving a kit) by HIV infection, diagnosis, and treatment status.	Uptake independent of history of testing diagnosis and treatment.	4 specific uptake scenarios: 1) twice higher among those never tested vs ever tested 2) PLHIV with a diagnosed infection don't receive tests 3) twice higher among PLHIV on ART vs others 4) twice higher among PLHIV with an undiagnosed infection vs others	Uptake assumptions modelled as independent relative risks all = 1 in the base-case.
Fraction of reactive HIVST of undiagnosed PLHIV followed by a confirmatory test	50%	80%	Base-case assumption derived from ATLAS phone survey data ¹¹⁵ . Sensitivity analysis assumption assumes improvements in use of HIVST (improved kit user manual, experience with COVID self-tests kits)
Time from reactive to confirmatory test (for those eventually confirming) and from confirmatory test to ART initiation	2 months and 1 month		ATLAS phone survey data (2 nd stage) ¹¹⁵

Test substitution fraction: HIVST substitute/replace conventional tests	20% (Côte d'Ivoire) 30% (Mali) 40% (Senegal)	1) No substitution (=0%) 2) 50% substitution	Analysis of subnational programmatic data in Côte d'Ivoire and Senegal ¹¹³ during ATLAS. Note that the estimated levels of substitution were not statistically different from zero. The larger fraction of replacement in Senegal is partly explained by the fact that conventional HIV rapid tests use blood from veins in the country (where fear of needles is highly prevalent), whereas rapid tests in Côte d'Ivoire use blood from a finger prick. Because no data on test replacement was available for Mali and that rapid tests generally use blood from finger prick, we conservatively assumed a fixed 30% of self-test will replace conventional tests in Mali, a value in between Côte d'Ivoire and Senegal estimates
HIVST sensitivity/specificity (in detecting HIV-1 and HIV-2 antibodies)	92% / 99%	100%	Manufacturer data ¹¹⁴ .

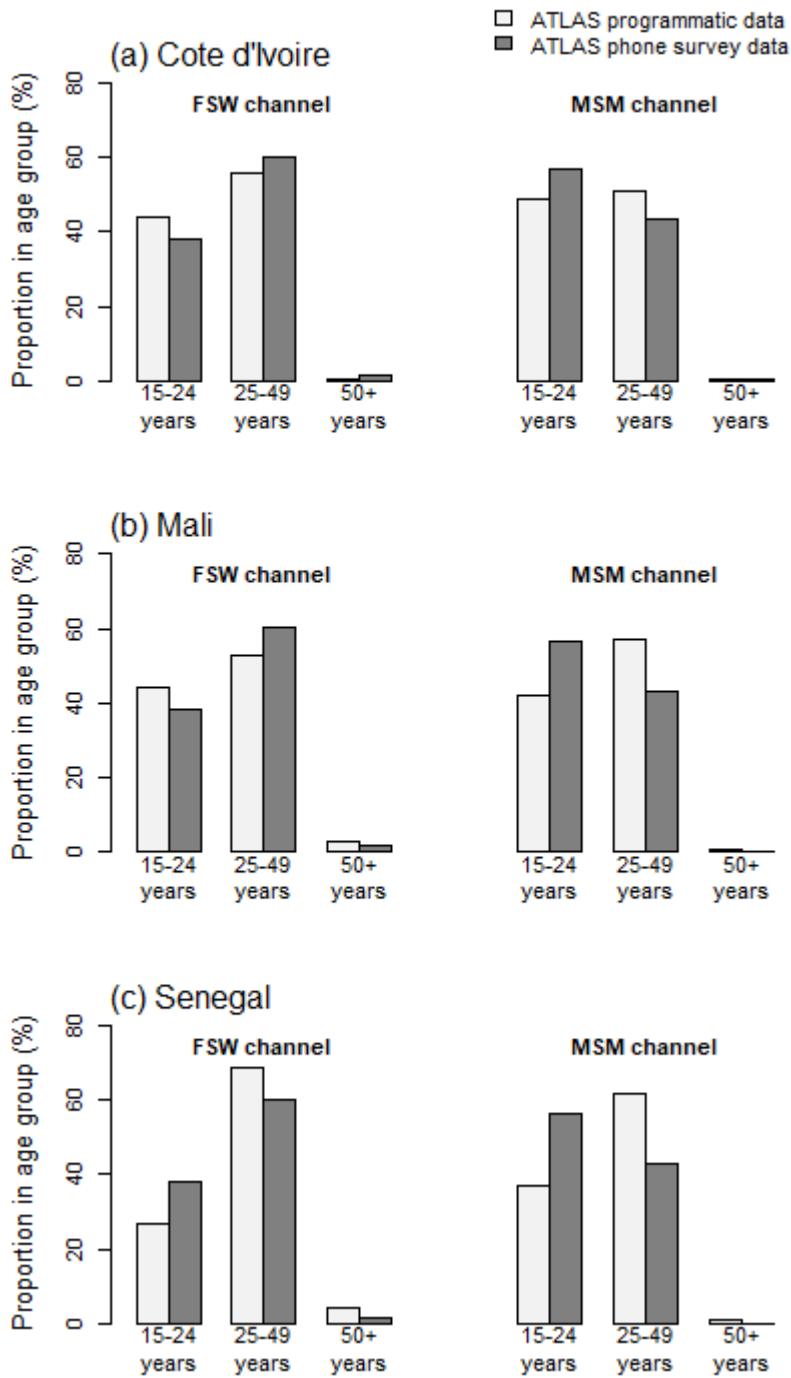


Figure S2: Proportions of HIV self-tests distributed through FSW and MSM outreach to different age groups in the programmatic data (white bars, base-case scenarios) in each ATLAS country, and in the ATLAS phone survey (stage 1) data (dark grey bars, sensitivity analysis scenarios) all countries combined.

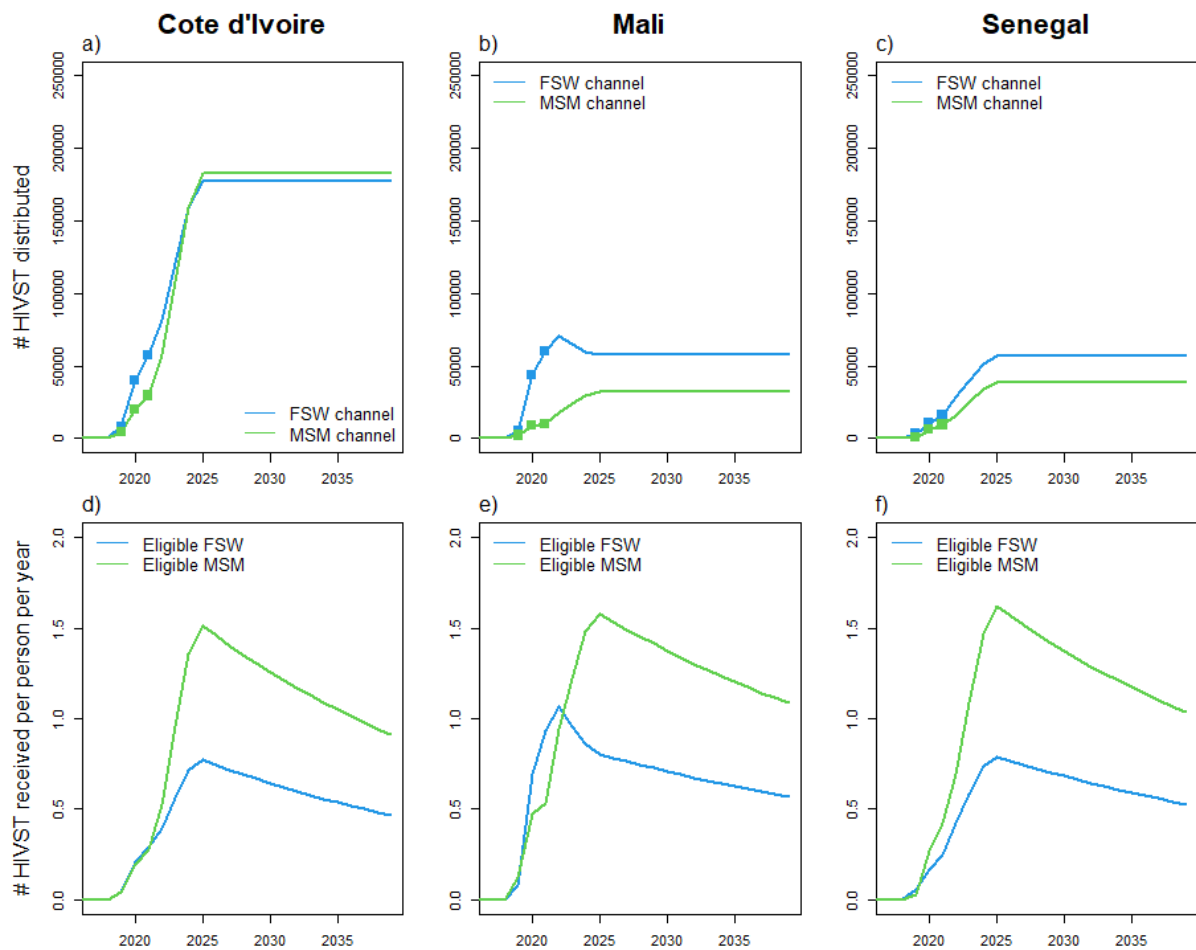


Figure S3: HIVST distribution from mid-2019 in each ATLAS country. Panels a-c) Number of HIVST distributed by ATLAS over 2019-2021 and over 2022-2038 during a hypothetical scale-up of HIVST through female sex workers (blue), and men who have sex with men (green) outreach channels. Panels d-f) Median number of HIVST received each year per FSW (blue) and MSM (green) not living with HIV or living with an untreated HIV infection. From January 2022, HIVST kits were assumed to be distributed at the same rate as during the best quarter (i.e., 3 months of distribution) of the ATLAS distribution period (2019-2021) in each country, which is why in panel b), more HIVST kits were distributed through the FSW channel in 2022 than in 2021. The decrease in numbers per capita on panels d-f) from 2025 is because the population is assumed to grow at a constant rate whereas the number of kits distributed over time is constant.

Methods: calculation of intervention impacts

Impacts of HIVST on new HIV diagnoses and treatment initiations

Impacts of ATLAS on new HIV diagnoses in the different risk groups over 2019-2021 (i.e., additional new diagnoses) were estimated by subtracting the cumulative number of new HIV diagnoses in the risk group over 2019-2021 within the “ATLAS-only” scenario from the cumulative number of new HIV diagnoses in the risk group within the “no-HIVST” over the same period. Impacts of ATLAS on new ART initiations were calculated in a similar way.

The impact of ATLAS on the coverage of HIV diagnosis in the different risk groups was calculated as the absolute increase (expressed in percentage points) of the proportion of PLHIV diagnosed at the end of 2021 in the ATLAS-only scenario compared to the scenario without HIVST.

Similarly, the impact of HIVST scale up in the countries over 2019-2028 and 2019-2038 on new HIV diagnoses were calculated by subtracting the cumulative number of new HIV diagnoses in the risk group over the specific period within the “HIVST scale-up” scenario from the cumulative number of new HIV diagnoses in the risk group within the “no-HIVST” over the same period.

The impact of HIVST scale up on the coverage of HIV diagnosis in was calculated as the absolute increase (expressed in percentage points) of the proportion of PLHIV diagnosed at the end of 2028 and at the end of 2038 in the HIVST scale-up scenario compared to the scenario without HIVST.

It is possible that less diagnoses and ART initiations in specific groups would occur in a scenario with HIVST than in a scenario without HIVST, because interventions decrease the number of onward new HIV infections (i.e., the number of infections that can be diagnosed and treated).

Time from infection to diagnosis

The time from infection to diagnosis (or death before being diagnosed) among risk groups in the “no-HIVST” (and in the “HIVST scale-up”) scenarios from 2020 were calculated in three steps for each simulation (Figure S4). First, we ran each scenario using the fitted parameter sets, but assuming that no new HIV infections could occur from January 2020 (“counterfactual scenario”). Second, we calculated the number of PLHIV of each risk group with an undiagnosed infection each year within each simulation and approximated it using cubic splines. Finally, the time from infection to diagnosis was determined as the time (calculated from January 2020) where half of the population which was undiagnosed in January 2020 has been diagnosed or deceased.

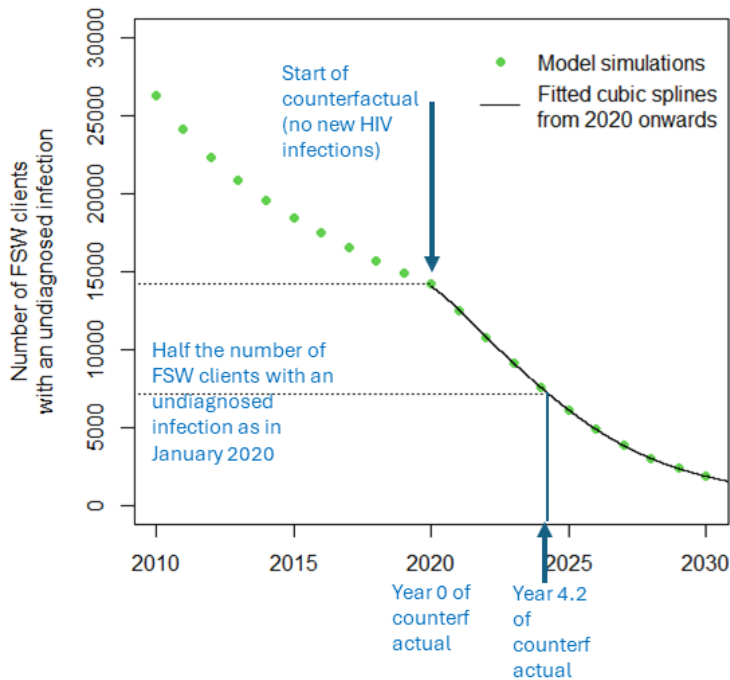


Figure S4: Calculation of the time from infection to diagnosis (or death before being diagnosed), illustrated here for one single simulation. Here, we calculated the time from January 2020 where half of the number of FSW clients in Côte d’Ivoire who had an undiagnosed infection in January 2020 had been diagnosed or deceased. Green points represent the annual model outputs from one single simulation, which were fitted using cubic splines to pinpoint the timing. In this example, the size of the undiagnosed population had halved after 4.2 years, which yielded a median time from infection to diagnosis (or death before being diagnosed) of 4.2 years.

Impact of HIVST on new HIV infections and HIV-related deaths

The absolute and relative number of new HIV infections averted by ATLAS and an HIVST distribution scale-up among KP over 2019-2021, 2019-2028, and 2019-2038 were calculated as the absolute and relative differences between the cumulative number of new HIV infections in the scenario with HIVST distribution over the period, compared to the number of new HIV infections in the scenario without any HIVST, over the same period. The same approach was used to calculate the impact of HIVST on HIV-related deaths.

Estimates of the absolute number of new HIV infections and HIV-related deaths for the three countries combined were obtained by pairing each simulation of a country with the corresponding simulations from the other countries.

Results: model fits (Côte d'Ivoire)

Demography

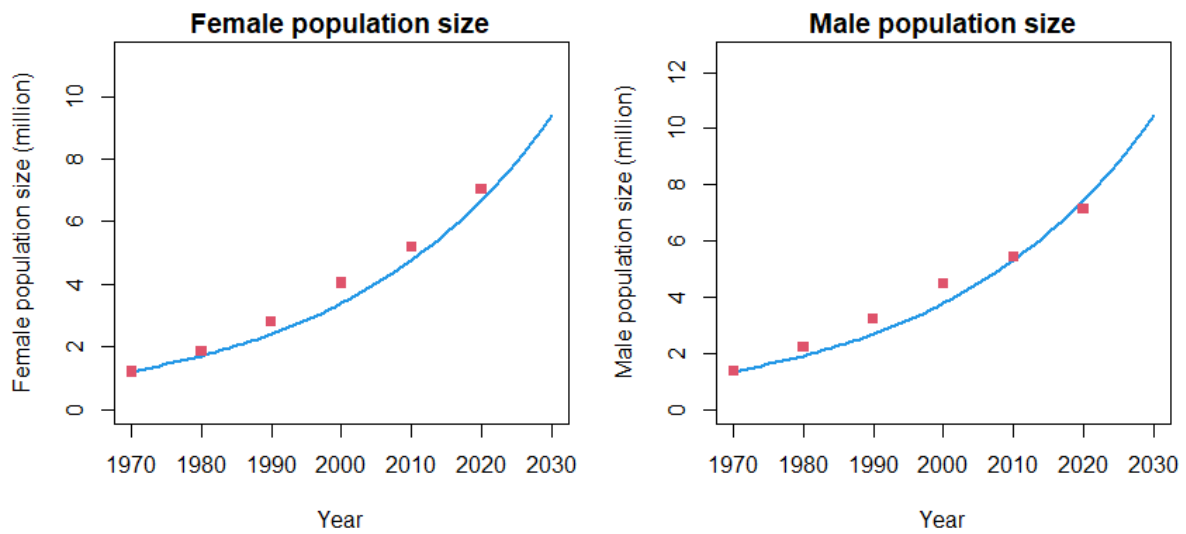


Figure S5a: Côte d'Ivoire model fitting to the size of the female and male population aged 15-59 years old over time. Blue curves represent model estimates and red squares the estimates from UNPD⁴.

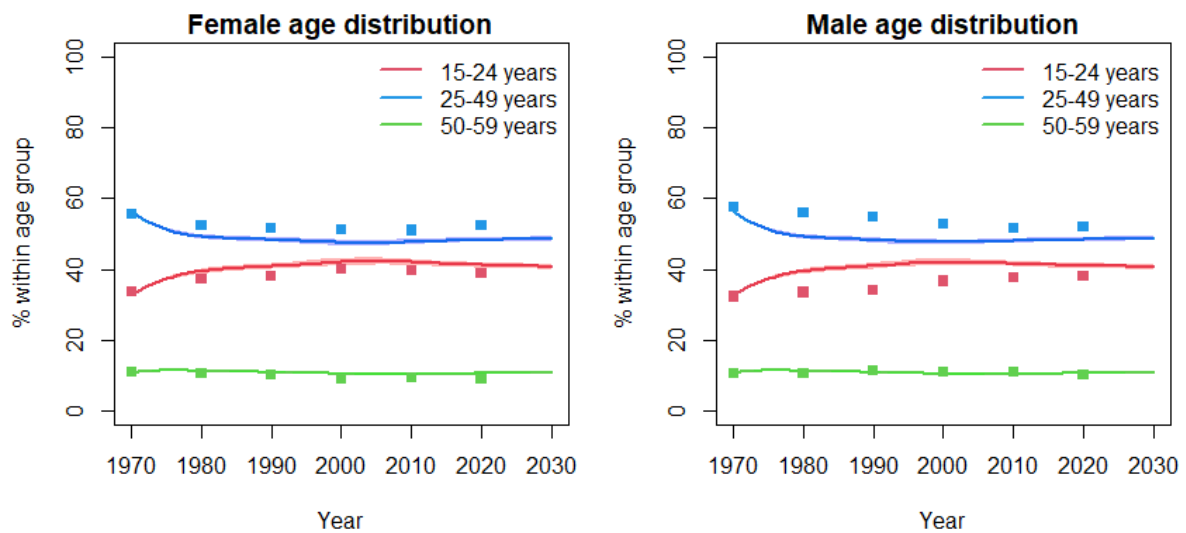


Figure S5b: Côte d'Ivoire model fitting to the age distribution of the female and male population aged 15-59 years old over time. Curves represent model estimates and the squares the estimates from UNPD. The latter were used to initialise the population age distribution in 1970 (combining males and females), and to calibrate the model to sex-specific estimates for 2020.

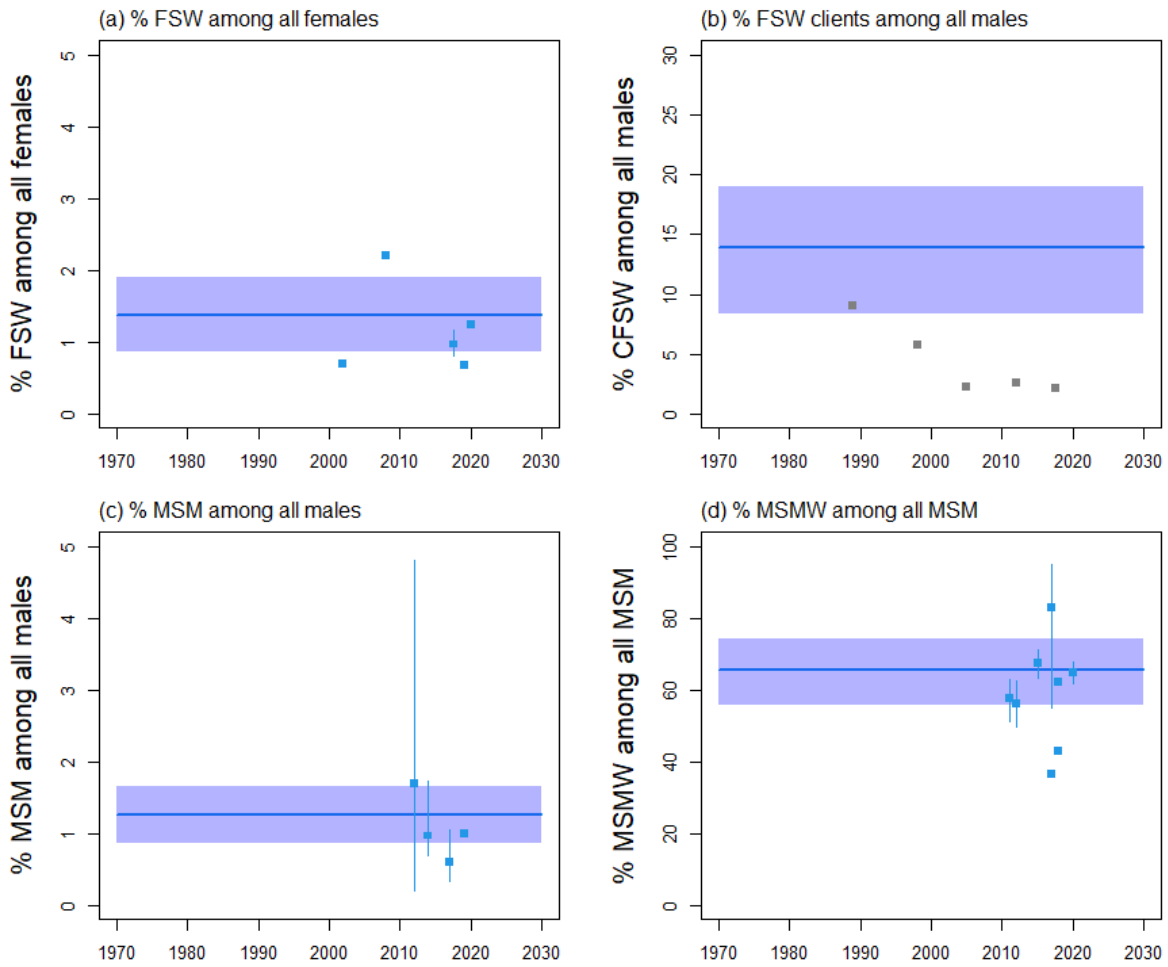


Figure S5c: Côte d'Ivoire model fitting to the size of key populations and their clients, with fractions of a) FSW among all females aged 15-59 years, b) FSW clients among all males aged 15-59 years, c) MSM among all males aged 15-59 years, and d) MSMW (men who have sex with men and women) among all MSM aged 15-59 years old over time. Blue curves and shades represent median and 90% UI (5thth and 95th percentiles across model fits), whereas squares and intervals represent empirical estimates (with 95% CI). Grey estimates in panel b) were reported from household surveys and were only used for comparison as they were deemed unrepresentative. The FSW clients population size in the model was calculated using the multiplier method as in ^{1,8,34,153}.

HIV epidemiology

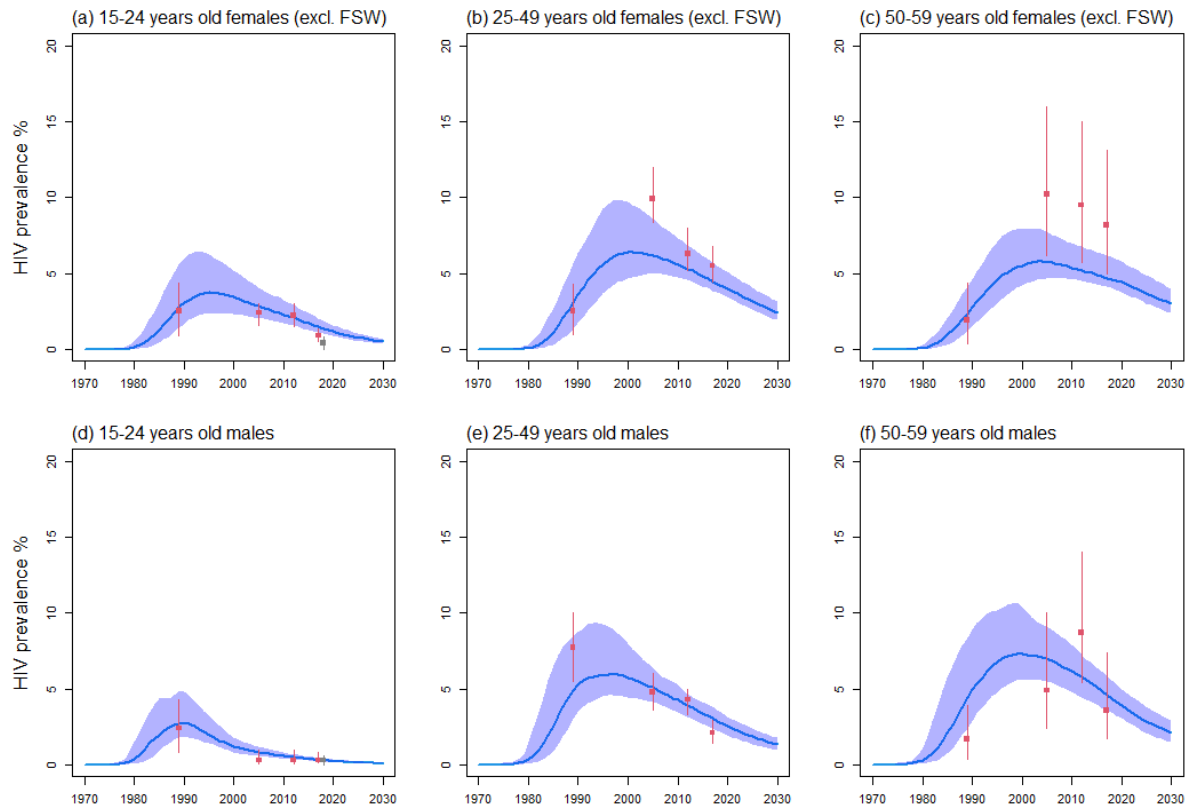


Figure S5d: Côte d'Ivoire model fitting to the HIV prevalence among all females aged a) 15-24, b) 25-49, and c) 50-59 years old (excluding FSW), as well as all males aged d) 15-24, e) 25-49 years, and f) 50-59 years old. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting (with 95% CI), and the grey square and intervals in panel a) are estimates from a recent survey about violence against children and youth in Côte d'Ivoire¹¹⁷ included for comparison (not used to fit the model). Estimates among females aged 50-59 years old in 2005 and 2012 (panel c) should be interpreted with caution as they correspond to the estimate for the 45-49 years old age group as in¹ (these surveys did not include women aged 50+ years or older).

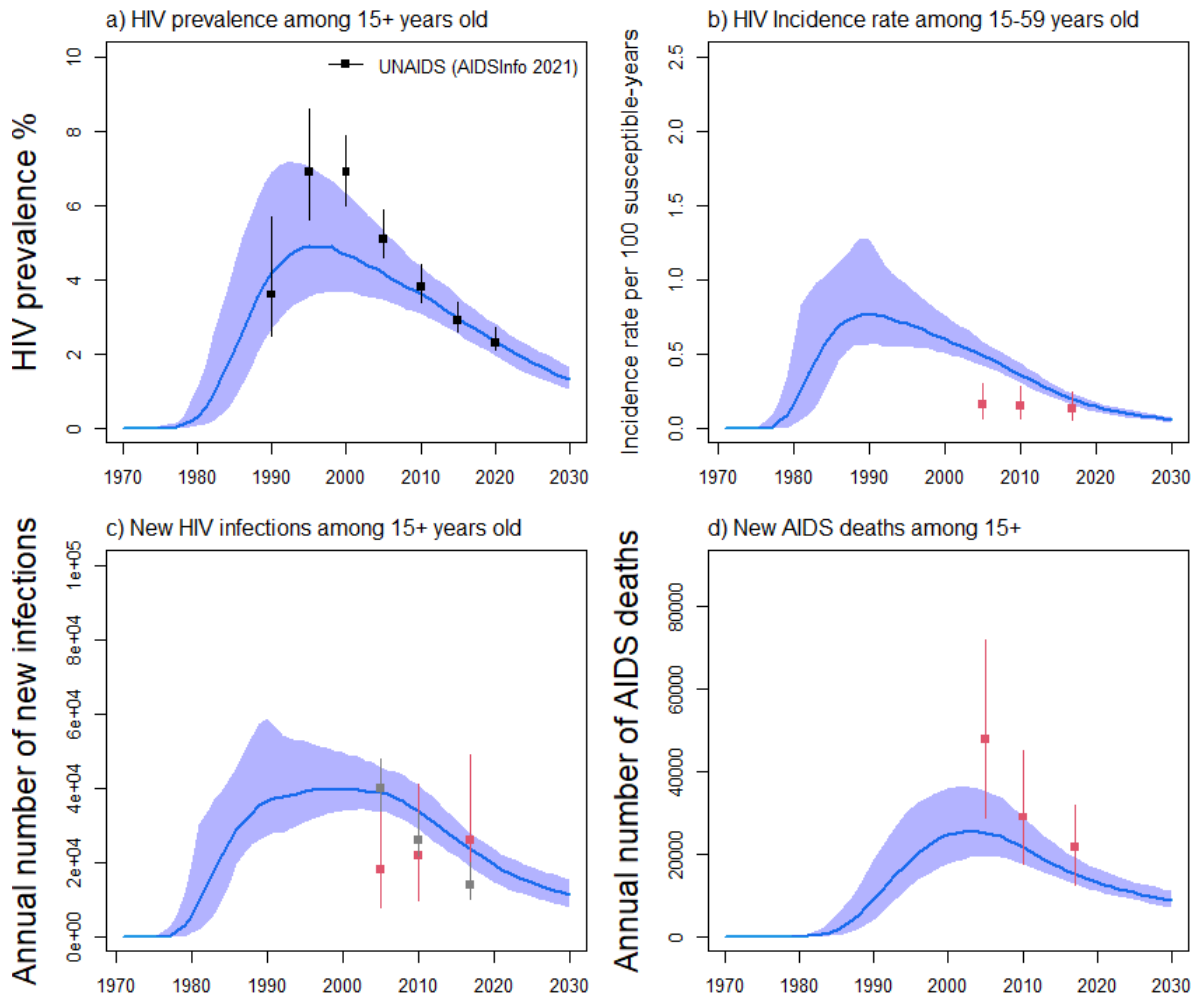


Figure S5e: Estimates of HIV prevalence among a) all adults aged over 15 years old, fits to b) HIV incidence rate per susceptible, c) annual number of new HIV infections and d) annual HIV-related deaths in Côte d'Ivoire from UNAIDS Data 2018 (from the Spectrum/EPP model¹⁵⁴). Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting (with 95% CI), dark squares and intervals in panel a) represent estimates from UNAIDS (also from the Spectrum/EPP model) used for comparison, whereas grey squares and intervals in panel c) represent new estimates from UNAIDS (Spectrum/EPP) which were published in July 2023 and not available at the time of our analysis.

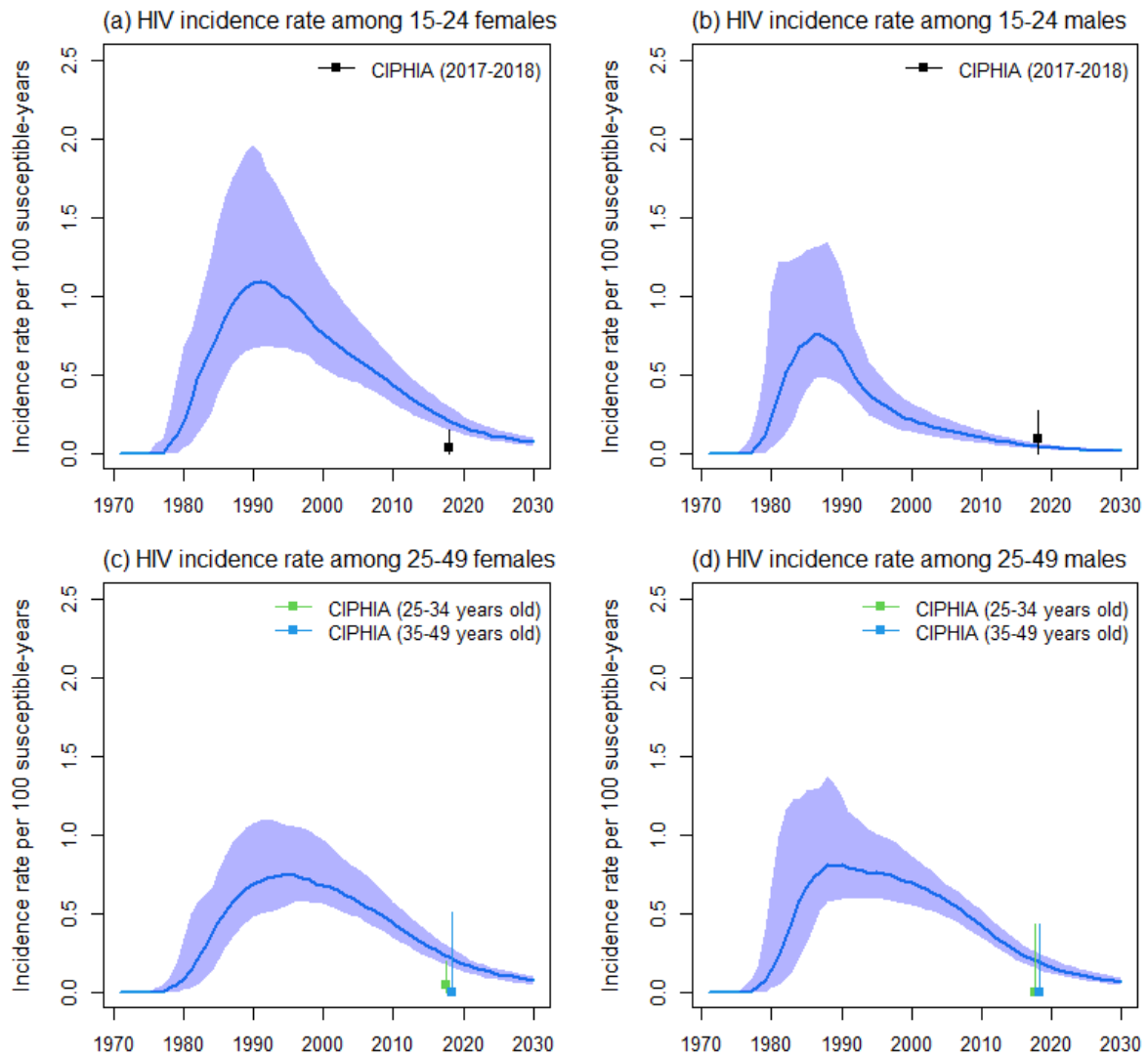


Figure S5f: Comparison of estimates of HIV incidence in the Côte d’Ivoire PHIA survey among a) females aged 15-24 years old, b) males aged 15-24 years old, c) females aged 25-49 years old, d) males aged 25-49 years old. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas squares and intervals represent empirical estimates from the PHIA survey (with 95% CI).

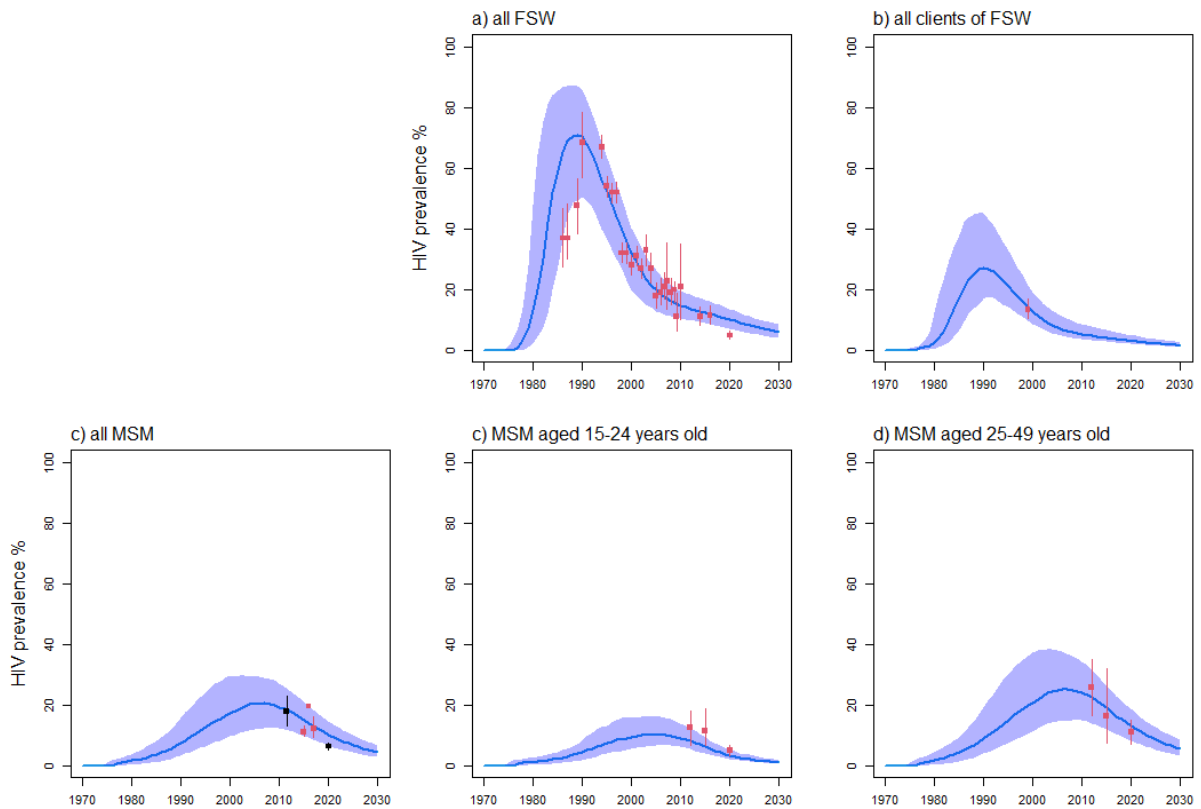


Figure S5g: Côte d'Ivoire model fitting to HIV prevalence estimates among all a) FSW, b) clients of FSW, c) MSM, as well as c) MSM aged 15-24 years old, and d) aged 25-49 years old. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting (with 95% CI), whereas dark estimates in panel c) represent estimates fitted among MSMW and MSME separately (see Figure S4h).

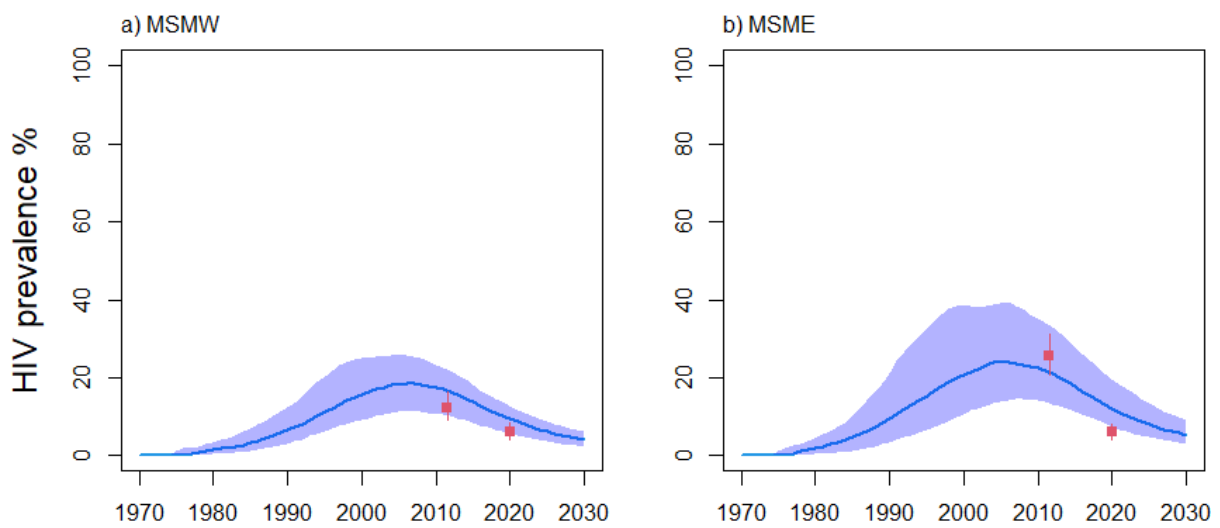


Figure S5h: Côte d'Ivoire model fitting to HIV prevalence estimates among all a) MSMW (men having sex with both men and women) and b) MSME (men having sex with another man) MSM. Blue

curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent empirical estimates (with 95% CI).

HIV treatment cascade

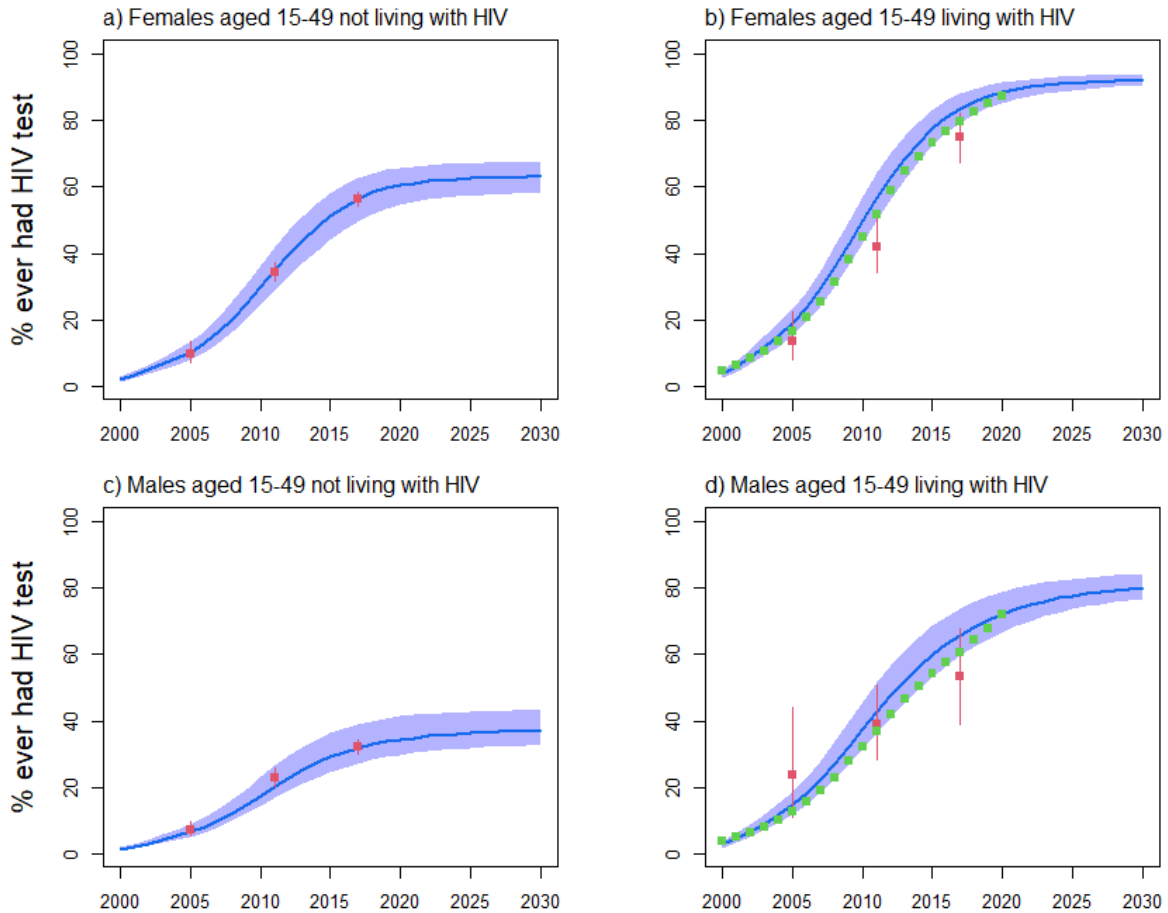


Figure S5i: Côte d’Ivoire model fitting to the fraction ever having tested for HIV among all females aged 15-49 years old a) not living with HIV, and b) living with HIV, and males aged 15-49 years old c) not living with HIV, and d) living with HIV. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting (with 95% CI), whereas green squares represent estimates from UNAIDS Shiny90 which were only used for comparison.

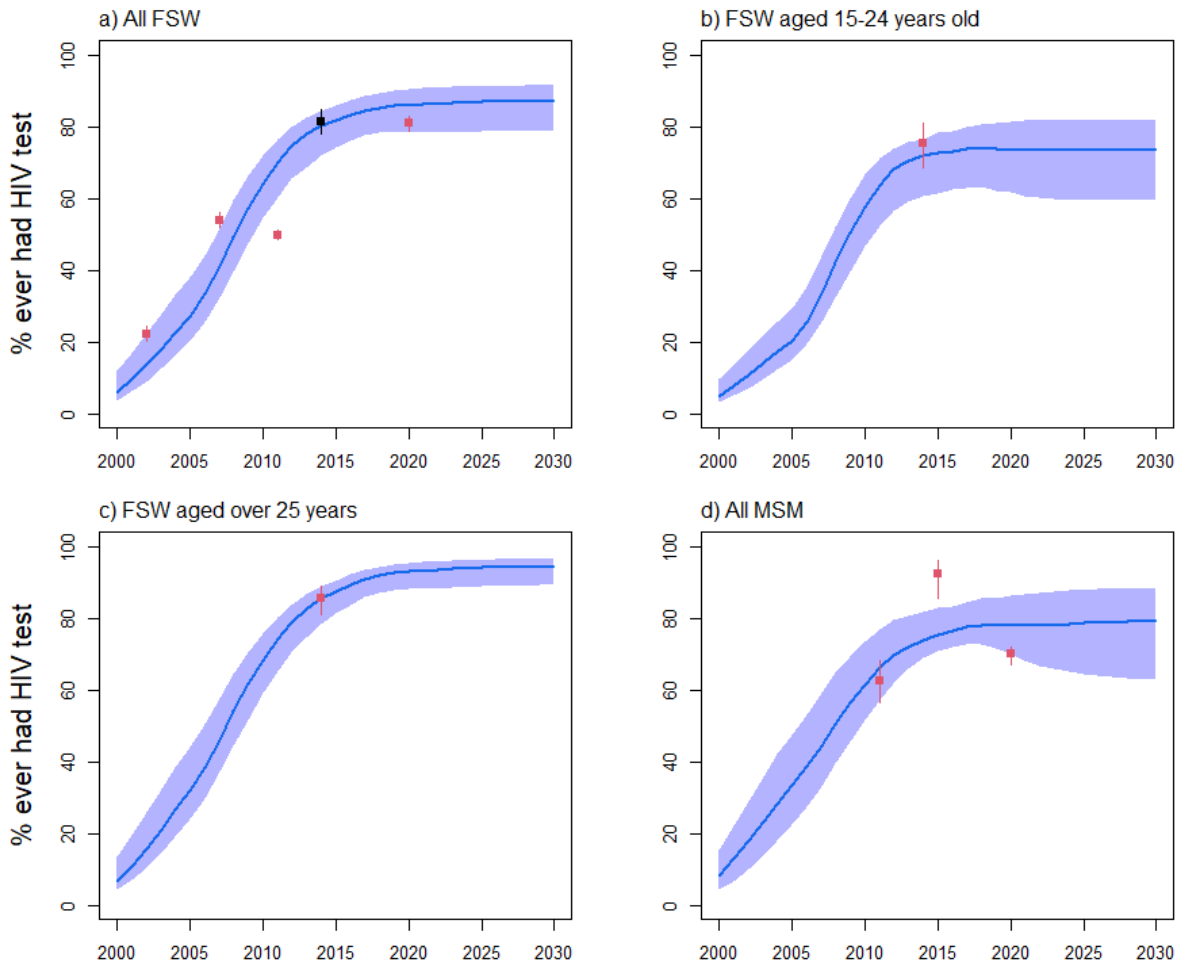


Figure S5j: Côte d’Ivoire model fitting to the fraction ever having tested for HIV among a) all FSW, b) FSW aged 15-24 years, c) FSW aged 25-49 years, and d) MSM. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting (with 95%CI), whereas dark squares in panel a) represent overall fraction from study outcomes shown in panels b) and c).

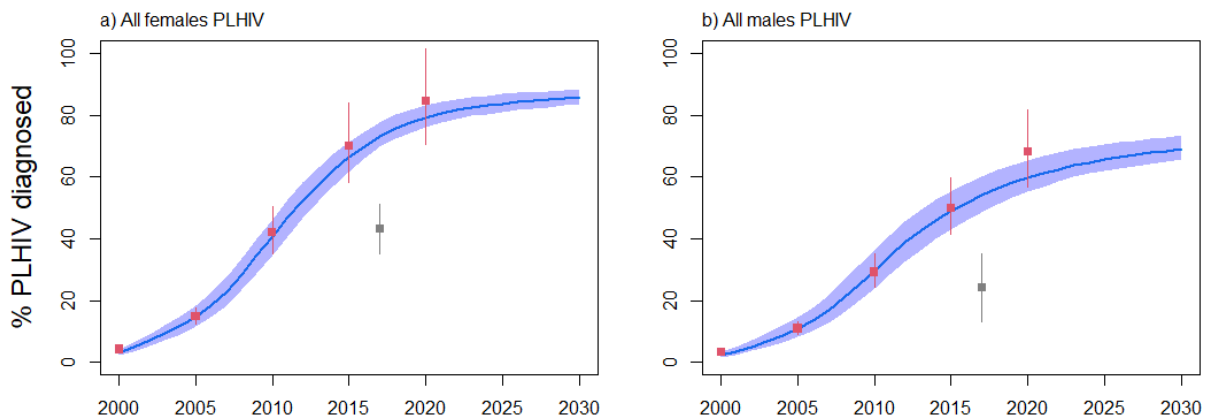


Figure S5k: Côte d’Ivoire model fitting to the fraction of a) all females living with HIV and b) all males living with HIV diagnosed (aware of their status). Blue curves and shades represent median and

90% UI (5th and 95th percentiles across model fits), red squares and intervals represent estimates from UNAIDS Shiny90 used for model fitting¹³¹, whereas grey squares and intervals represent estimates from PHIA³², which were underestimates because this fraction of people diagnosed (reporting being aware of their positive status) lower than the fraction of PLHIV having traces of ARV drugs in their blood in the survey.

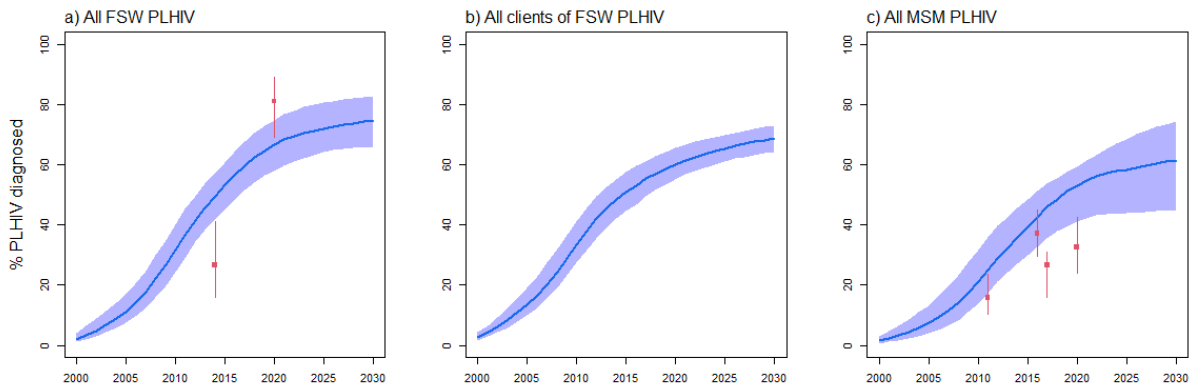


Figure S5l: Côte d'Ivoire model fitting to fraction of a) all FSW living with HIV, b) all male clients of FSW living with HIV, and c) all MSM living with HIV diagnosed. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent estimates from empirical surveys (with 95% CI). Empirical estimates are self-reported and likely to be under-estimates.¹⁵⁵

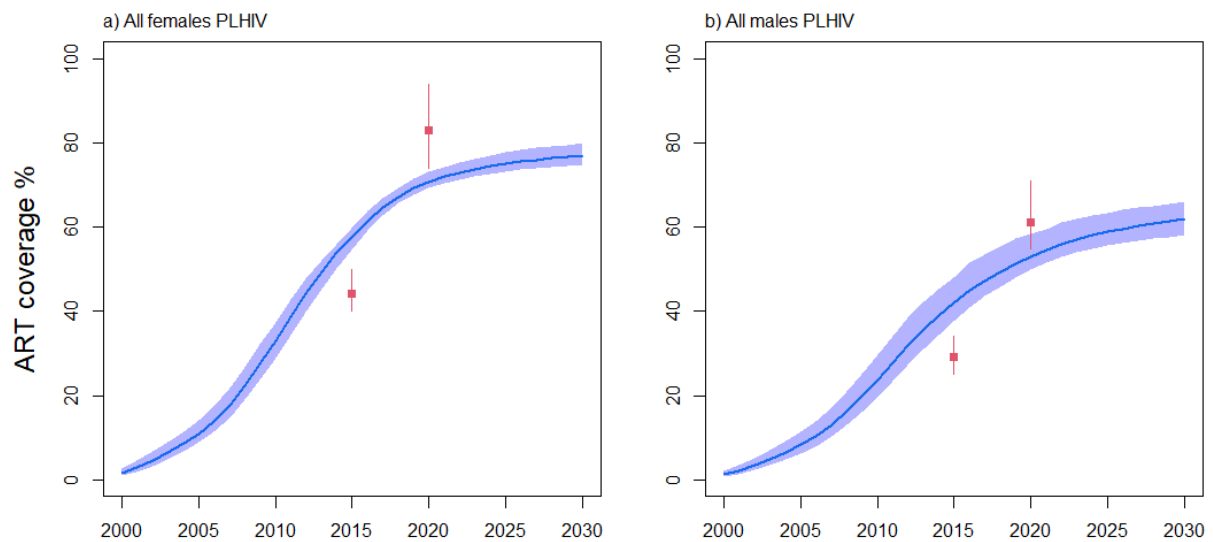


Figure S5m: Côte d'Ivoire model fitting to ART coverage among a) all females and b) all males aged 15-59 years old living with HIV. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent estimates from UNAIDS (with 95% CI), using the Spectrum/EPP model. Note that high coverages in red for the year 2020 could not be reproduced by our model as they don't agree well with estimates of the fraction of all females and all males PLHIV with a suppressed HIV viral load in the 2017 PHIA survey (see Table S2a and Figure S5o).

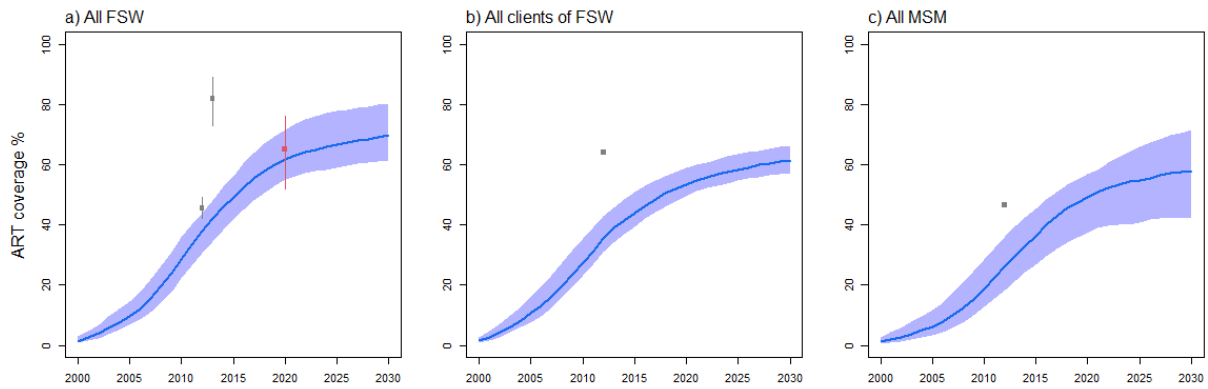


Figure S5n: Côte d'Ivoire model fitting to ART coverage among a) all FSW, b) all male clients of FSW, and c) all MSM living with HIV. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent empirical estimates from local surveys (with 95% CI)¹²². Estimates in grey represent estimates from an STI clinic¹²⁰, which were assumed to be overestimates and not included for model fitting but shown for comparison.

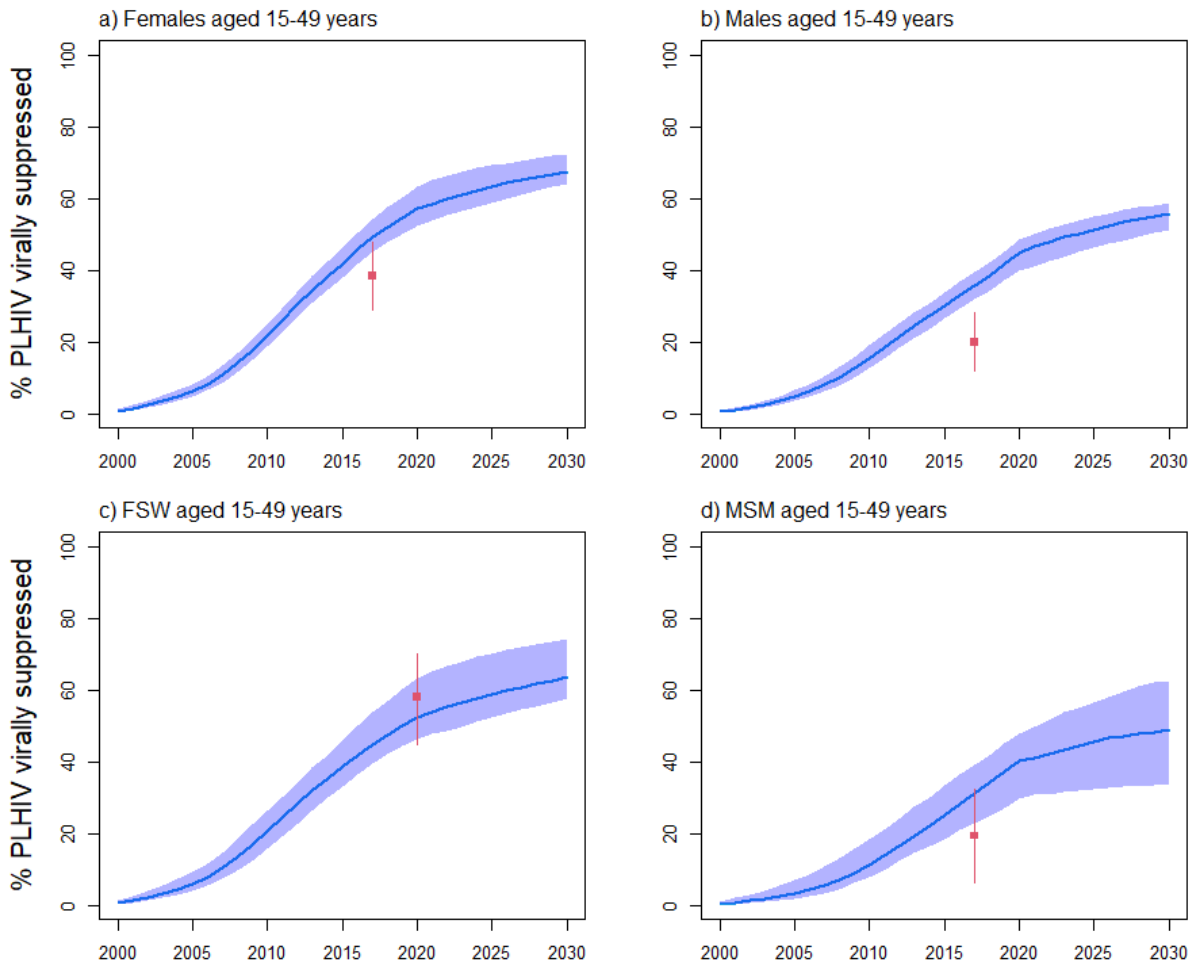


Figure S5o: Côte d'Ivoire model fitting to HIV viral load suppression coverage among a) all females, b) all males, c) all FSW, and d) all MSM living with HIV aged 15-49 years. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent empirical estimates from local surveys. Note that low coverages in red in panel b)

for the year 2017 could not be reproduced by our model as they don't agree well with UNAIDS estimates of the fraction of males PLHIV which are treated (see Table S2a and Figure S5m).

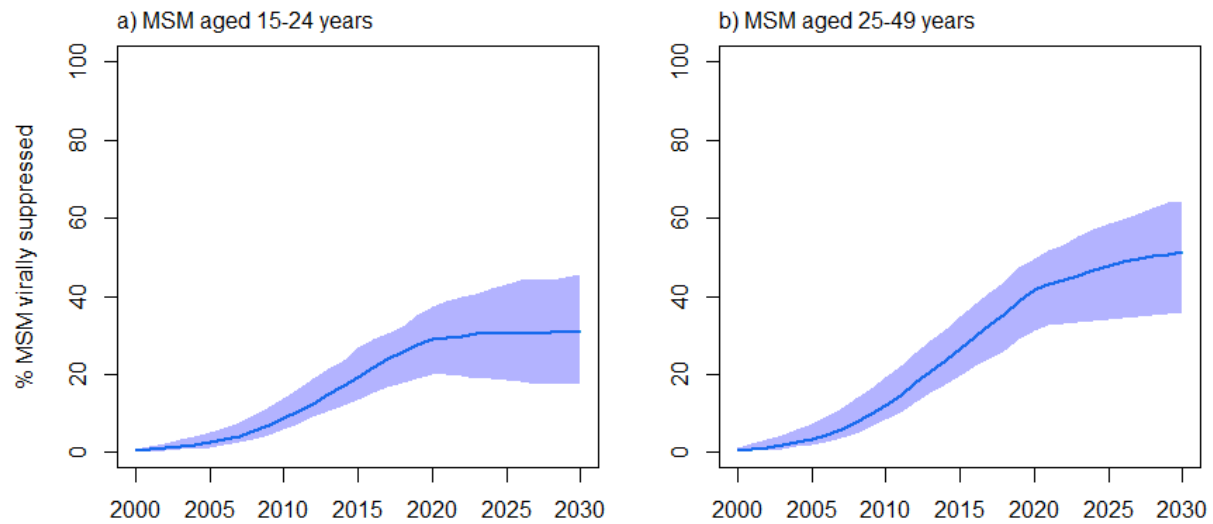


Figure S5p: Côte d'Ivoire model fitting to HIV viral load suppression coverage among MSM aged a) 15-24 years and b) 25-49 years living with HIV. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits). No data was available.

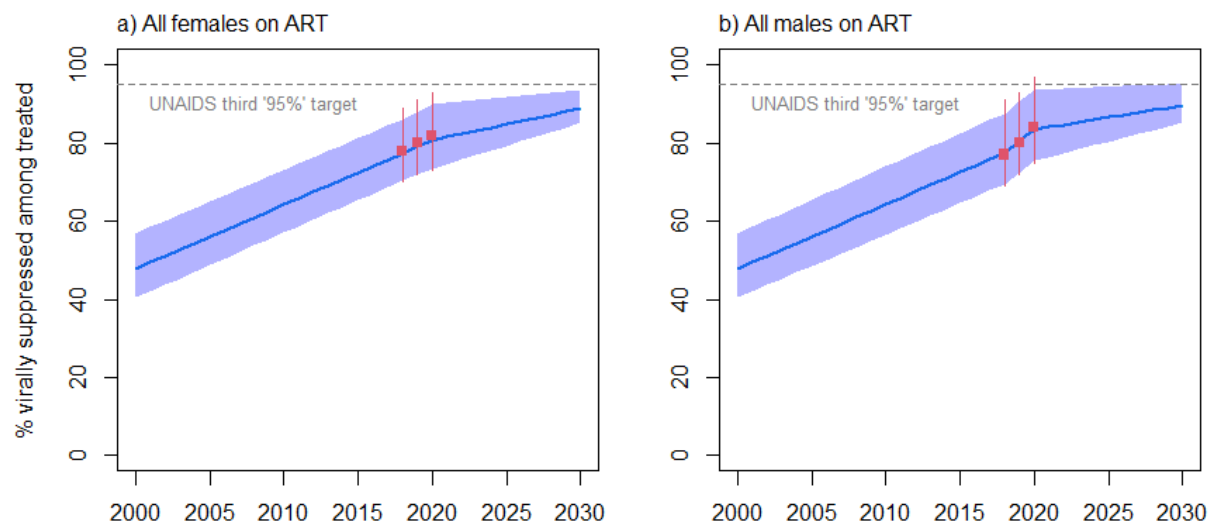


Figure S5q: Côte d'Ivoire model fitting to fractions of a) females and b) males PLHIV on ART which are virally suppressed (the third UNAIDSs “95%” indicator) over time. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent estimates from UNAIDS used as parameters and not at fitting targets. The grey dashed line corresponds to the UNAIDS’s third “95%” target whereby 95% of PLHIV on ART should be virally suppressed in 2025.

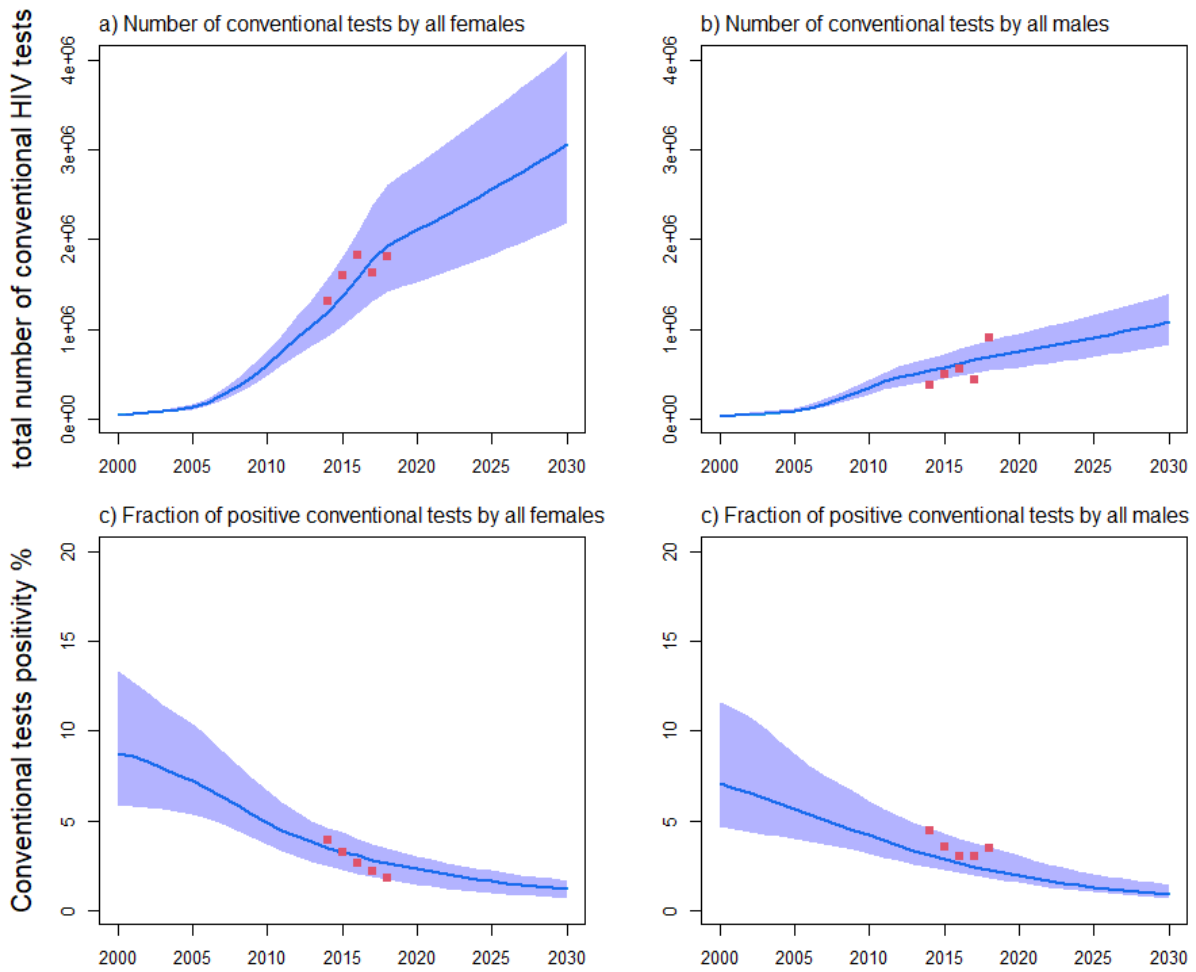


Figure S5r: Côte d'Ivoire model fitting to programmatic data⁶⁸ on the total number of conventional tests among a) all females and b) all males. Proportions of positive conventional tests among c) all females, and d) all males. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares represent programmatic data communicated by UNAIDS.

Results: model fits (Mali)

Demography

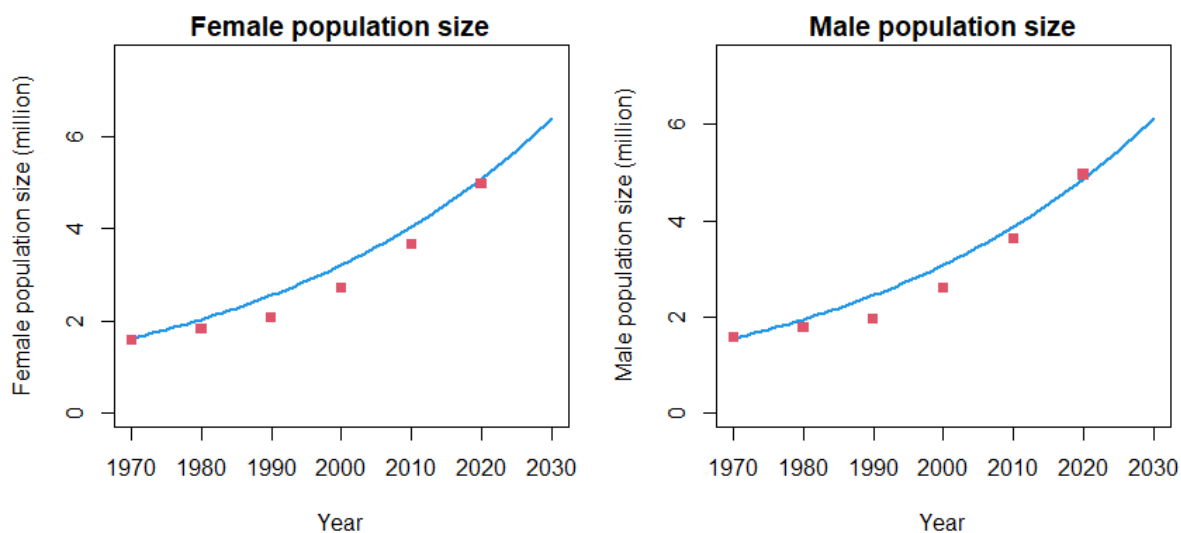


Figure S6a: Mali model fitting to the size of the female and male population aged 15-59 years old over time. Blue curves represent model estimates and red squares the estimates from UNPD⁴.

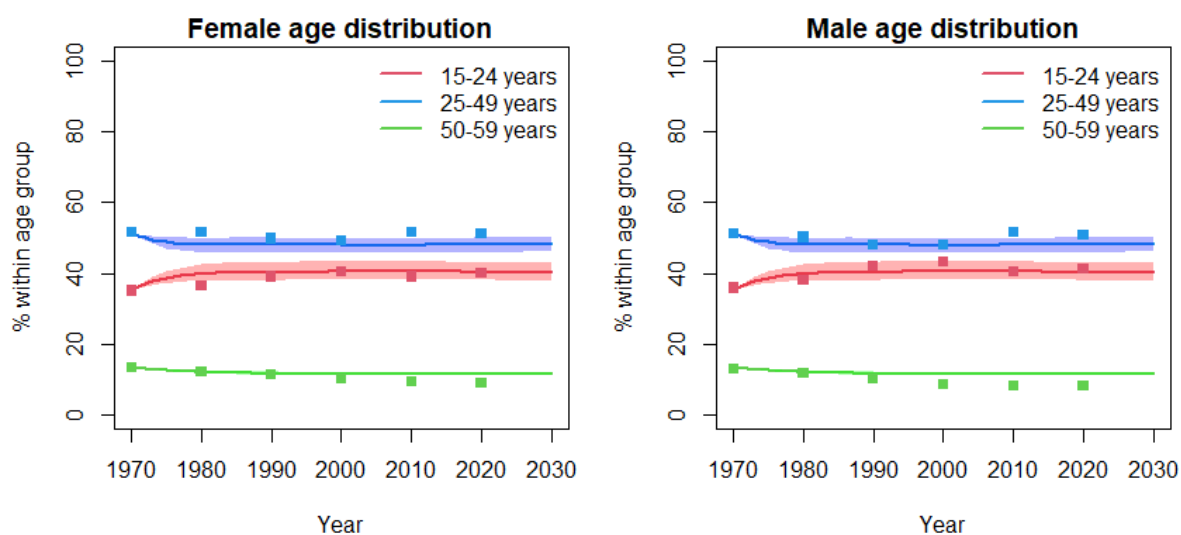


Figure S6b: Mali model fitting to the size of the female and male population aged 15-59 years old over time. Blue curves represent model estimates and red squares the estimates from UNPD⁴. The latter were used to initialise the population age distribution in 1970 (combining males and females), and to calibrate the model to sex-specific estimates for 2020.

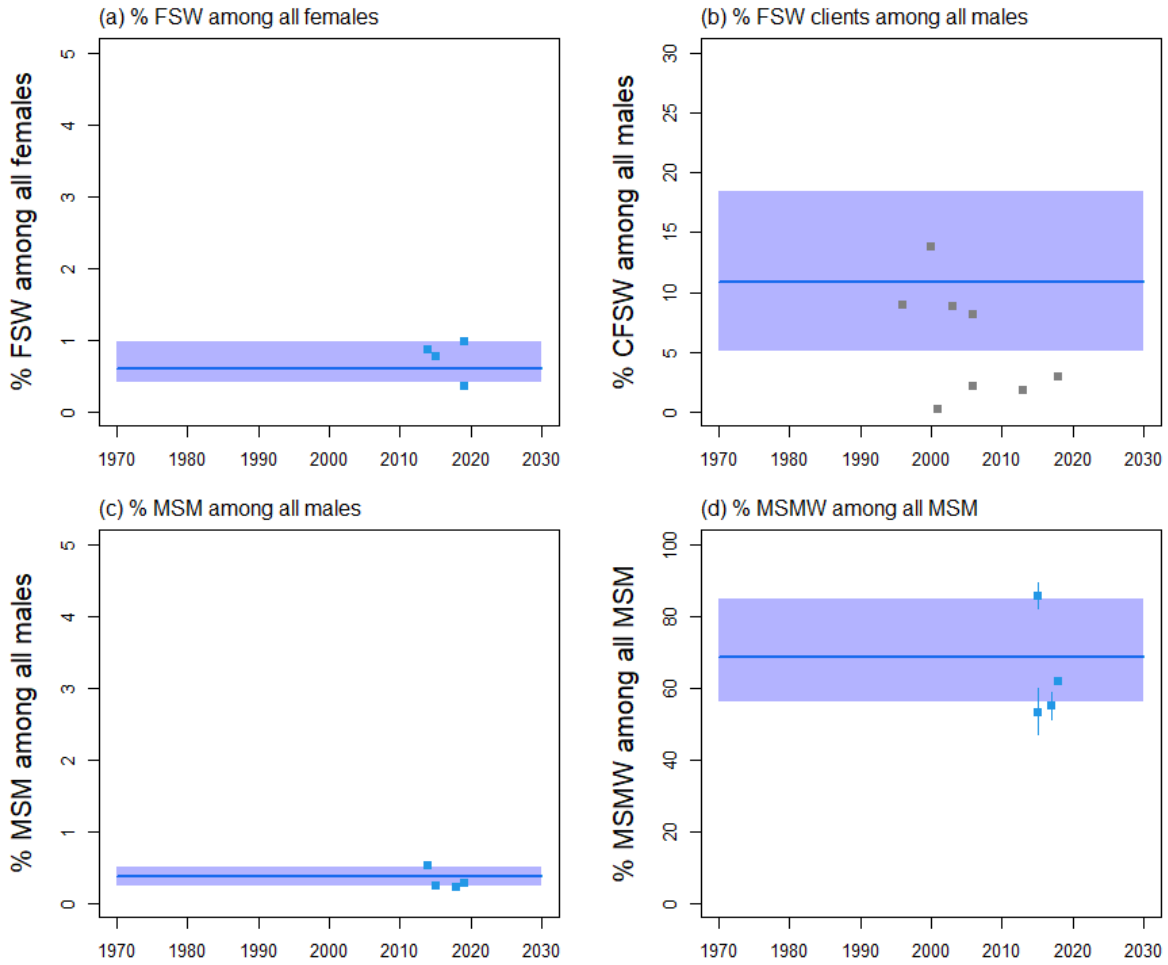


Figure S6c: Mali model fitting to the size of key populations and their clients, with fractions of a) FSW among all females aged 15-59 years, b) FSW clients among all males aged 15-59 years, c) MSM among all males aged 15-59 years, and d) MSMW (men who have sex with men and women) among all MSM aged 15-59 years old over time. Blue curves and shades represent median and 90% UI (5thth and 95th percentiles across model fits), whereas squares and intervals represent empirical estimates (with 95% CI). Grey estimates in panel b) were reported from household surveys and studies among truck drivers, and were only used for comparison as they were deemed to unrepresentative, The FSW clients population size in the model was calculated using the multiplier method as in^{1,8,34,153}.

HIV epidemiology

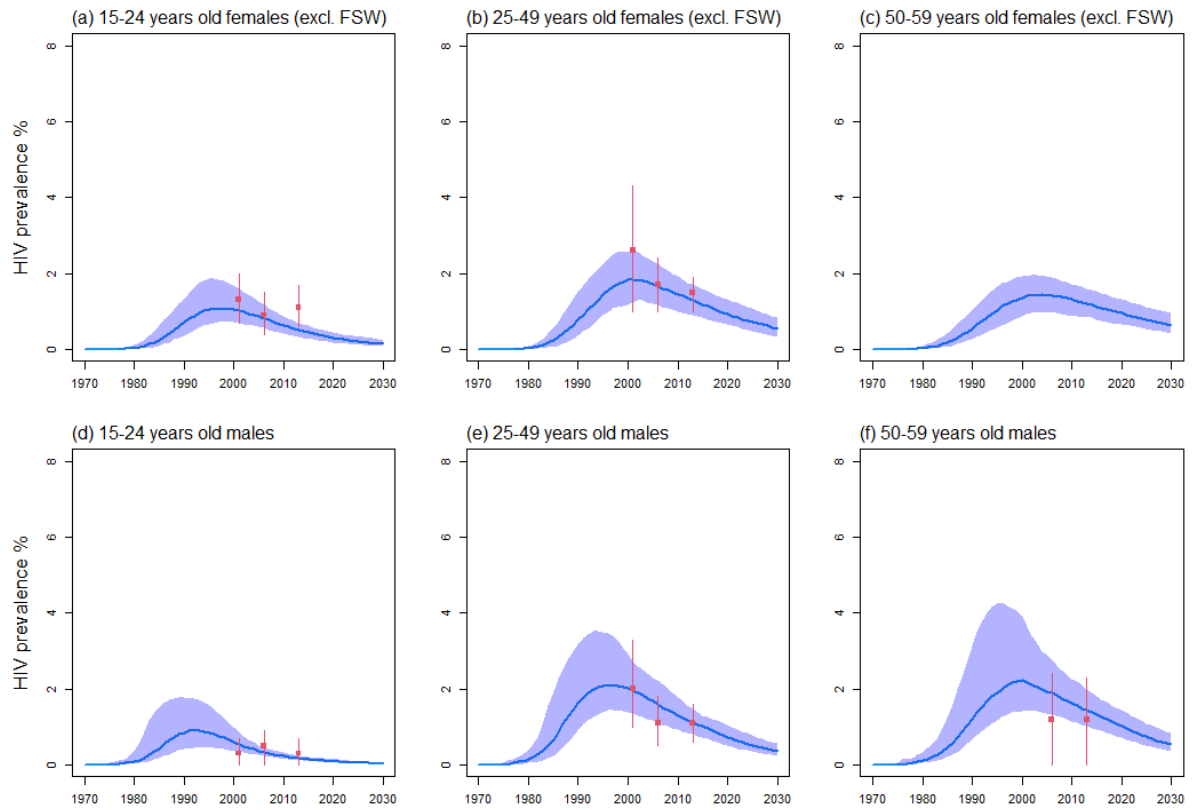


Figure S6d: Mali model fitting to the HIV prevalence among all females aged a) 15-24, b) 25-49, and c) 50-59 years old (excluding FSW), as well as all males aged d) 15-24, e) 25-49 years, and f) 50-59 years old. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting (with 95% CI).

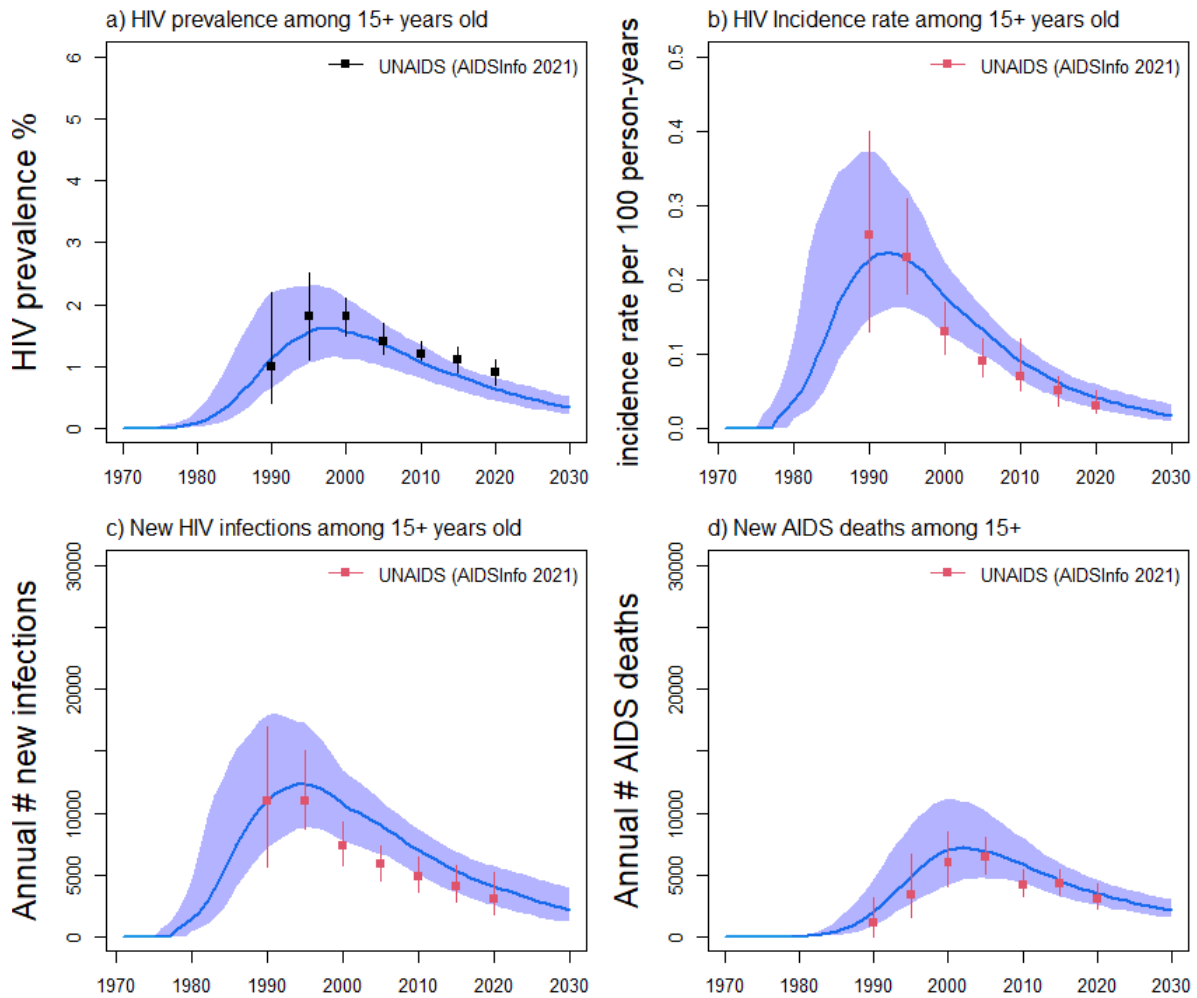


Figure S6e: Estimates of HIV prevalence among a) all adults aged over 15 years old, fits to b) HIV incidence rate, c) annual number of new HIV infections and d) annual HIV-related deaths in Mali from UNAIDS (from the Spectrum/EPP model¹⁵⁴). Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting, whereas the dark squares and intervals in panel a) represent estimates from UNAIDS (also from the Spectrum/EPP model) only used for comparison.

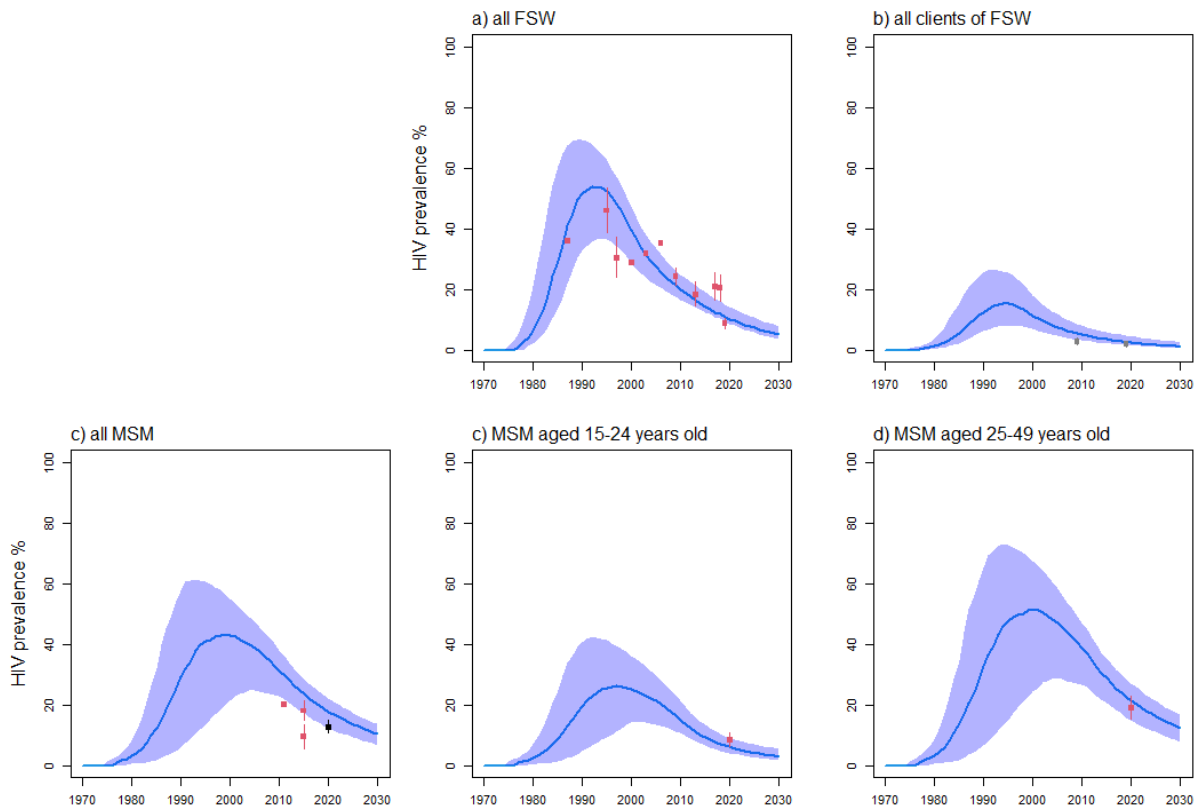


Figure S6f: Mali model fitting to HIV prevalence estimates among all a) FSW, b) clients of FSW, c) MSM, as well as c) MSM aged 15-24 years old, and d) aged 25-49 years old. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting, whereas the dark square on panel c) represents the estimate fitted by age.

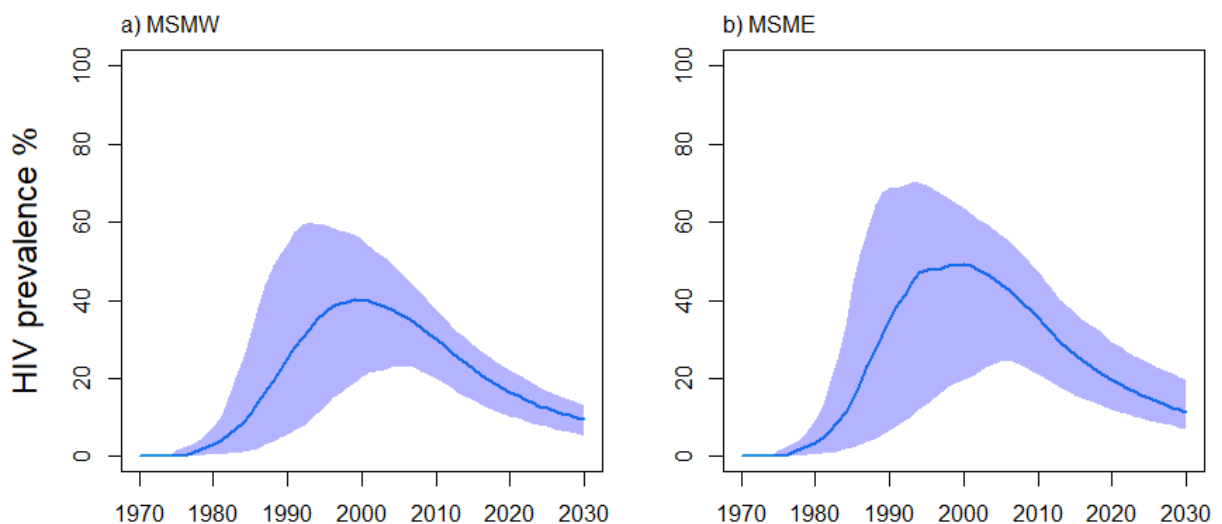


Figure S6g: Mali model estimates of the HIV prevalence among all a) MSMW (men having sex with both men and women) and b) MSME (men having sex with another men) MSM. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits). No data was available.

HIV treatment cascade

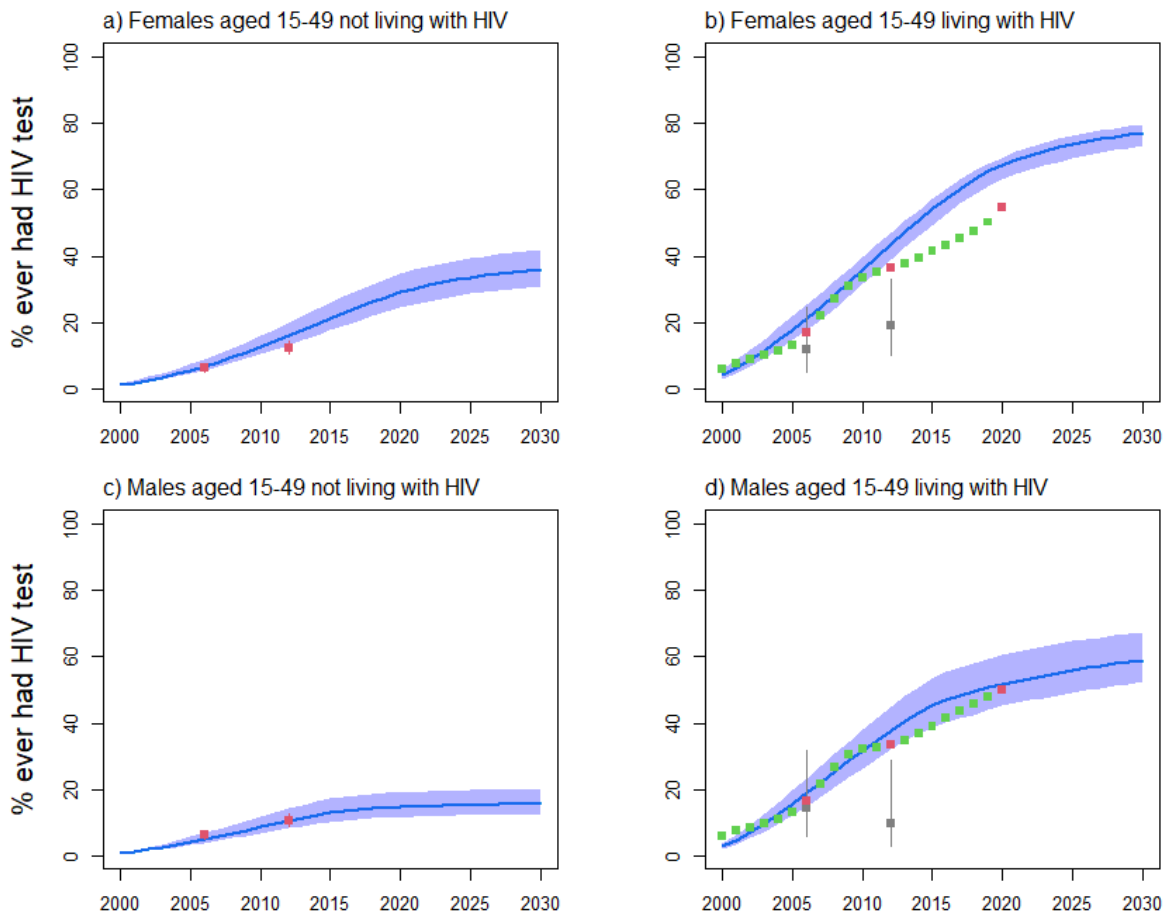


Figure S6h: Mali model fitting to the fraction ever having tested for HIV among all females aged 15-49 years old a) not living with HIV, b) living with HIV, and males aged 15-49 years old c) not living with HIV, d) living with HIV. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent estimates from UNAIDS Shiny90¹³¹ used for model fitting (green=Shiny90 estimates used for comparison), whereas grey squares represent estimates from DHS surveys among PLHIV which were used for comparison.

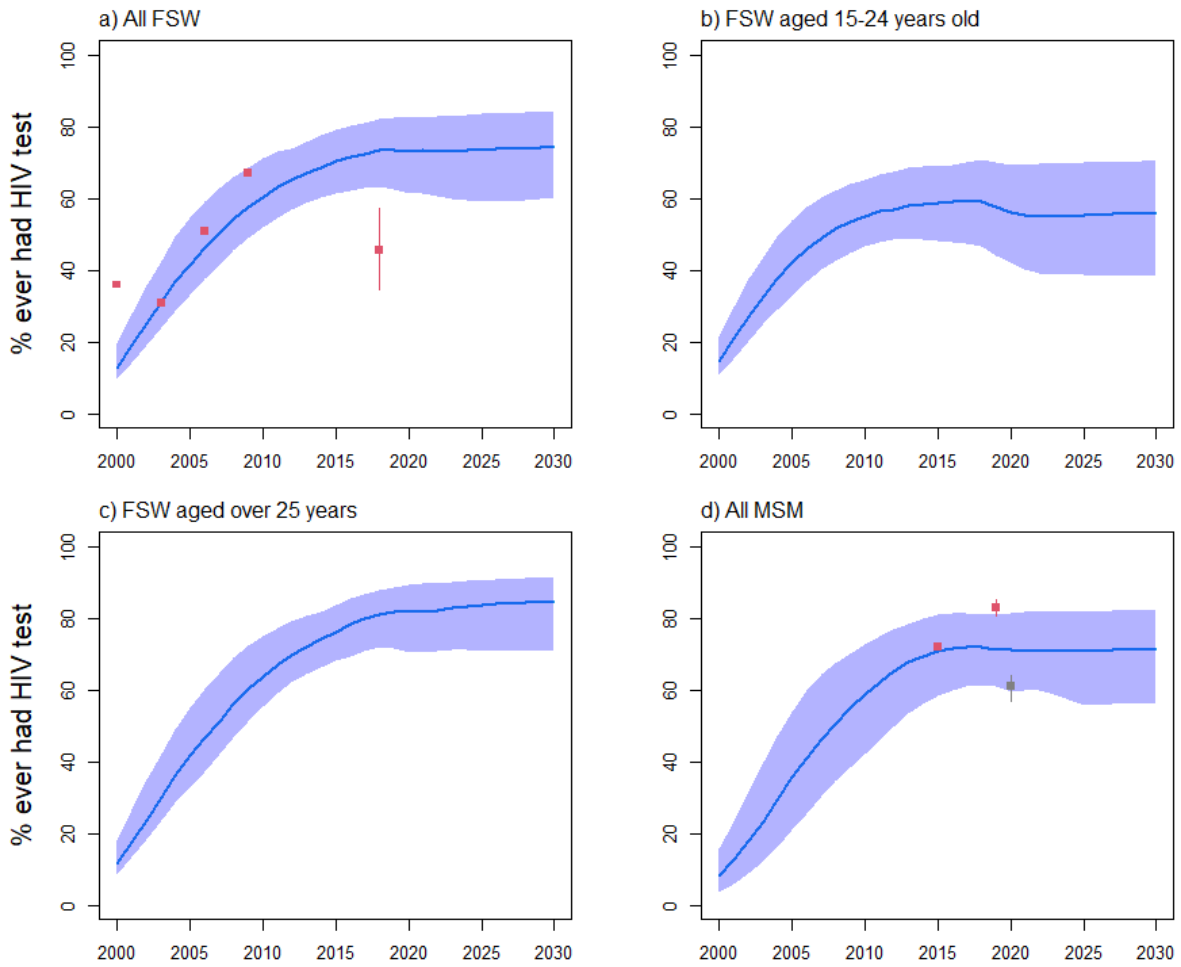


Figure S6i: Mali model fitting to the fraction ever having tested for HIV among a) all FSW, b) FSW aged 15–24 years, c) FSW aged 25–49 years, and d) MSM. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting, the grey square for 2020 in panel d) was an estimate of the fraction of MSM having had an HIV test in the last year, which was used for comparison. We anticipated the estimate from Tounkara et al. for the year 2018¹⁰⁴ in panel a) to be lower than expected, as it was calculated among FSW living with HIV only and because all the women reporting being newly diagnosed during the study reported never having tested for HIV in the past.

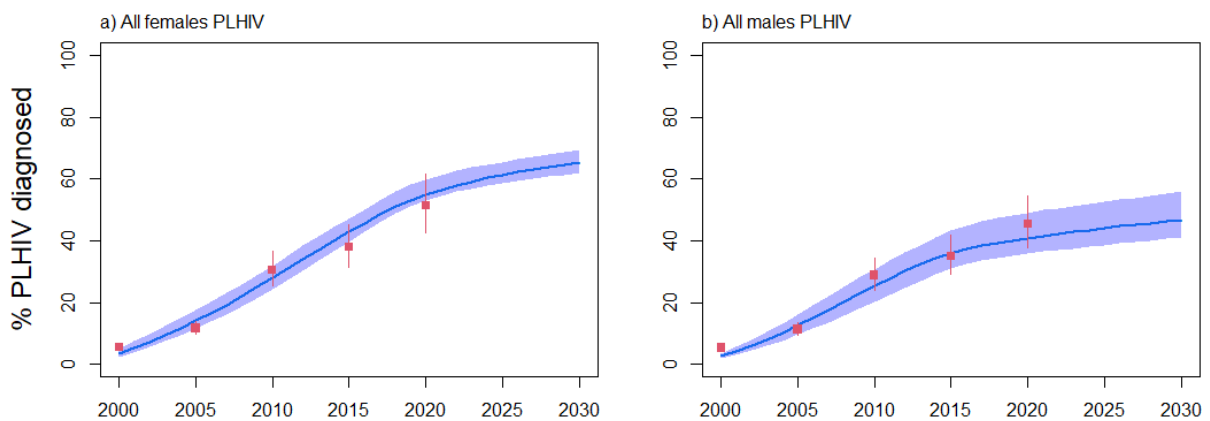


Figure S6j: Mali model fitting to the fraction of a) all females living with HIV and b) all males living with HIV being diagnosed. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent estimates from UNAIDS Shiny90 used for model fitting.

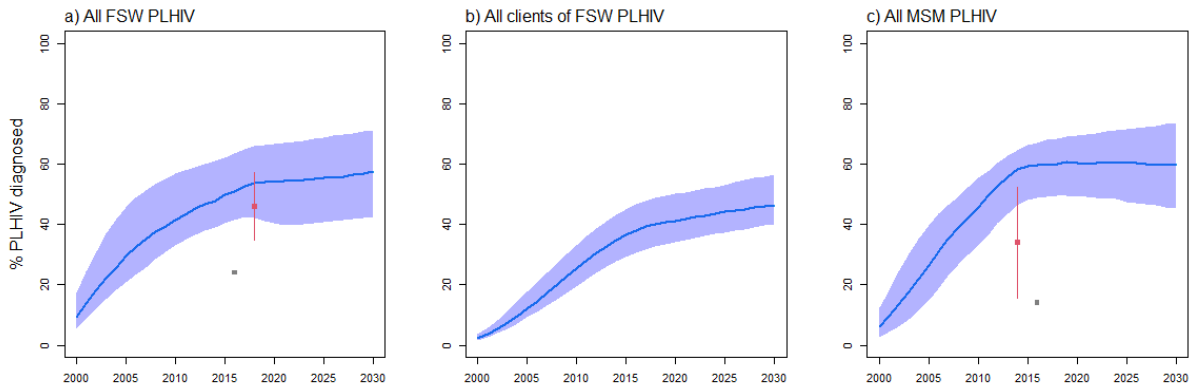


Figure S6k: Mali model fitting to the fraction of a) all FSW living with HIV, b) all male clients of FSW living with HIV, and c) all MSM living with HIV diagnosed. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent estimates from empirical surveys^{48,104}, whereas grey squares represent national estimates for which no report or underlying study could be identified, and which were only used for comparison. Empirical estimates are self-reported and likely to be under-estimates.¹⁵⁵. In particular, the estimate from Hakim et al.⁴⁸ in panel c) could not be well fitted as it did not agree well with data on HIV viral suppression among MSM in the country(see Figures S6n and S6o).

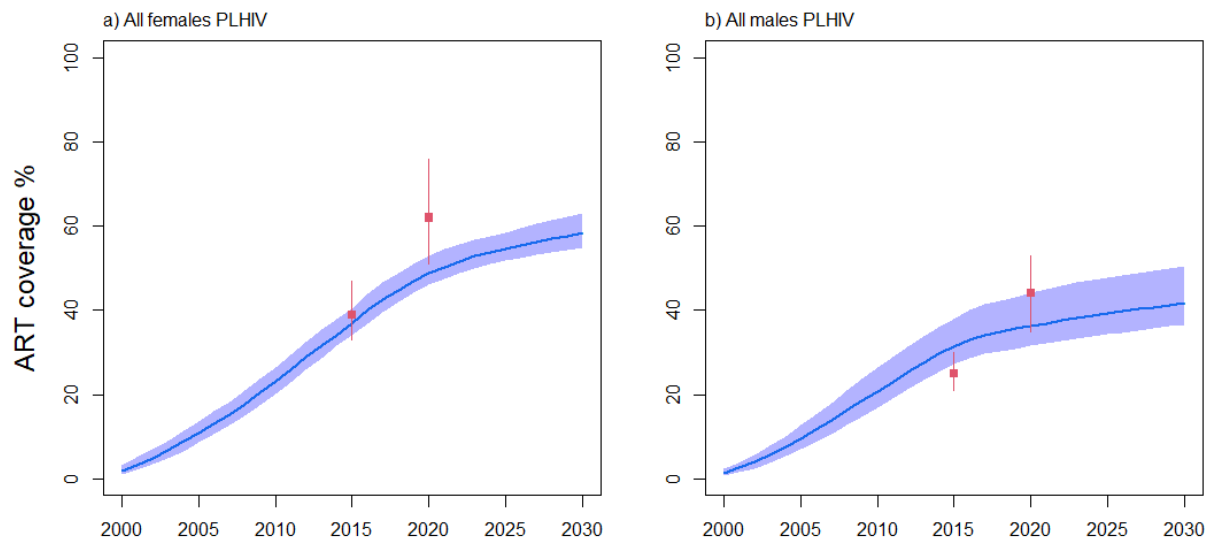


Figure S6l: Mali model fitting to ART coverage among a) all females and b) all males living with HIV. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent estimates from UNAIDS (with 95% CI), using the Spectrum/EPP model.



Figure S6m: Mali model fitting to ART coverage among a) all FSW, b) all male clients of FSW, and c) all MSM living with HIV. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent empirical estimates from local surveys. Dark point and interval in panel c) represent self-reported use of ART, and all study participants reporting being on ART were virally suppressed (which was fitted by age in our model, see figure S6o). Grey squares in panels a) and c) represent estimates for which no report or underlying study could be identified. Although no ART coverage data was used, we fitted the Mali model to estimates of viral suppression in the country.

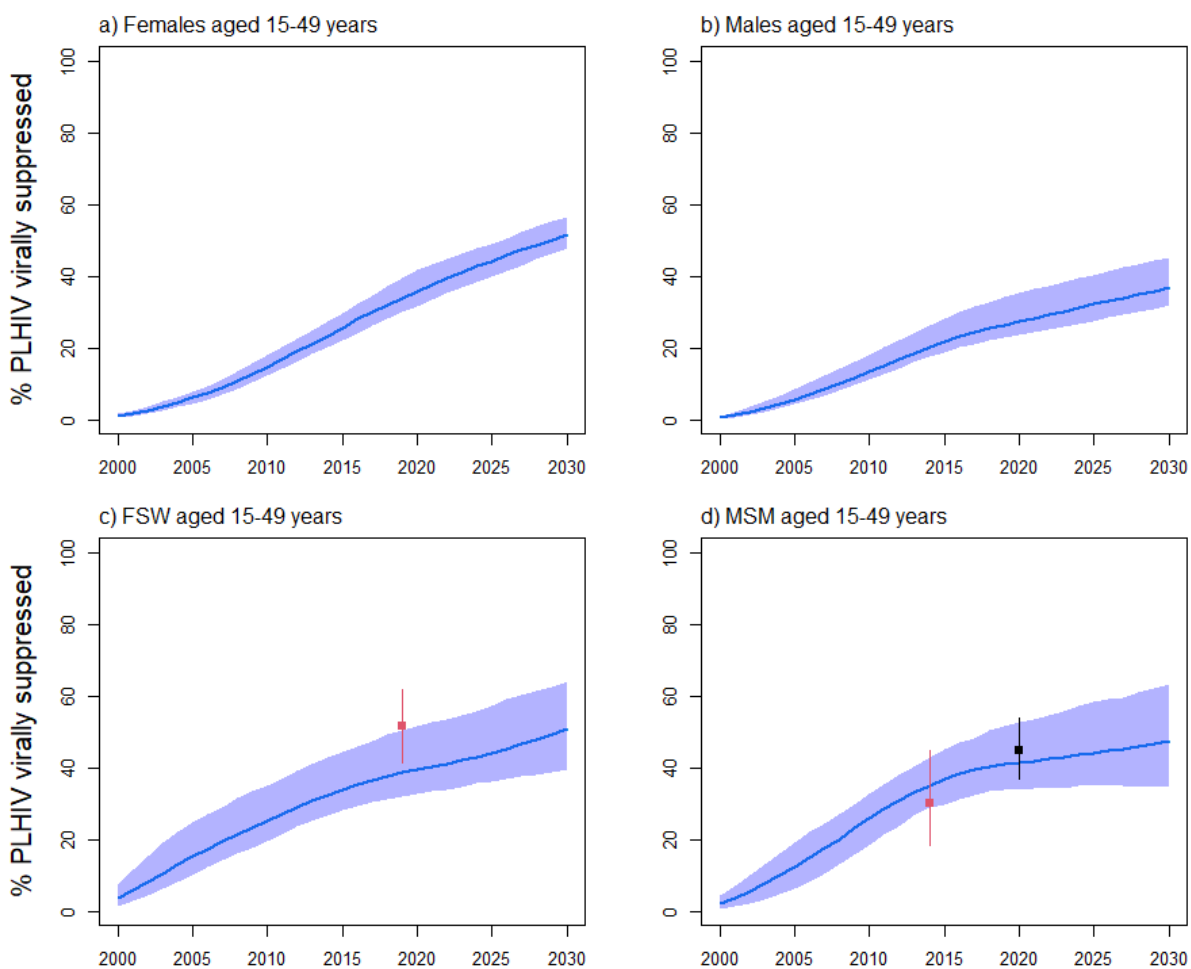


Figure S6n: Mali model fitting to HIV viral load suppression coverage among a) all females, b) all males, c) all FSW, and d) all MSM aged 15-49 years living with HIV. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent empirical estimates from local surveys. The black square in panel d) was only used for comparison; it was aggregated from the age-stratified 2020 estimates used at the fitting stage (see figure S5o).

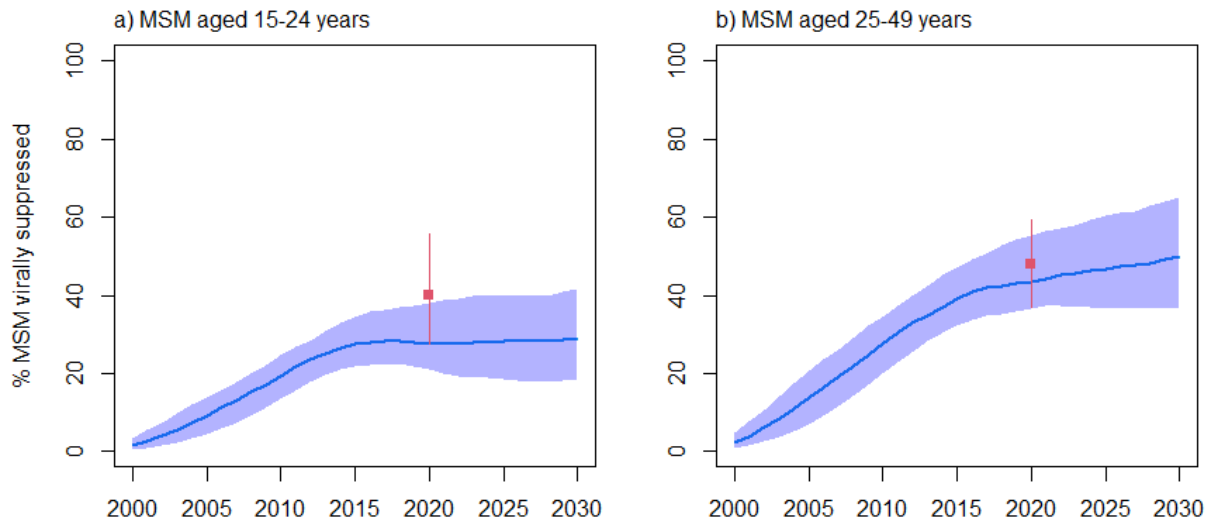


Figure S6o: Mali model fitting to HIV viral load suppression coverage among MSM living with HIV aged a) 15-24 years and b) 25-49 years. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent empirical estimates.

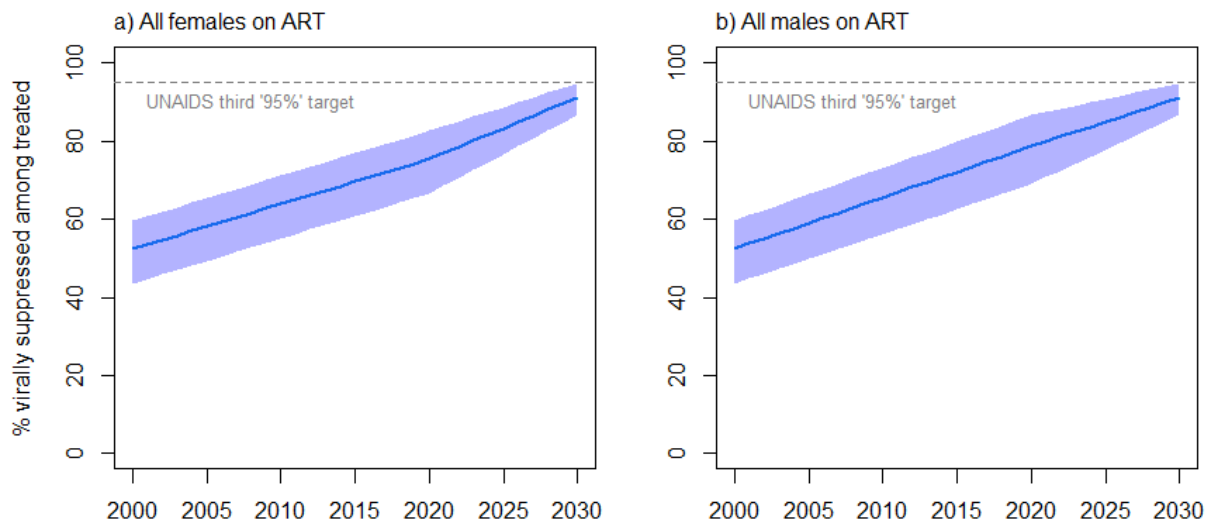


Figure S6p: Mali model estimates of the fraction of a) females and b) males living with HIV on ART which are virally suppressed (the third UNAIDSs “95%” indicator) over time, which is used as a parameter in our model. There were no available estimates of this fraction, and the plausible fractions were estimated by using the relationship between the 1st and 3rd “95%” indicators in Côte d’Ivoire and Senegal and applying this relationship to the estimate of the 1st “95%” indicator in Mali. The grey dashed line corresponds to the UNAIDS’s third “95%” target whereby 95% of PLHIV on ART should be virally suppressed in 2025.

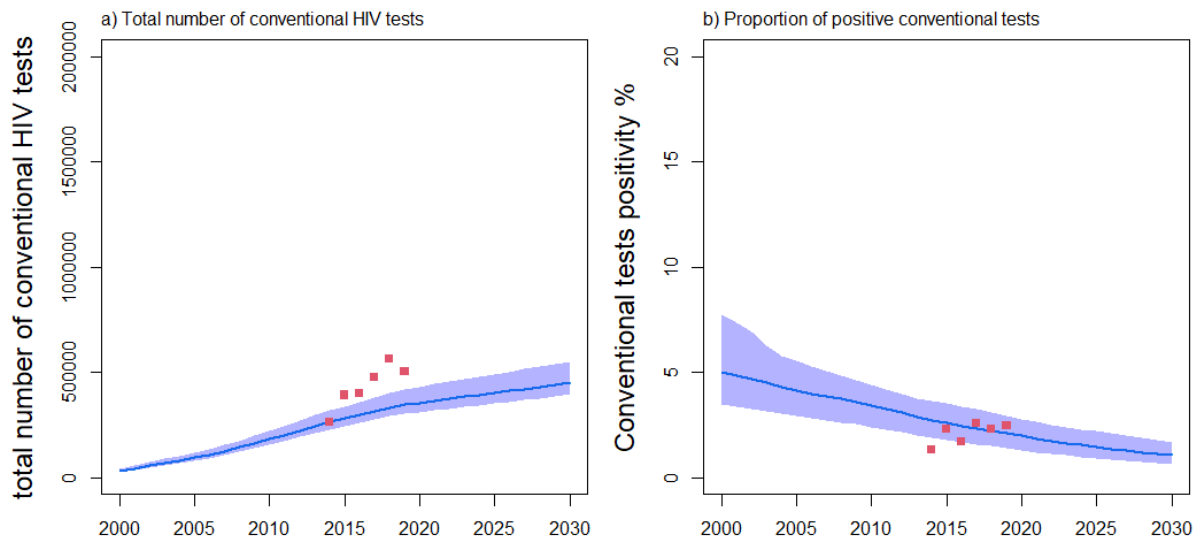


Figure S6q: Mali model fitting to programmatic data⁶⁸ on a) the total number of conventional tests and b) proportion of these tests which were positive. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares represent programmatic data from UNAIDS⁶⁸.

Results: model fits (Senegal)

Demography

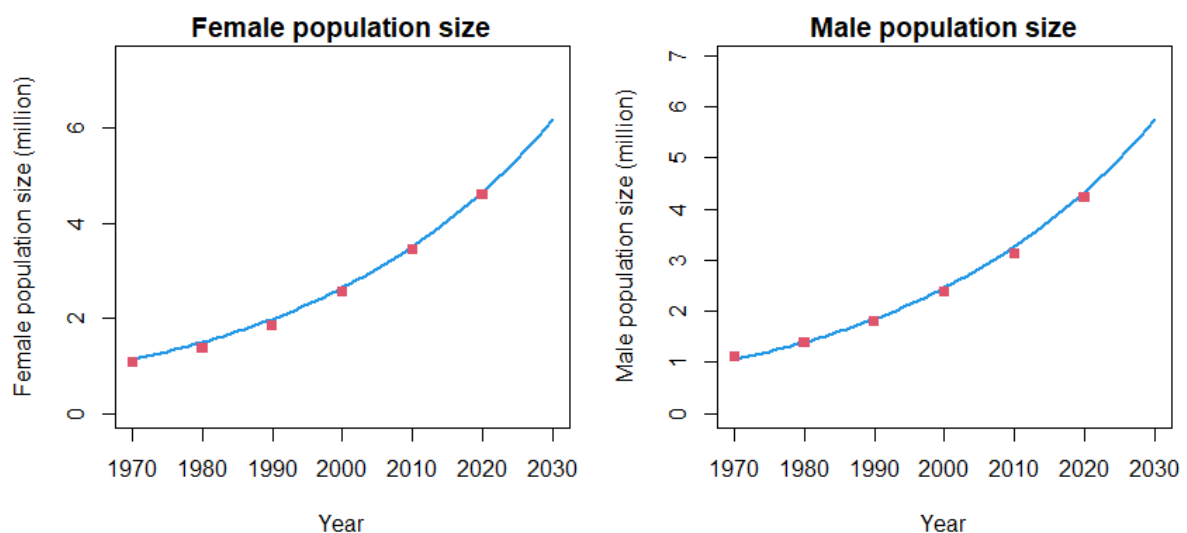


Figure S7a: Senegal model fitting to the size of the (left) female and (right) male populations aged 15-59 years old over time. Blue curves represent model estimates, while red squares show estimates from UNPD.

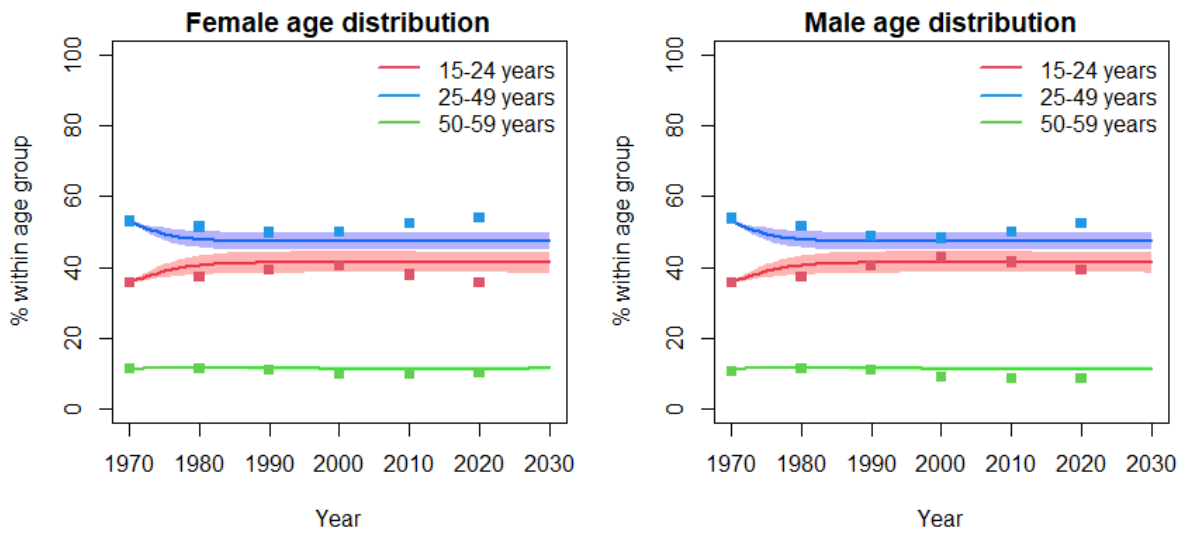


Figure S7b: Senegal model fitting to the age distribution of (left) females and (right) male populations aged 15-59 years old over time. Curves represent model estimates while squares show estimates from UNPD. The latter were used to initialise the population age distribution in 1970 (combining males and females), and to calibrate the model to sex-specific estimates for 2020.

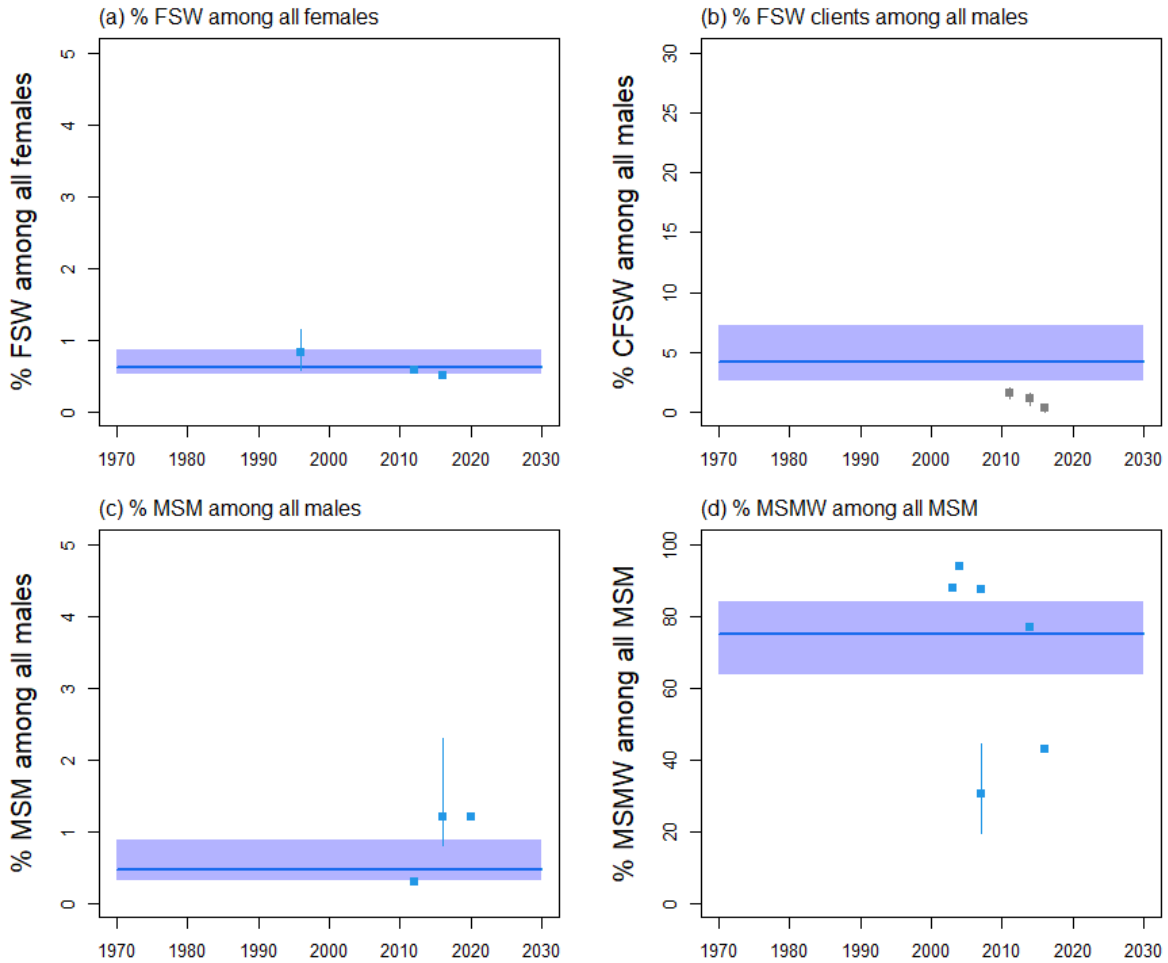


Figure S7c: Senegal model fitting to the size of key populations and their clients, with the fraction of a) FSW among all females aged 15-59 years, b) FSW clients among all males aged 15-59 years, c) MSM among all males aged 15-59 years, and d) MSMW (men who have sex with men and women) among all MSM aged 15-59 years old over time. Blue curves and shades represent median and 90% UI (5thth and 95th percentiles across model fits), whereas squares and intervals represent empirical estimates. Grey estimates in panel b) were reported from household surveys and were only used for comparison as they were deemed to be unrepresentative, The FSW clients population size in the model was calculated using the multiplier method as in ^{1,8,34,153}. Larger fractions of MSM population in panel c) could not be reproduced by the model due to incompatibilities with 1) concomitant low HIV prevalence among all males and high prevalence among MSM, and 2) concomitant high ART coverage among all males and low ART coverage among MSM.

HIV epidemiology

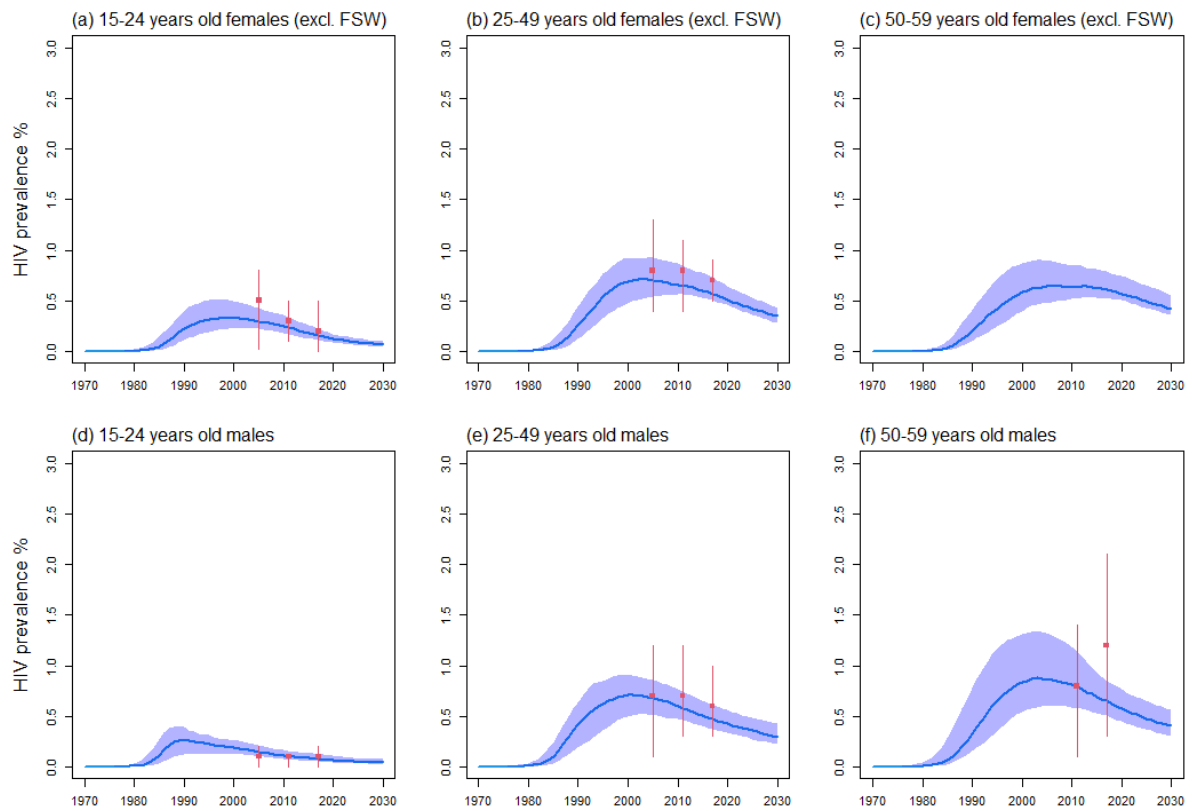


Figure S7d: Senegal model fitting to the HIV prevalence among all females aged a) 15-24, b) 25-49, and c) 50-59 years old (excluding FSW), as well as all males aged d) 15-24, e) 25-49 years, and f) 50-59 years old. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent empirical estimates used for model fitting.

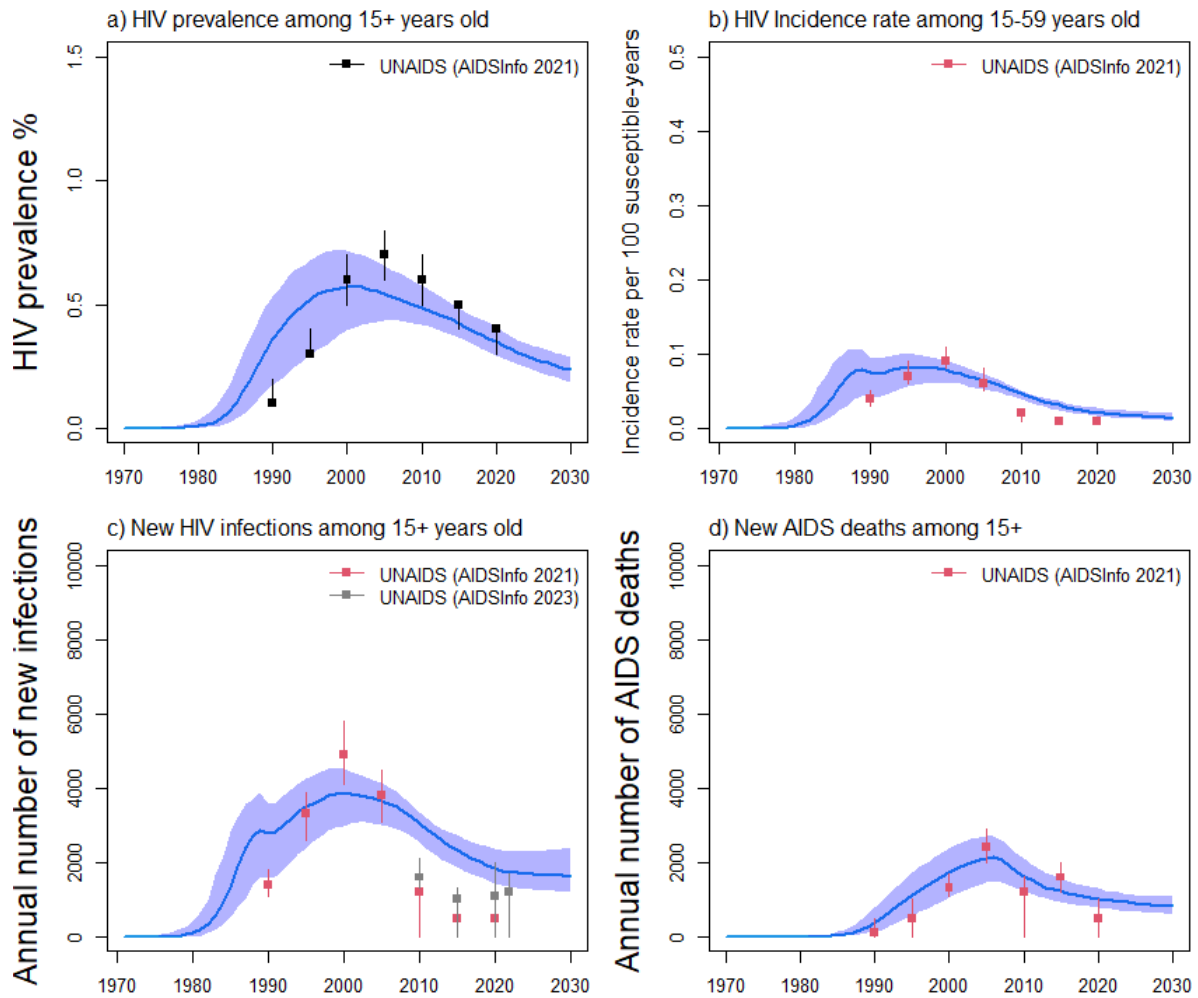


Figure S7e: Estimates of HIV prevalence among a) all adults aged over 15 years old, fits to b) HIV incidence rate, c) annual number of new HIV infections and d) annual HIV-related deaths in Senegal from UNAIDS (from the Spectrum/EPP model¹⁵⁴). Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting, whereas the dark squares and intervals in panel a) represent estimates from UNAIDS (also from the Spectrum/EPP model) only used for comparison, whereas grey squares and intervals in panel c) represent new estimates from UNAIDS (Spectrum/EPP) which were published in July 2023 and not available at the time of our analysis.

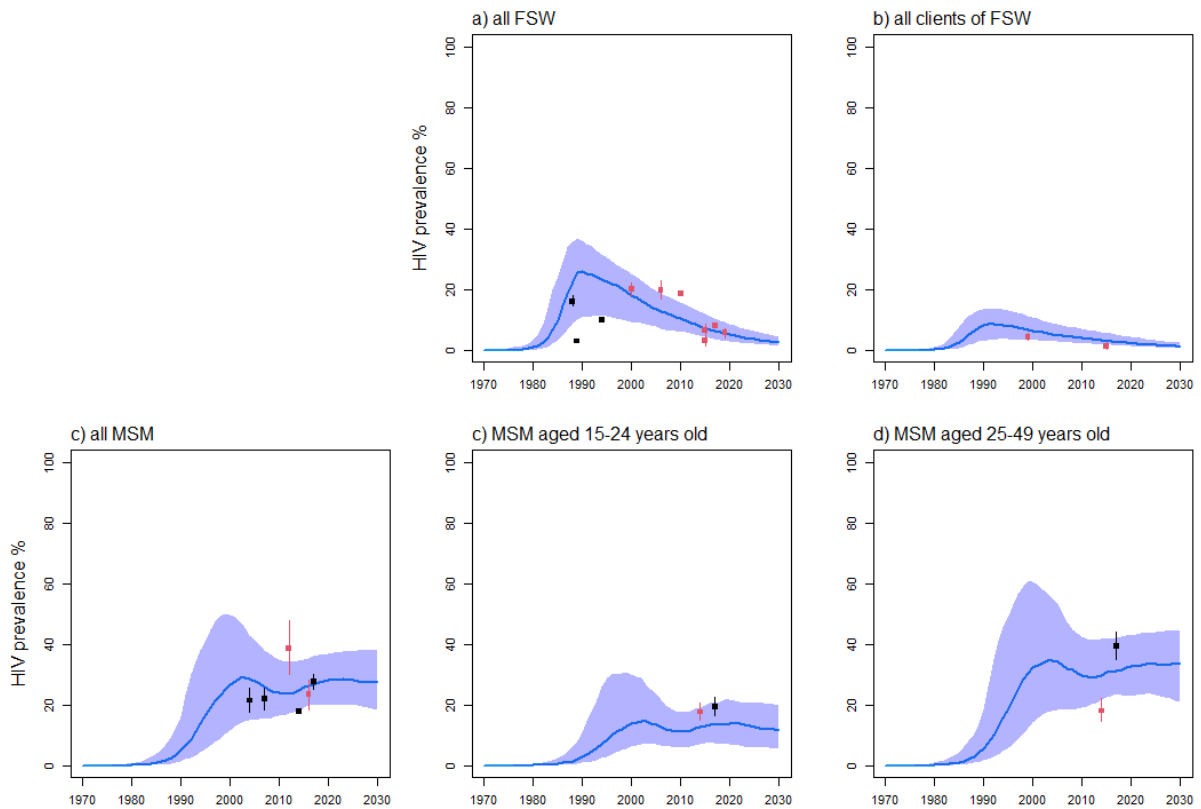


Figure S7f: Senegal model fitting to HIV prevalence estimates among a) all FSW, b) all clients of FSW, c) MSM, as well as c) MSM aged 15-24 years old, and d) aged 25-49 years old. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting. Dark squares for FSW correspond to estimates which could not be sourced to a particular study or report and were only used for comparison, whereas those on panel c-d) represent estimates fitted by age and for bisexuals/exclusive MSM separately.

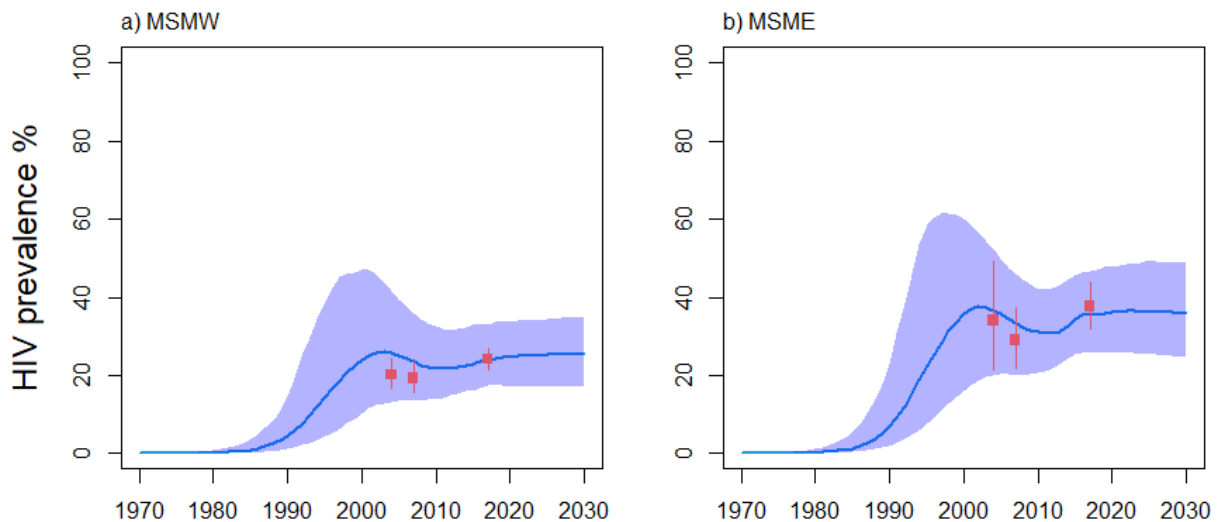


Figure S7g: Senegal model fitting to HIV prevalence estimates among all a) MSMW (men having sex with both men and women) and b) MSME (men having sex with other men exclusively) MSM. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent empirical estimates.

HIV treatment cascade

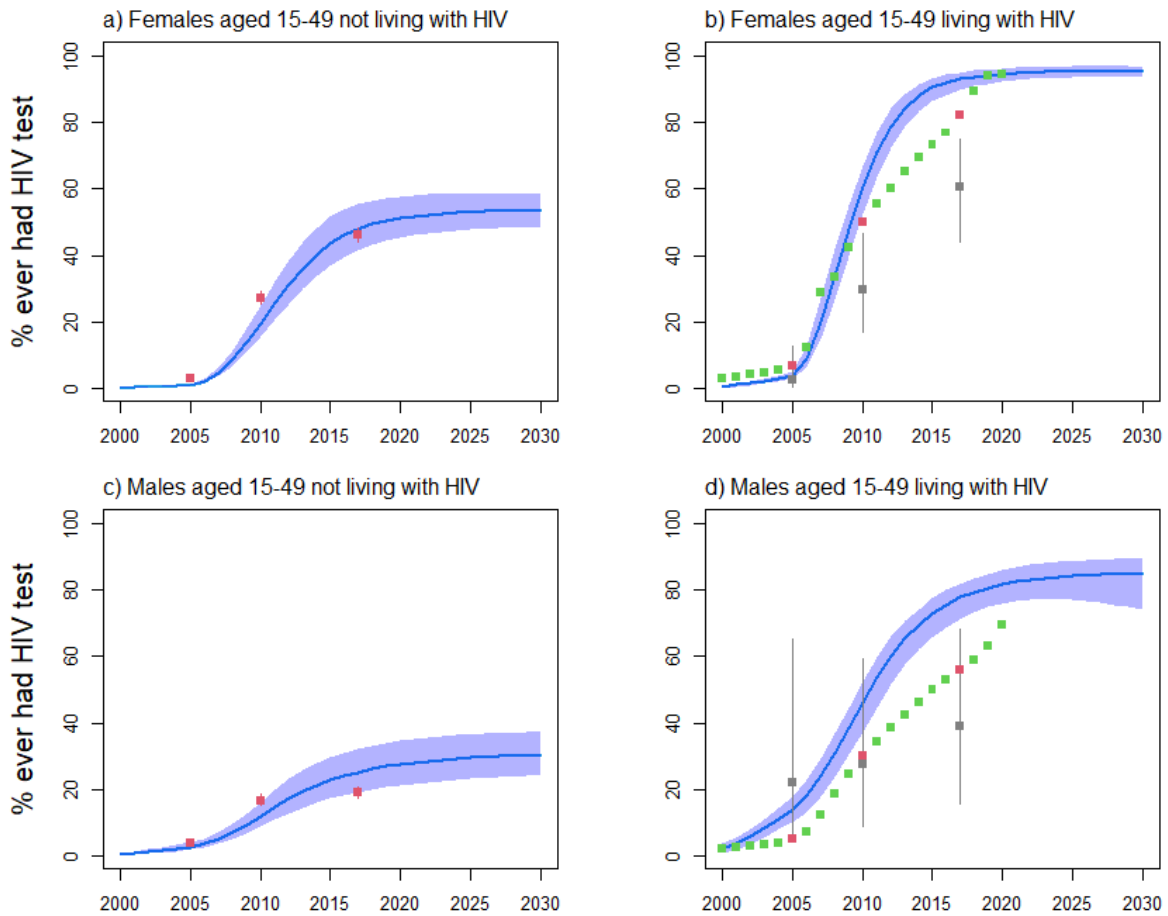


Figure S7h: Senegal model fitting to the fraction ever having tested for HIV among all females aged 15-49 years old a) not living with HIV, and b) living with HIV, and males aged 15-49 years old c) not living with HIV, and d) living with HIV. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent estimates from UNAIDS Shiny90 used for model fitting (green=those used for comparison), whereas grey squares represent estimates among PLHIV from DHS surveys only used for comparison. Our model estimates among PLHIV (panels b) and d)) were higher than empirical estimates because of high coverage of ART for the recent period being predicted by UNAIDS (see Figure S7l).

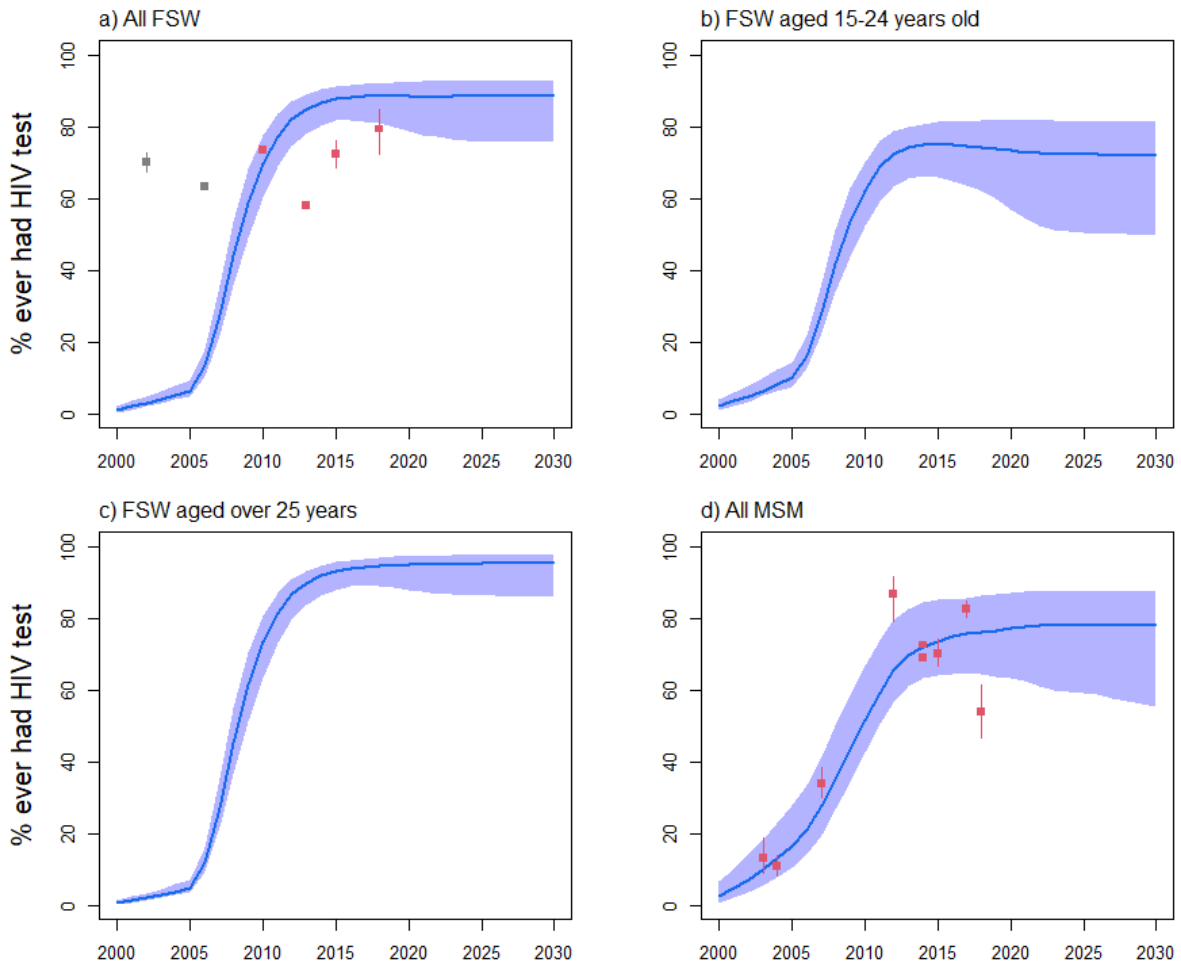


Figure S7i: Senegal model fitting to the fraction ever having tested for HIV among a) all FSW, b) FSW aged 15-24 years, c) FSW aged 25-49 years, and d) all MSM. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent empirical estimates used for model fitting, whereas the grey squares in panel a) corresponded to studies from STI clinics, which were only used for comparison.

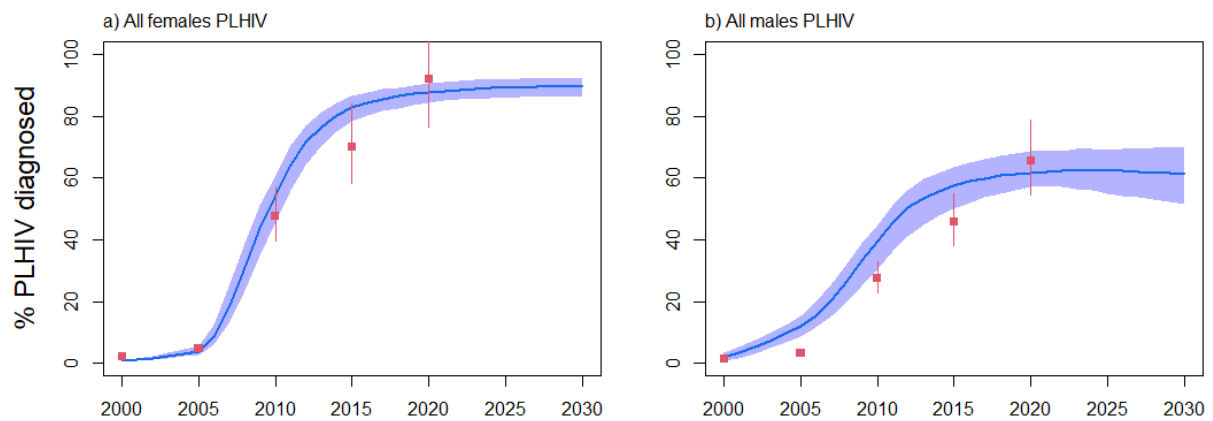


Figure S7j: Senegal model fitting to the fraction of a) all females living with HIV and b) all males living with HIV being diagnosed. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent estimates from UNAIDS Shiny90 used for model fitting.

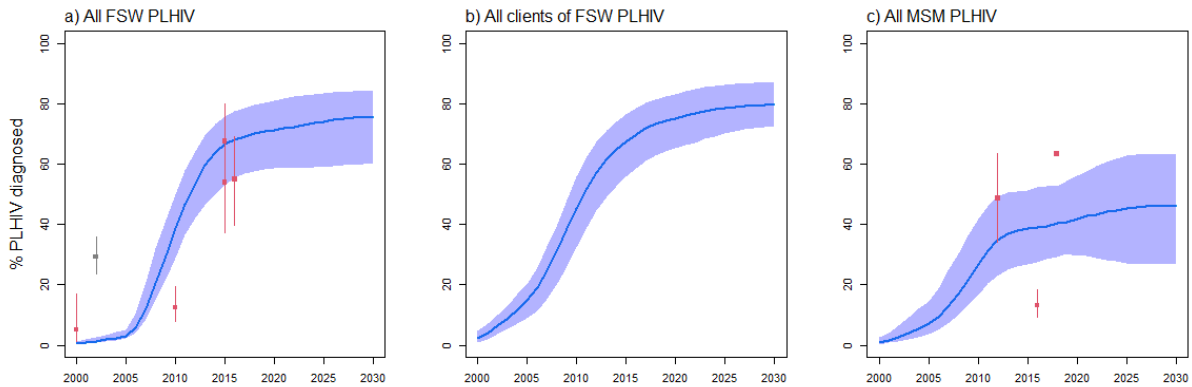


Figure S7k: Senegal model fitting to the fraction of a) all FSW living with HIV, b) all male clients of FSW living, and c) all MSM living with HIV being diagnosed. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), red squares and intervals represent estimates from empirical surveys, whereas grey square in panel a) represent estimates from an STI clinic. Empirical estimates are self-reported and likely to be under-estimates.¹⁵⁵

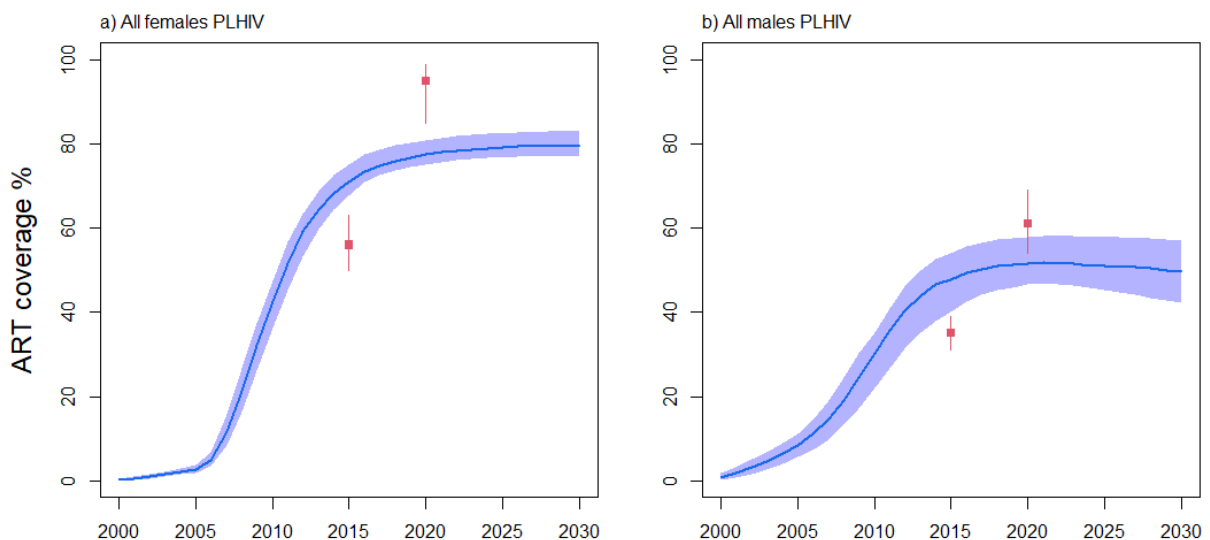


Figure S7l: Senegal model fitting to ART coverage among a) all females and b) all males. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent estimates from UNAIDS (with 95% CI), using the Spectrum/EPP model. In panel a) our model predicts lower coverage of ART in 2020 compared to the Spectrum/EPP estimates as the latter are higher than proportions of female PLHIV which are diagnosed.

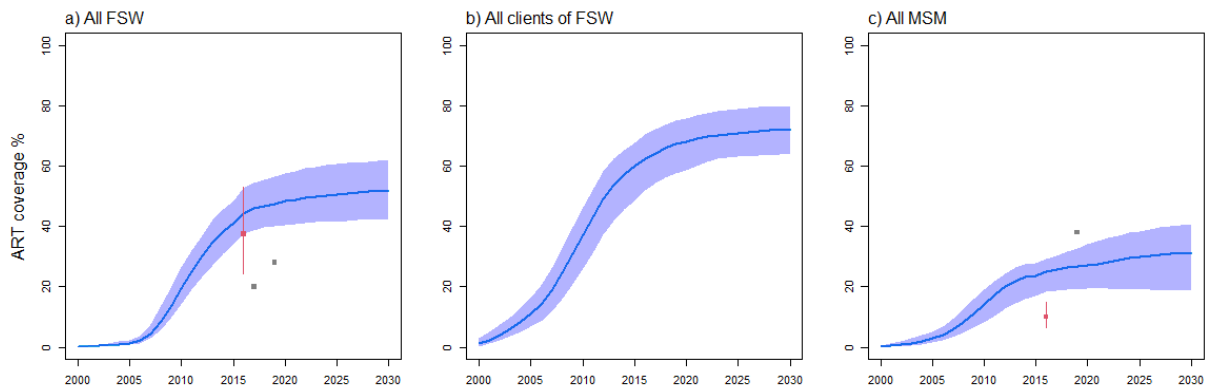


Figure S7m: Senegal model fitting to ART coverage among a) all FSW, b) all male clients of FSW, and c) all MSM. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent empirical estimates from local surveys. Dark point and interval in panel c) represent self-reported use of ART (as opposed to estimates using viral load data), and all study participants reporting being on ART were virally suppressed (which was fitted by age in our model). Grey squares in panels a) and c) represent estimates from the UNAIDS key population atlas for which no report or underlying study could be identified. In panel c) our model predicted higher coverage of ART among MSM living with HIV than in Lyons et al. ⁷⁹ as it was self-reported by study participants and does not agree well with estimates from all males.

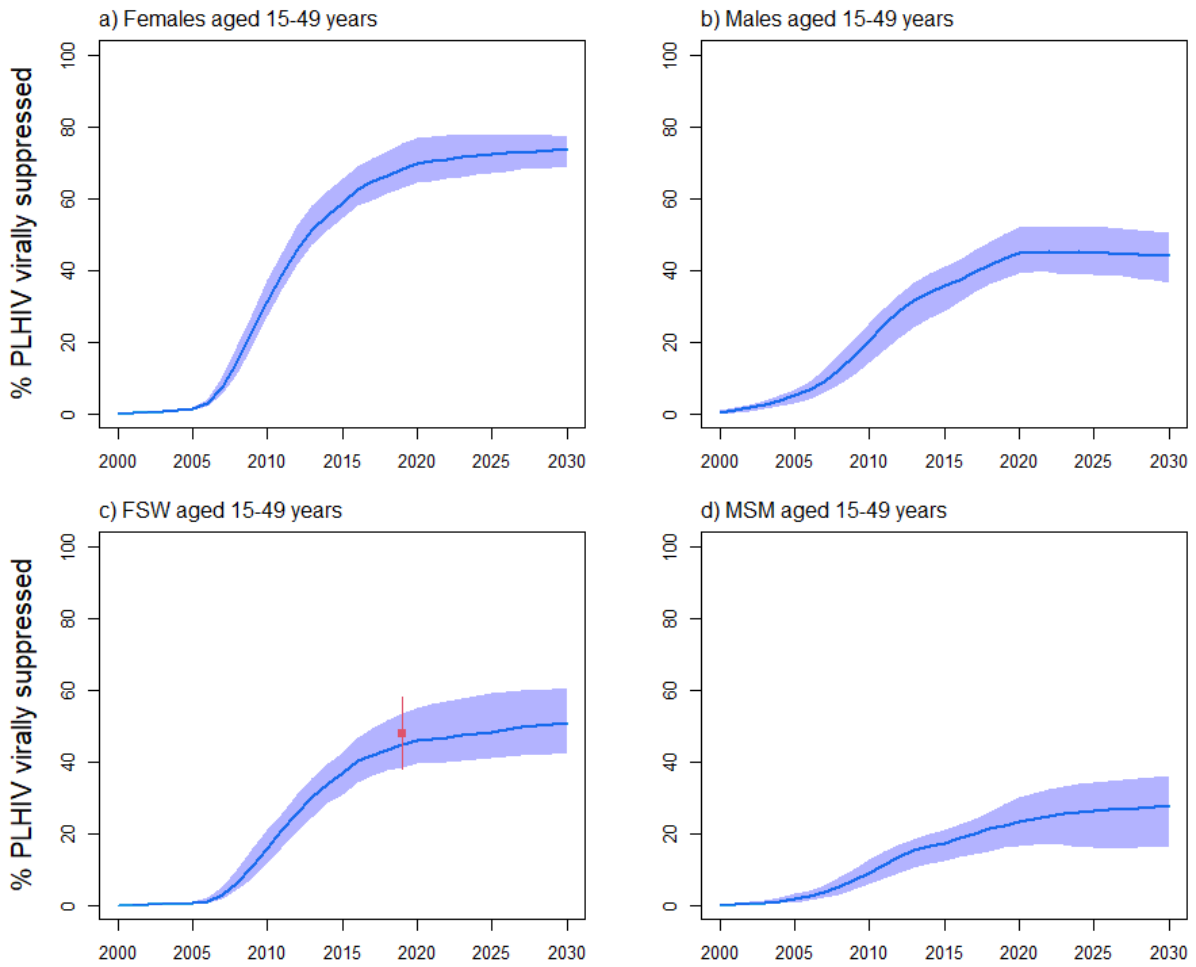


Figure S7n: Senegal model fitting to HIV viral load suppression coverage among a) all females, b) all males, c) all FSW, and d) all MSM aged 15-49 years living with HIV. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits), whereas red squares and intervals in panel c) represent empirical estimate from a local survey.

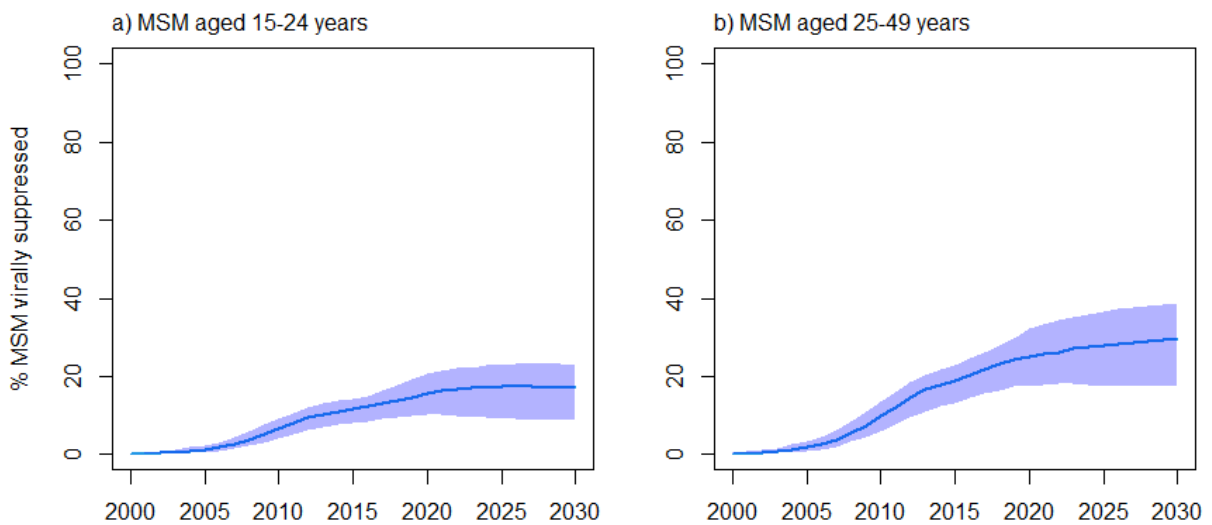


Figure S7o: Senegal model fitting to HIV viral load suppression coverage among all MSM aged a) 15-24 years and b) 25-49 years. Blue curves and shades represent median and 90% UI (5th and 95th percentiles across model fits). No data was available.

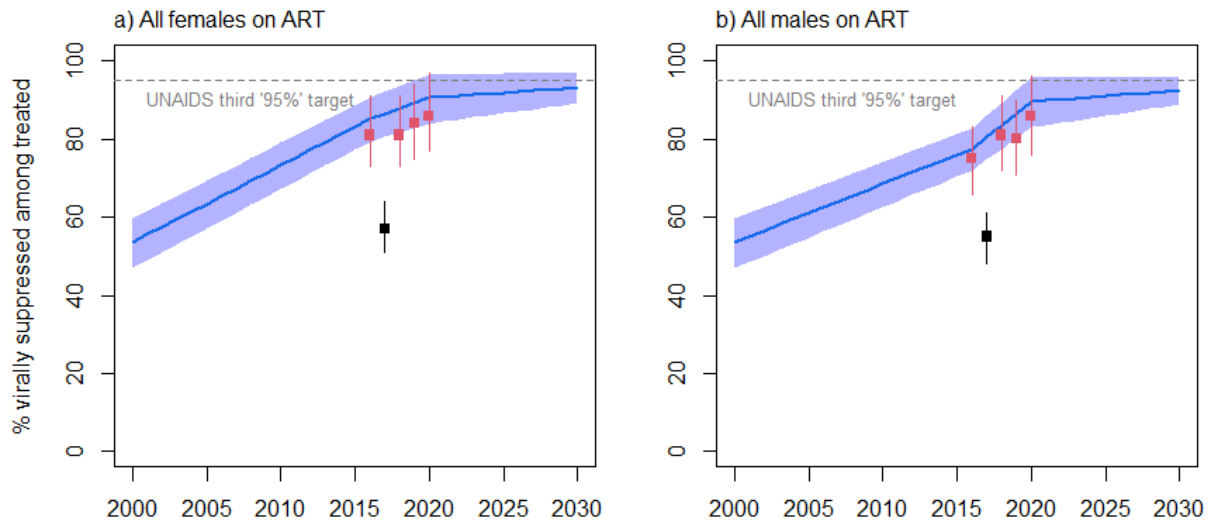


Figure S7p: Senegal model fitting to fractions of a) females and b) males living with HIV on ART which are virally suppressed (the third UNAIDSs “95%” indicator) over time. Blue curves and shades represent median and 95% UI (5th and 95th percentiles across model fits), whereas red squares and intervals represent estimates from UNAIDS used as parameters. The grey dashed line corresponds to the UNAIDS’s third “95%” target whereby 95% of PLHIV on ART should be virally suppressed in 2025. The estimate for 2017 was assumed to be an outlier and not considered in our analysis.

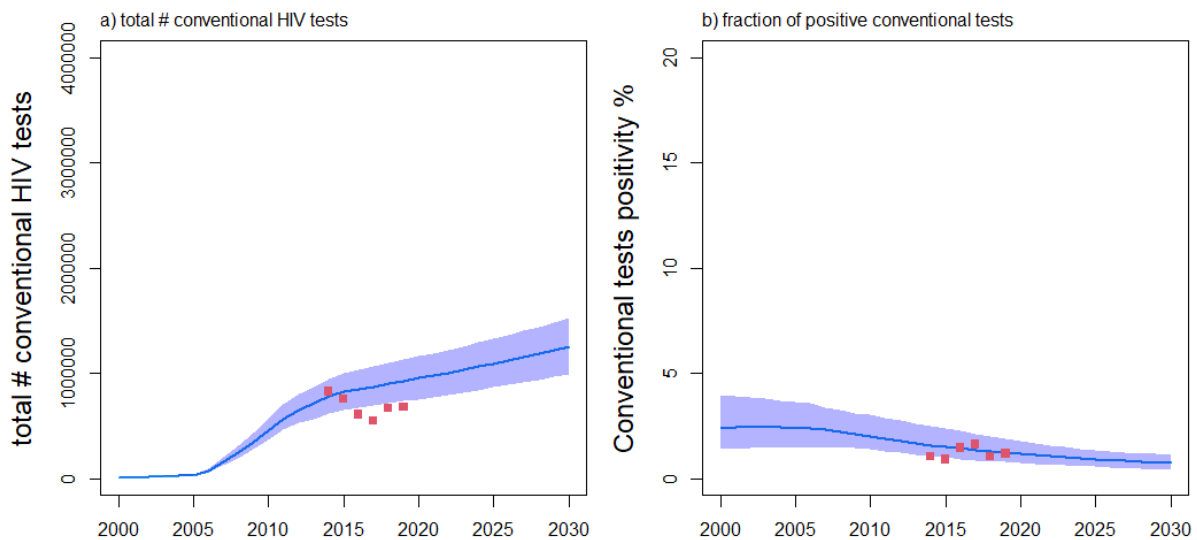


Figure S7q: Senegal model fitting to programmatic data on a) the total number of conventional tests among and b) proportion of these tests which were positive. Blue curves and shades represent median

and 90% UI (5th and 95th percentiles across model fits), whereas red squares represent programmatic data communicated by UNAIDS.

Results: HIVST distribution and impact

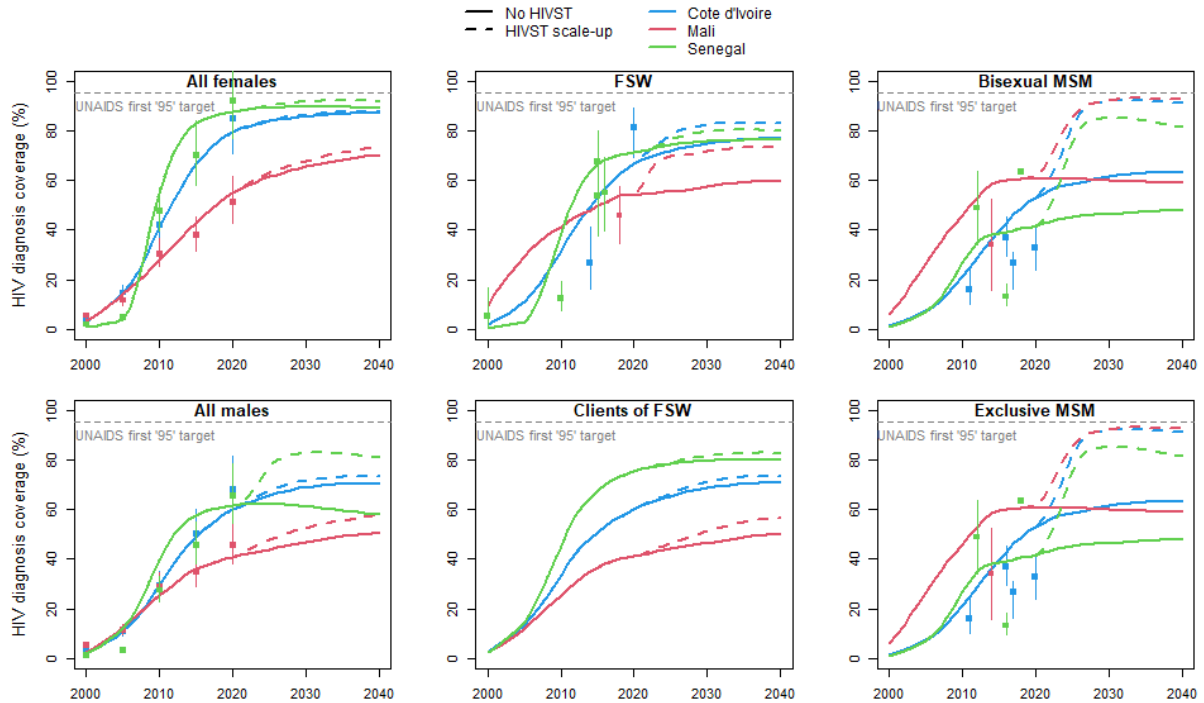


Figure S8: Empirical (points and intervals) and modelled (lines) proportion of diagnosed PLHIV from different risk groups over 2000-2040 in Côte d'Ivoire (blue), Mali (red) and Senegal (green). Plain lines represent median estimates across model fits of a counterfactual scenario ("no HIVST"). Dashed lines represent median estimates under our scenario 3 representing ATLAS distribution of HIVST kits to FSW and MSM over 2019-2021, followed by a scale-up and plateau in HIVST distribution from 2025.

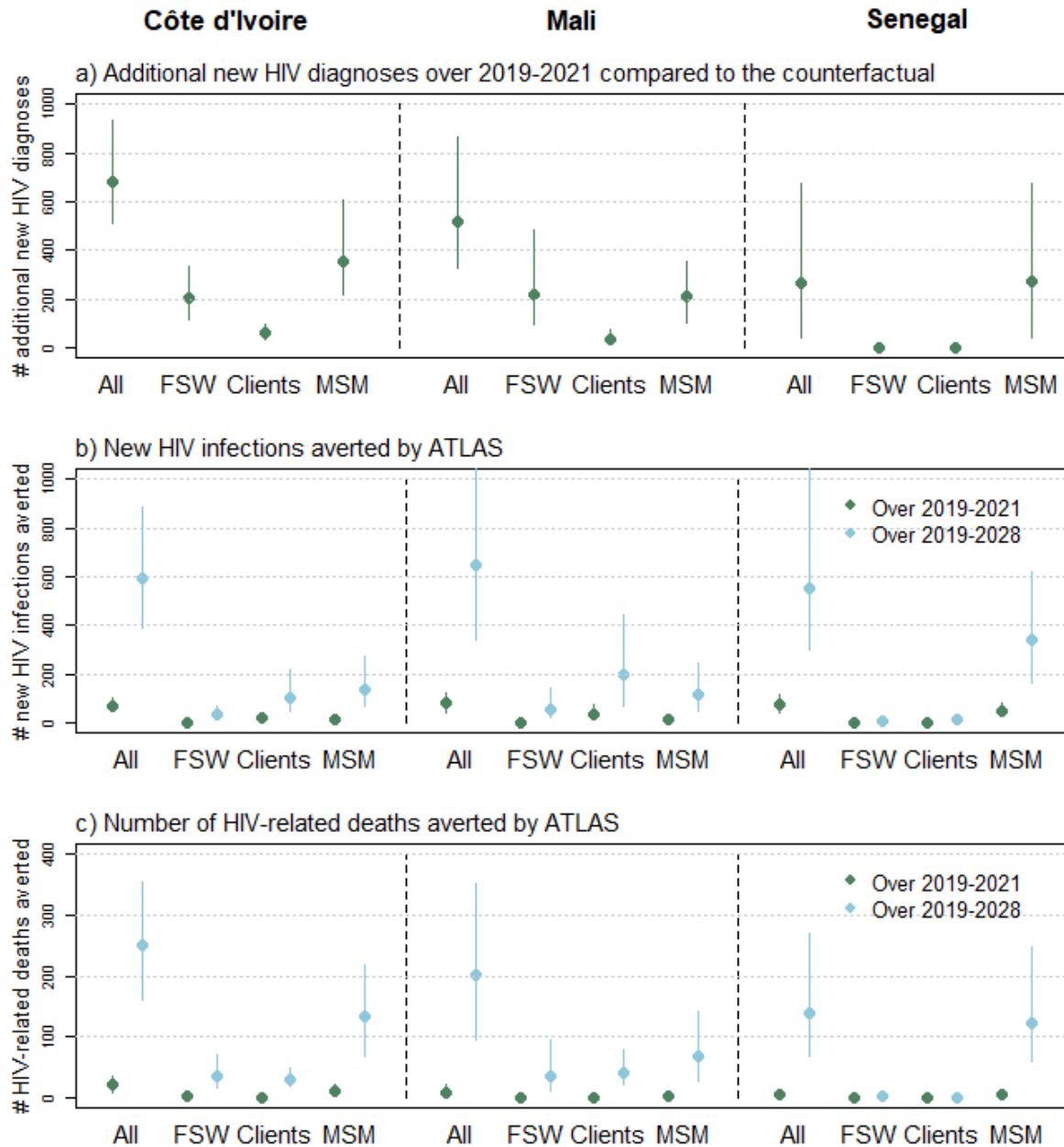


Figure S9: Estimated impact (in absolute numbers) of the ATLAS-only scenario compared to the counterfactual (“no-HIVST” scenario): a) additional new HIV diagnoses over the three-year intervention (2019-2021) and numbers of b) HIV infections (c) and HIV-related deaths averted by ATLAS over 2019-2021 (green points) and 2019-2028 (light blue points). Points height represent median of model estimates, whereas error bars represent 90% UI of estimates (5th and 95th percentiles of estimates across model simulations).

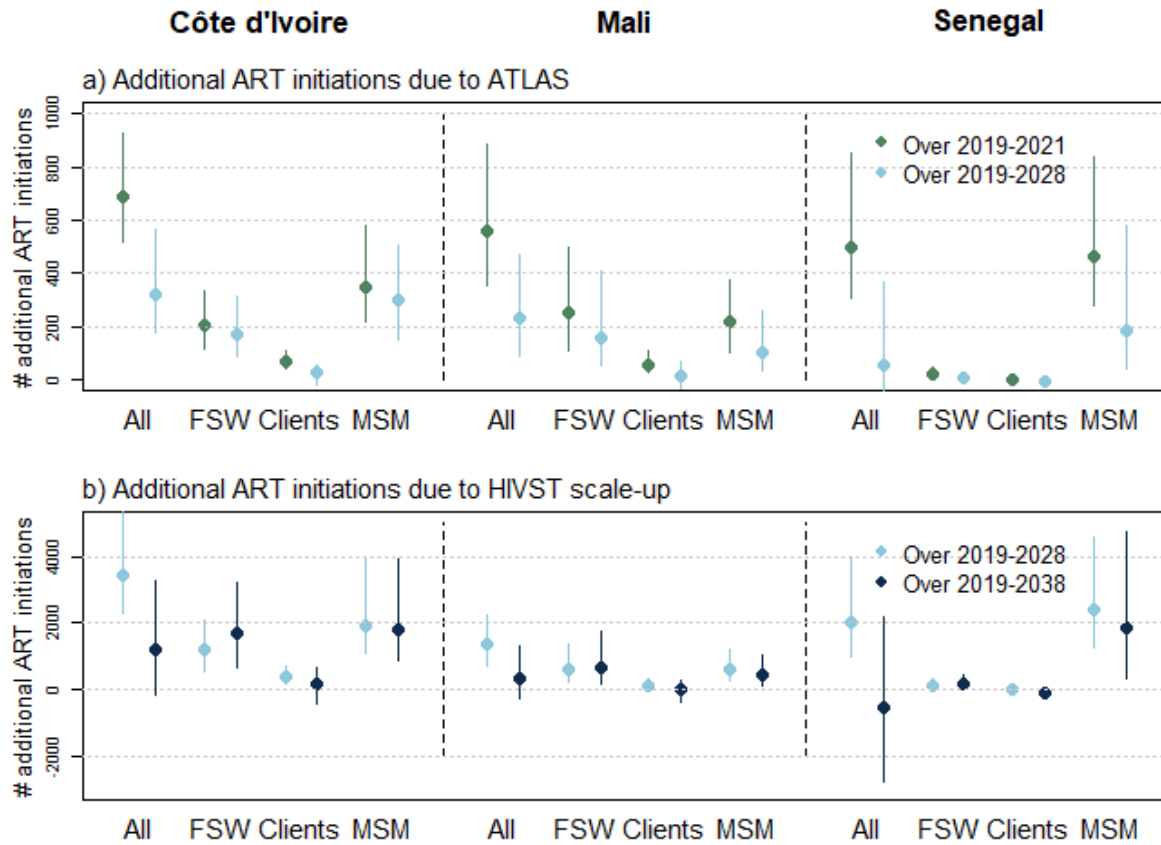


Figure S10: Estimated impact (in absolute numbers) of a) ATLAS and b) HIVST scale-up scenario compared to the counterfactual (no-HIVST scenario): additional new ART initiations over a) 2019-2021 (green points) and 2019-2028 (light blue points), and b) over 2019-2028 (light blue points) and 2019-2038 (dark blue points). Points height represent median of model, whereas error bars represent 90% UI of estimates (5th and 95th percentiles of estimates across model simulations).

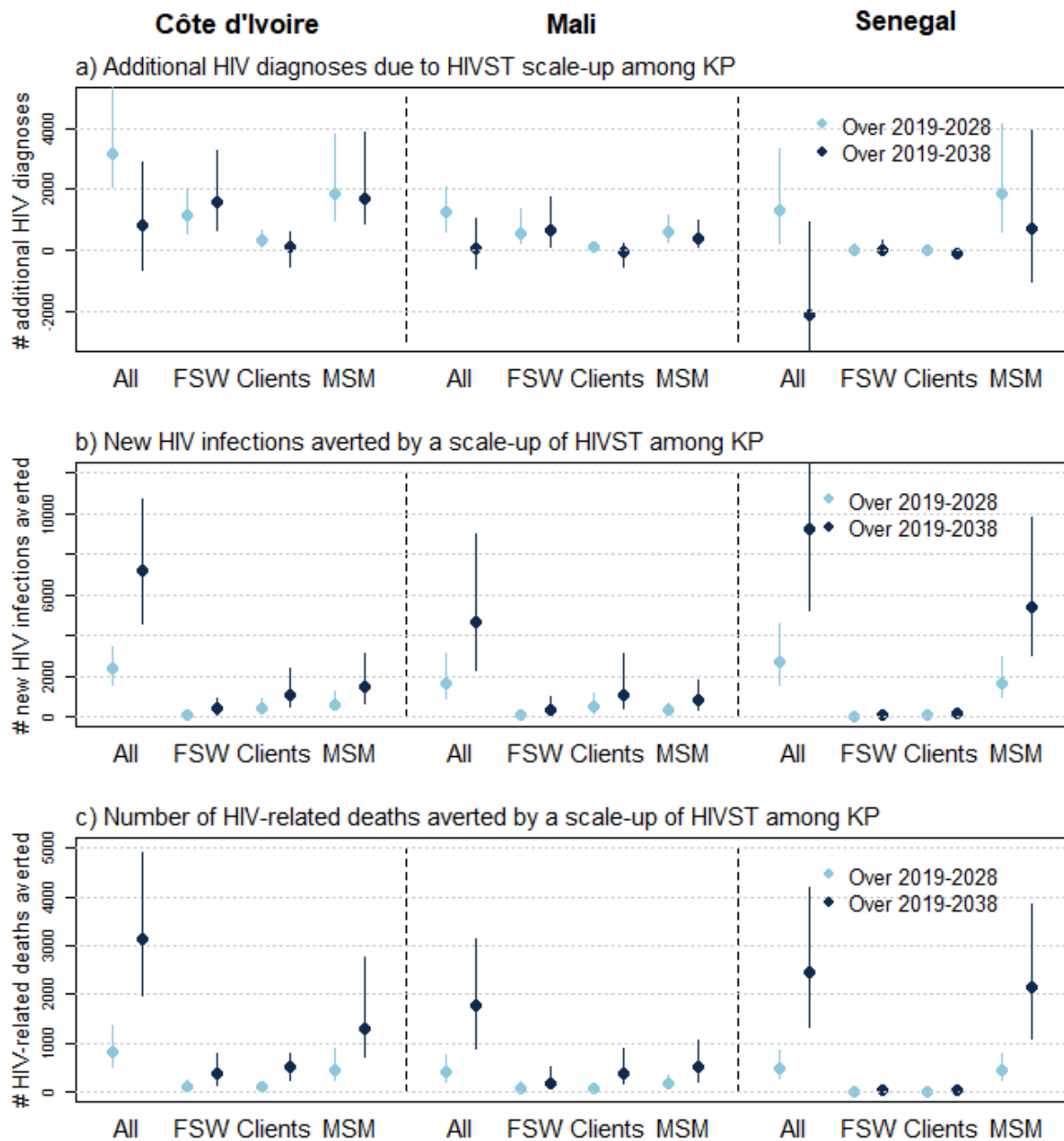


Figure S11: Estimated impact (in absolute numbers) of the HIVST scale-up scenario compared to the counterfactual (no-HIVST scenario): a) additional new HIV diagnoses over 2019-2028 (light blue points) and 2019-2038 (dark blue points) and numbers of b) HIV infections (c) and HIV-related deaths averted by ATLAS over 2019-2028 and 2019-2038. Points height represent median of model estimates, whereas error bars represent 90% UI of estimates (5th and 95th percentiles of estimates across model simulations). “All” is the sum of all risk groups, including non-key populations. The negative numbers of new HIV diagnoses in panel a) are because, in the long term, the intervention decreases the number of HIV infections that can be diagnosed by decreasing the number of new HIV infections, while the intervention particularly increases new HIV diagnoses among key populations.

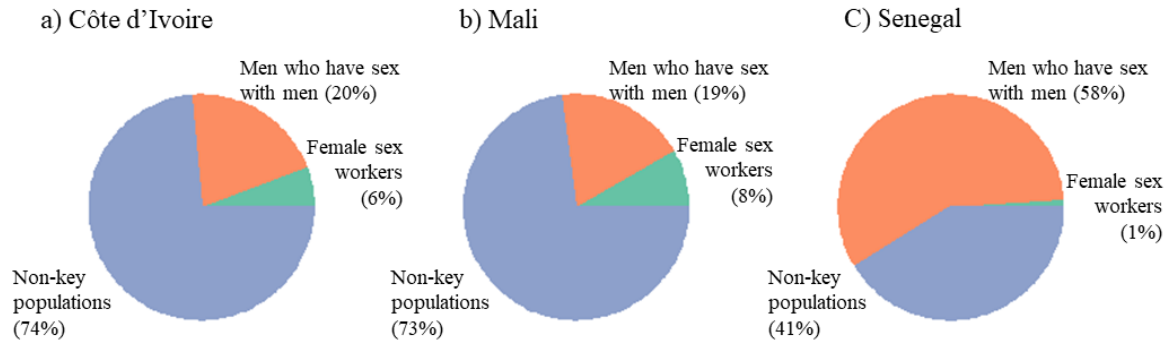


Figure S12a: Estimated distributions of infections averted by ATLAS scale-up by risk group over 2019-2038 in a) Côte d'Ivoire, b) Mali, and c) Senegal

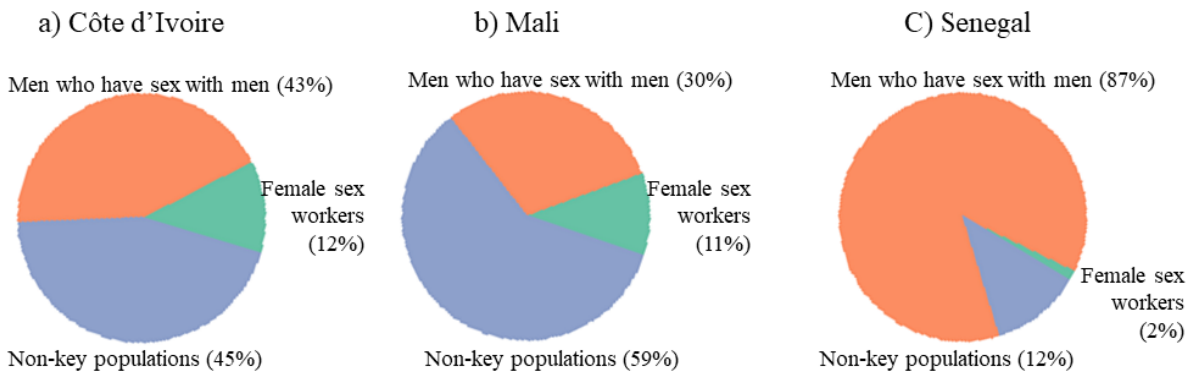


Figure S12b: Estimated distributions of HIV-related deaths averted by ATLAS scale-up by risk group over 2019-2038 in a) Côte d'Ivoire, b) Mali, and c) Senegal

Table S6a: Estimated increase in HIV diagnosis coverage (expressed in percentage points) due to ATLAS and HIVST scale-up among KP in Côte d'Ivoire, Mali, and Senegal from 2019 compared to a counterfactual scenario with no HIVST. Median and 90% UI (5th and 95th percentiles) of estimates are shown.

HIVST distribution scenario	Population	Côte d'Ivoire			Mali			Senegal		
		After 3 years	After 10 years	After 20 years	After 3 years	After 10 years	After 20 years	After 3 years	After 10 years	After 20 years
ATLAS-only (2019-2021)	Overall	0.2pp (0.2-0.3)	0.1pp (0.07-0.2)	0.03pp (0.01-0.07)	0.9 pp (0.5-1.5)	0.7pp (0.4-1.4)	0.4pp (0.2-0.9)	1.1 pp (0.3-2.7)	0.9pp (0.2-2.3)	0.04pp (-0.1-0.6)
	FSW	2.0pp (1.2-3.6)	0.3pp (0.1-0.7)	0.05pp (0.02-0.1)	7.7 pp (2.9-14.6)	1.4pp (0.5-3.9)	0.6pp (0.2-1.8)	0.0 pp (0.1-1.1)	0.1pp (0.06-0.6)	0.0pp (0.0-0.1)
	Clients	0.3pp (0.2-0.4)	0.2pp (0.1-0.4)	0.04pp (-0.002-0.1)	0.5 pp (0.3-1.1)	1.0pp (0.5-1.8)	0.4pp (0.1-1.0)	0.1 pp (0.0-0.1)	0.1pp (0.07-0.3)	0.09pp (0.04-0.3)
	MSM	4.6pp (3.1-8.3)	3.2pp (1.7-5.7)	1.1pp (0.4-2.6)	9.3 pp (3.9-14.7)	4.7pp (1.6- 9.6)	1.5pp (0.4-4.9)	5.7 pp (1.0-17.2)	2.5pp (0.6-8.1)	0.1pp (-0.1-1.4)
HIVST scale-up (2019-2038)	Overall	0.2pp (0.2-0.3)	1.3pp (0.8-1.9)	1.2pp (0.7-2.0)	0.9 pp (0.5-1.5)	3.6pp (2.0-6.4)	4.8pp (2.5- 9.7)	1.1 pp (0.3-2.7)	10.6pp (5.3-16.8)	13.6pp (6.3-21.4)
	FSW	2.0pp (1.2-3.6)	7.6pp (4.2-11.7)	5.8pp (3.3-9.2)	7.7 pp (2.9-14.6)	13.7pp (5.9-24.2)	12.1pp (4.7-24.0)	0.0 pp (0.1-1.1)	4.1pp (0.8-14.7)	3.1pp (1.1-13.2)
	Clients	0.3pp (0.2-0.4)	2.3pp (1.7-3.3)	2.6pp (1.6-4.0)	0.5 pp (0.3-1.1)	4.1pp (2.4-6.6)	5.7pp (3.2-10.2)	0.1 pp (0.0-0.1)	1.6pp (1.0-2.7)	2.7pp (1.6-4.3)
	MSM	4.6pp (3.1-8.3)	30.3pp (20.0-45.4)	27.1pp (16.0-46.0)	9.3 pp (3.9-14.7)	31.3pp (19.9-44.8)	32.1pp (18.0-49.1)	5.7 pp (1.0-17.2)	40.5pp (23.3-59.6)	36.2pp (19.7-57.2)

Table S6b: Estimated proportion of averted infections due to ATLAS and HIVST scale-up among KP in Côte d'Ivoire, Mali, and Senegal from 2019 compared to a counterfactual scenario with no HIVST. Median and 90% UI (5 th and 95 th percentiles) of estimates are shown.										
		Côte d'Ivoire			Mali			Senegal		
HIVST distribution scenario	Population	Over ATLAS (2019-2021)	Over 10 years (2019-2028)	Over 20 years (2019-2038)	Over ATLAS (2019-2021)	Over 10 years (2019-2028)	Over 20 years (2019-2038)	Over ATLAS (2019-2021)	Over 10 years (2019-2028)	Over 20 years (2019-2038)
ATLAS-only (2019-2021)	Overall	0.1% (0.09-0.2)	0.4% (0.3-0.6)	0.4% (0.2-0.6)	0.7% (0.4-1.2)	2.1% (1.1-3.7)	2.2% (1.2-4.1)	1.4% (0.8-2.3)	3.3% (1.7-6.3)	2.7% (1.2-6.1)
	FSW	0.2% (0.1-0.3)	0.6% (0.4-1.1)	0.6% (0.3-1.1)	0.4% (0.2-0.8)	2.2% (1.1-3.6)	2.5% (1.2-4.4)	0.2% (0.1-0.3)	0.6% (0.3-1.1)	0.7% (0.4-1.6)
	Clients	0.4% (0.2-0.8)	0.7% (0.4-1.6)	0.5% (0.3-1.3)	2.0% (0.8-3.4)	3.9% (1.8-7.1)	3.4% (1.6-6.8)	0.6% (0.4-1.1)	1.0% (0.6-2.0)	1.0% (0.6-2.5)
	MSM	1.5% (1.0-2.7)	4.6% (3.1-7.5)	4.3% (2.7-6.9)	4.0% (1.8-6.5)	9.7% (4.4-16.1)	8.7% (3.7-16.3)	3.1% (1.6-5.7)	5.9% (2.6-11.5)	3.7% (1.5-8.3)
HIVST scale-up (2019-2038)	Overall	0.1% (0.09-0.2)	1.6% (1.0-2.4)	2.9% (1.7-4.6)	0.7% (0.4-1.2)	5.3% (3.0-8.9)	9.3% (5.2-16.6)	1.4% (0.8-2.3)	16.2% (10.0-23.1)	29.2% (17.8-40.1)
	FSW	0.2% (0.1-0.3)	2.3% (1.6-3.6)	4.9% (3.1-7.4)	0.4% (0.2-0.8)	4.8% (2.7-7.7)	9.3% (5.0-16.1)	0.2% (0.1-0.3)	2.7% (1.7-4.5)	6.9% (4.2-10.4)
	Clients	0.4% (0.2-0.8)	3.4% (1.8-5.9)	5.5% (2.9-9.1)	2.0% (0.8-3.4)	10.0% (5.1-17.6)	14.0% (7.4-23.9)	0.6% (0.4-1.1)	5.9% (3.7- 9.9)	11.6% (7.0-17.2)
	MSM	1.5% (1.0-2.7)	20.5% (15.3-27.6)	31.4% (22.6-41.8)	4.0% (1.8-6.5)	27.3% (18.0-36.2)	42.2% (28.6-55.4)	3.1% (1.6-5.7)	28.0% (21.3-37.5)	41.9% (31.2-54.4)

Table S6c: Estimated proportion of averted HIV-related deaths due to ATLAS and HIVST scale-up among KP in Côte d'Ivoire, Mali, and Senegal from 2019 compared to a counterfactual scenario with no HIVST. Median and 90% UI (5th and 95th percentiles) of estimates are shown.

		Côte d'Ivoire			Mali			Senegal		
HIVST distribution scenario	Population	Over ATLAS (2019-2021)	Over 10 years (2019-2028)	Over 20 years (2019-2038)	Over ATLAS (2019-2021)	Over 10 years (2019-2028)	Over 20 years (2019-2038)	Over ATLAS (2019-2021)	Over 10 years (2019-2028)	Over 20 years (2019-2038)
ATLAS-only (2019-2021)	Overall	0.05% (0.02-0.09)	0.2% (0.1-0.3)	0.3% (0.2-0.4)	0.09% (0.03-0.2)	0.7% (0.4-1.3)	1.1% (0.6-2.1)	0.2% (0.06-0.5)	1.5% (0.8-3.1)	1.9% (1.0-4.3)
	FSW	0.5% (0.1-1.0)	1.4% (0.6-2.6)	1.1% (0.5-1.8)	0.6% (-0.02-2.2)	3.9% (1.7-8.5)	3.5% (1.7-7.4)	0.2% (0.05-0.5)	0.6% (0.3-1.3)	0.6% (0.4-1.2)
	Clients	0.05% (0.02-0.09)	0.3% (0.2-0.5)	0.4% (0.2-0.7)	0.08% (0.04-0.2)	0.7% (0.4-1.3)	1.4% (0.7-2.5)	0.01% (0.004-0.04)	0.1% (0.08-0.3)	0.3% (0.2-0.5)
	MSM	0.9% (0.4-1.4)	3.5% (2.2-5.7)	3.7% (2.2-5.9)	1.2% (0.2-3.4)	6.6% (2.9-12.3)	7.5% (3.3-12.8)	1.0% (0.2-2.2)	5.0% (2.1-10.9)	5.0% (2.0-10.5)
HIVST scale-up (2019-2038)	Overall	0.05% (0.02-0.09)	0.7% (0.4-1.3)	1.7% (1.1-2.6)	0.09% (0.03-0.2)	1.5% (0.8-2.7)	3.8% (2.0-6.2)	0.2% (0.06-0.5)	5.5% (3.2-9.4)	15.1% (9.1-24.8)
	FSW	0.5% (0.1-1.0)	4.7% (2.2-8.6)	8.5% (4.6-12.9)	0.6% (-0.02-2.2)	8.8% (4.0-16.8)	13.7% (7.3-23.9)	0.2% (0.05-0.5)	2.7% (1.5-5.9)	6.3% (3.8-11.5)
	Clients	0.05% (0.02-0.09)	0.9% (0.6-1.3)	2.7% (1.8-3.9)	0.08% (0.04-0.2)	1.4% (0.8-2.4)	4.5% (2.7-7.5)	0.01% (0.004-0.04)	0.4% (0.2-0.8)	2.2% (1.4-3.5)
	MSM	0.9% (0.4-1.4)	13.2% (7.7-18.0)	24.2% (17.0-31.3)	1.2% (0.2-3.4)	15.9% (9.3-26.6)	29.7% (20.0-43.3)	1.0% (0.2-2.2)	18.4% (12.4-27.4)	37.8% (26.9-50.1)

Sensitivity analysis

We conducted a sensitivity analysis to assess the influence of key assumptions of our main HIVST scale-up scenario on the secondary distribution of self-tests by risk groups (i.e., approximately doubling the fraction of tests received by non-KPs, Tables S4a,b), age distribution of HIVST users (based on a phone survey conducted by ATLAS¹⁴⁸ instead of programmatic data, with little change in average age of population, figure S2), more HIVST distributed over time (reflecting population growth, instead of a constant number of kits distributed annually) (table S5), higher uses of distributed tests (100% instead of 80%), twice higher likelihood of receiving a HIVST kit for people having never tested for HIV and undiagnosed PLHIV (instead of the uniform likelihood of receiving a kit), higher rate of confirmation of reactive HIVST (80% instead of 50%), less substitutions of conventional test for HIVST (none instead of 20-40%) or more substitutions (50% instead of 20-40%), and higher accuracy of self-tests (i.e., 100%/100% sensitivity/specificity instead of 92/99%).

The estimated fraction of new HIV infections and deaths averted by scaling up HIVST among KP remained qualitatively similar for all alternative assumptions explored and countries (figures S13a,b). The largest difference was observed when doubling the uptake of HIVST among undiagnosed PLHIV compared to HIV-uninfected populations (around 1.7-times more new HIV infections are averted over 10 years), and when assuming a large (50%) fraction of HIVST replacing conventional tests in Côte d'Ivoire (around 1.7-times less new HIV infections averted over 10 years) compared to the 20% replacement scenario. Interestingly, assuming higher levels of secondary distribution of HIVST towards non-KP compared to the base-case (so that ~36% of self-tests kits are used by non-KP during scale-up, vs ~66% in the base-case) reduced the fraction of infections or deaths averted over 2019-2028 by ~1.3-fold compared to the base-case).

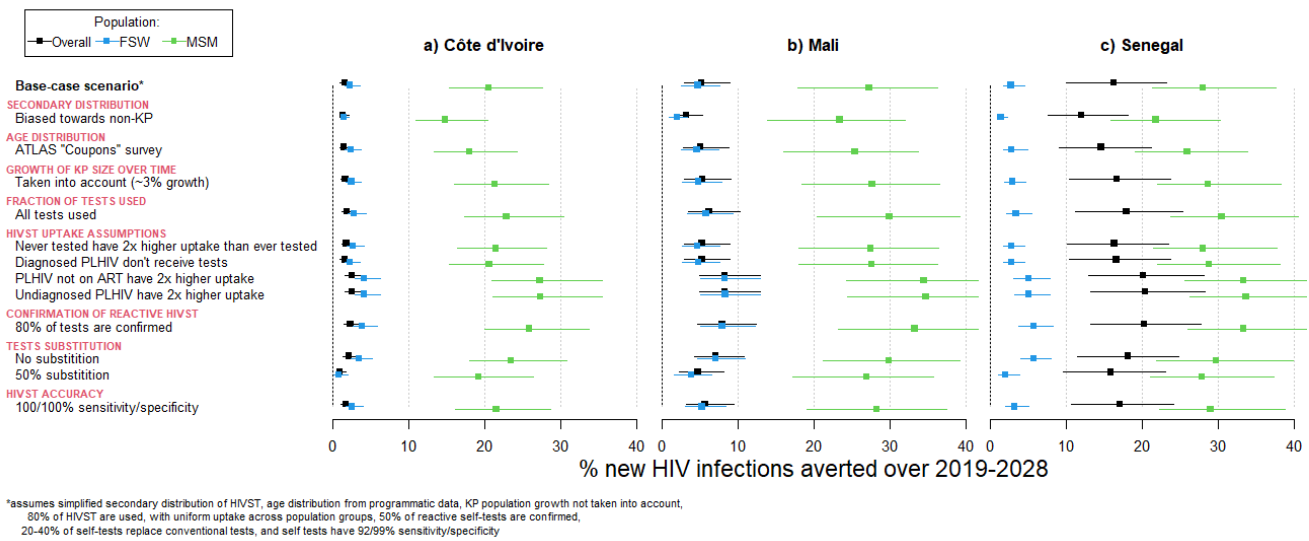


Figure S13a: Estimated fraction of new HIV infections averted by a scale-up of HIVST among KP over 2019-2028 in the three ATLAS countries within our base-case scenario (top row) as well as sensitivity scenarios. The impact was calculated overall (black squares and intervals), as well as among FSW (blue squares and intervals) and MSM (green squares and intervals). Squares represent median estimates across model fits, whereas error bars represent 90% UI of estimates (5th and 95th percentiles of estimates across model simulations).

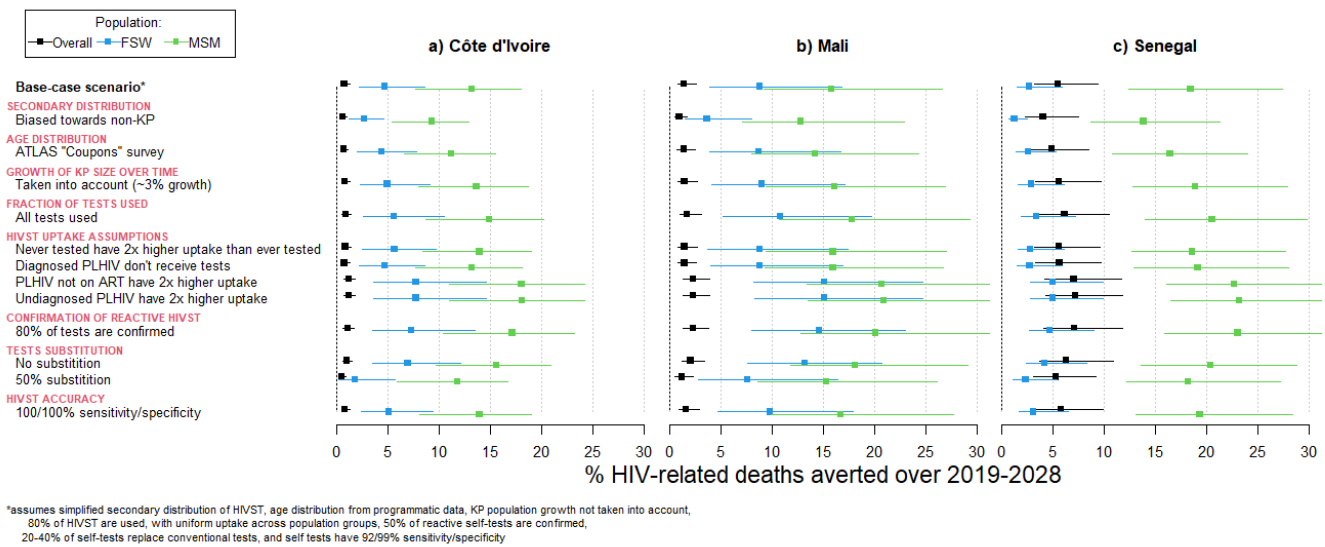


Figure S13b: Estimated fraction of HIV-related deaths averted by a scale-up of HIVST among KP over 2019-2028 in the three ATLAS countries within our base-case scenario (top row) as well as sensitivity scenarios. The impact was calculated overall (black squares and intervals), as well as among FSW (blue squares and intervals) and MSM (green squares and intervals). Squares represent median estimates across model fits, whereas error bars represent 90% UI of estimates (5th and 95th percentiles of estimates across model simulations). Impacts are larger among MSM because of greater numbers of tests distributed to them on average (see Figure S3), and because new diagnosis decreases the risk of MSM to die from HIV and prevent more infections among their partners.

Composition of the ATLAS Team

ATLAS Research Team

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